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A climate Encouraging the Growth and Flourishing of Monkeypox in Indonesia

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ABSTRACT

Introduction: Introduction: Climate change has significant impacts on human health and has the potential to trigger the emergence of various diseases by changing temperature, rainfall, wind patterns, and sunlight exposure. These changes create environmental conditions that support the survival, reproduction, and spread of disease-causing agents, such as viruses and bacteria. Adaptation of disease agents to these changes increases the risk of disease spreading in the community. In addition, climate change also expands the range of some disease agents, which were previously limited to certain areas, thus having a wider impact. Low temperatures (10–25°C), high humidity (≥70%), and limited sunlight (UV index <6) promote the environmental persistence of the monkeypox virus, whereas high temperatures (>30°C) and UV exposure (290–320 nm) accelerate its degradation, influencing transmission patterns and infection risk in humans and animals.
Methods: This study examines the climate conditions that may support the development of monkeypox in Jakarta. The main focus of this study is to identify climate factors, such as temperature, humidity, and rainfall patterns, that allow the spread of monkeypox virus. Climate data are analyzed to understand how these conditions play a role in increasing the risk of monkeypox virus transmission, both from animals to humans and between humans.
Results: Our findings indicate a minimum temperature of 27.96°C, a maximum of 33.74°C, and an average of 30.11°C. The average humidity was 74.21%. The duration of sunlight ranged from a minimum of 7.30 hours to a maximum of 9.60 hours.
Conclusion: Climate factors are key triggers in the development of Monkeypox within the environment. Specific temperature and humidity levels can create favorable conditions for the spread of the Monkeypox virus in certain regions. Additionally, extreme climate fluctuations may influence the spread patterns and severity of the disease, underscoring the importance of understanding how environmental conditions affect the transmission of diseases like Monkeypox.

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INTRODUCTION

Monkeypox is a zoonotic disease caused by the monkeypox virus (MPXV), which belongs to the Orthopoxvirus genus within the Poxviridae family. This virus can infect a range of species, including humans, vertebrates, and arthropods (1, 2). Before 1970, Monkeypox was observed exclusively in animals, not humans. However, between 1970 and 1986, ten cases of human monkeypox were recorded in West African countries, including Sierra Leone, Nigeria, Liberia, and Ivory Coast. In contrast, 394 cases were reported from countries around the Congo Basin, such as Cameroon, the Central African Republic, and Zaire (now the Democratic Republic of the Congo) (3, 4). Climate change has led to habitat shifts for numerous animal species, including primates and rodents that serve as reservoirs for MPXV (5). Deforestation and land-use changes, primarily driven by human activities in response to climate change, have intensified human interactions with wild species that act as reservoirs for the virus. The clearing of forests for agriculture or settlements has resulted in habitat fragmentation, increasing the risk of MPXV spillover from animals to humans (6).

The clinical symptoms of monkeypox (MPX) in humans are similar to other poxviruses, with patients typically experiencing lymph node swelling, chills, back pain, headaches, and sometimes a characteristic rash. Despite the growing body of evidence indicating both acute and past infections in various animals, the specific animal species that serve as the reservoir for the Monkeypox virus (MPXV) remain unclear. A variety of animals have been reported as being infected with MPXV, including house mice (Mus musculus), Gambian pouched rats (Oryctolagus cuniculus), squirrels, woodchucks (Marmota monax), jerboas (Jaculus sp.), and African dormice (Atherurus africanus) (1, 7-9).

In response to the global spread of the disease, the World Health Organization (WHO) declared Monkeypox an international public health emergency in 2022 (10). This marked a significant escalation in global concern, as Monkeypox, once confined to certain African countries, had begun to emerge across multiple continents, including Europe, the Americas, and Asia. The rapid spread of the virus highlighted gaps in global health preparedness and surveillance, particularly for diseases historically considered regionally endemic. The WHO's declaration seeks to not only raise awareness but also to mobilize global efforts for coordinated surveillance, research, and resource allocation to manage the outbreak. Collaborative efforts are necessary to strengthen public health systems, enhance diagnostic capacities, and accelerate the development of vaccines and treatments for Monkeypox (11-13). The declaration also calls for governments and international health bodies to prioritize funding and create contingency plans to mitigate future outbreaks. In addition, public health campaigns are essential to educate communities on prevention measures, limit misinformation, and promote early detection and reporting of new cases.

The spread of Monkeypox appears to be closely linked to meteorological factors such as temperature, dew point, rainfall, humidity, and wind speed. While preliminary studies suggest that temperature and dew point may have a significant influence on MPXV cases, with observed values of 51.56 (95% CI: -274.55, 377.68) and -69.59 (95% CI: -366.61, -227.43), further research is necessary to fully understand how these environmental conditions impact transmission on a local and community level (14).

Public health problems are often related to the process of disease occurrence that is influenced by environmental, lifestyle, and socio-economic factors. One of them is monkeypox, which can spread rapidly in environments with poor sanitation and high population density. An unhygienic environment allows the development of pathogens, such as the monkeypox virus, which is spread through direct contact or exposure to disease-carrying animals. In addition, lifestyles such as smoking habits, unhealthy diets, and lack of physical activity also play a role in increasing non-communicable diseases, such as diabetes, hypertension, and heart disease. Socio-economic factors, including education and access to health services, affect the level of awareness and ability of the community to prevent and treat diseases (15-17). Lack of health education hinders early detection, so that people tend to ignore symptoms of the disease until it becomes more severe and poses a high risk to public health.

In Indonesia, a significant case of Monkeypox was reported on August 19, 2022, involving a 27-year-old male patient in Jakarta. By September 15, 2022, the country had two suspected cases and had discarded 63 other potential cases across ten provinces (18). Monkeypox can spread through both animal-to-human and human-to-human transmission. Animal-to-human transmission may occur through contact with the bodily fluids of infected animals or by consuming undercooked meat from these animals. Infected animals can also transmit the virus through bites or scratches. Human-to-human transmission occurs through direct contact with an infected person's bodily fluids, respiratory droplets, or sores and lesions, which can appear around the mouth, nose, hands, or body. Transmission can also occur from mother to child through the placenta during pregnancy.

This rapid global spread of Monkeypox underscores the importance of continued surveillance, research, and public health interventions aimed at controlling its transmission. Further studies on the environmental and social factors that influence the spread of this virus are crucial to mitigating future outbreaks.

METHOD

Research Location

This research was conducted in the Special Capital Region of Jakarta. This area was chosen due to the presence of monkeypox cases.

Collecting data

Climatology data

The data collection method involved several mediums, such as literature studies and utilizing websites providing global weather and climate services, along with information about Indonesian climate data. Literature studies were conducted to gather data related to precedents, typology studies, and data associated with the design. Websites relevant to the site potential included www.meteoblue.com (19) and https://dataonline.bmkg.go.id/home (20). The services provided by Meteoblue encompass current weather information, short and long-term weather forecasts, and climate and environmental information. Additionally, Meteoblue offers features like radar animations, weather maps, and information about weather conditions in specific locations worldwide. https://dataonline.bmkg.go.id/home is a website providing information about climate data in Indonesia. This website allows users to input the location they seek climate data for, presenting information regarding Minimum Temperature, Maximum Temperature, Average Temperature, Average Humidity, Duration of Sunlight, Maximum Wind Speed, and Minimum Wind Speed. The climate data utilized in this study were obtained from various regions across Jakarta. These data were collected online and derived from processed datasets provided by official institutions, such as Meteoblue and the Indonesian Meteorological, Climatological, and Geophysical Agency (BMKG).

Monkeypox diseases

The data regarding monkeypox cases in Indonesia were obtained from reports by the Ministry of Health of the Republic of Indonesia published through various national media outlets.

Analysis data

The gathered data from literature studies and website observations were analyzed to derive solutions in the design process. This data was analyzed using frequency distribution, which includes Minimum, Maximum, Mean, and Standard Deviation (SD). These statistical analyses assist in understanding the range and central tendencies of the collected data, aiding in the design and decision-making process.

Ethical Consideration

The ethical approval of this study was obtained from the Research Ethics Committee, Indonesian Public Health Association (IPHA), with approval number: 027/KEPK- IAKMI/IV/2023.

RESULTS

The mean daily maximum (depicted by the solid red line) illustrates the highest temperature on an average day for each month in Jakarta. Similarly, the "mean daily minimum" (the solid blue line) displays the average lowest temperature. The dashed red and blue stripes, representing hot days and cold nights, respectively, indicate the average temperature of the warmest day and the chilliest night for each month over the past 30 years. When planning a vacation, it's advisable to anticipate the mean temperatures while preparing for warmer and cooler days. The wind speeds are not initially shown on the graph but can be activated at the bottom of the display. The precipitation chart is valuable for planning seasonal effects like the monsoon climate in India or the wet season in Africa. Months with precipitation levels exceeding 150mm are predominantly wet, while those below 30mm are generally dry (19).

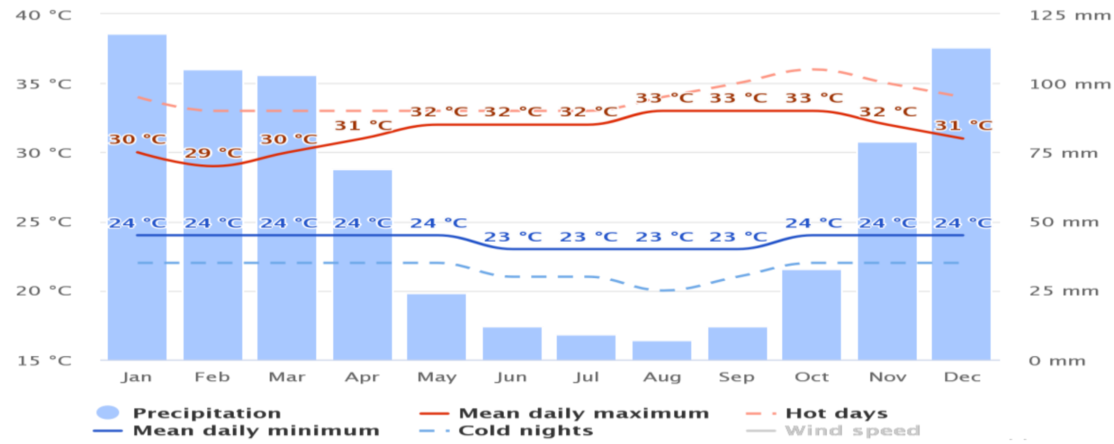

Figure 1. Average temperatures and precipitation

The graph illustrates the count of days per month categorized into sunny, partly cloudy, overcast, and days with precipitation. Days with cloud cover below 20% are classified as bright, those with 20-80% as partly cloudy, and those with over 80% cover as overcast. Reykjavík in Iceland typically experiences predominantly gray days, whereas Sossusvlei in the Namib desert is recognized as one of the sunniest locations on the planet (19).

Weather conditions, including the number of sunny, partly cloudy, overcast, and rainy days, may influence the spread of monkeypox. Research suggests that environments with high humidity and frequent rainfall may prolong the survival of the virus on surfaces, thereby increasing the risk of transmission through indirect contact (21). Sunny Days (Cloud Cover < 20%), Areas with high sun exposure, such as Sossusvlei in the Namib Desert, tend to have low humidity levels, which may reduce the virus's survival in the environment**.** Partly Cloudy Days (Cloud Cover 20-80%) these conditions may create a balance between temperature and humidity that allows the virus to persist longer on surfaces. Overcast Days (Cloud Cover > 80%) regions with frequent overcast days, such as Reykjavík in Iceland, often experience higher humidity levels, potentially enhancing the stability of the virus on surfaces and increasing the risk of transmission. Rainy Days high rainfall can contribute to an increase in rodent populations and other potential vectors involved in the spread of MPXV. Additionally, rainfall can influence human mobility, potentially accelerating disease transmission.

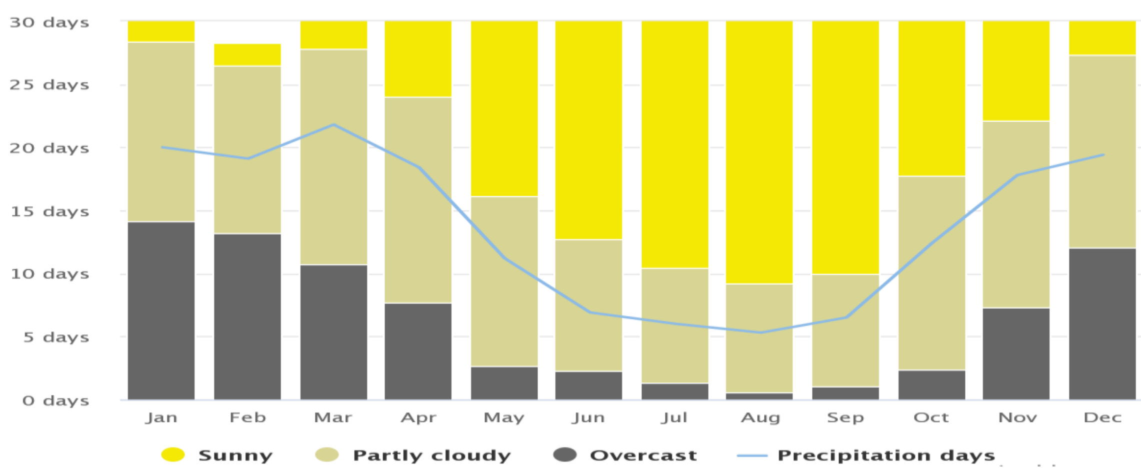

Figure 2. Cloudy, sunny, and precipitation days

The maximum temperature diagram for Jakarta exhibits the frequency of days per month reaching specific temperatures. Dubai, one of the hottest cities globally, experiences nearly no days below 40°C in July. Additionally, the diagram highlights the cold winters in Moscow, depicting a few days where temperatures do not even reach -10°C as the daily maximum (19).

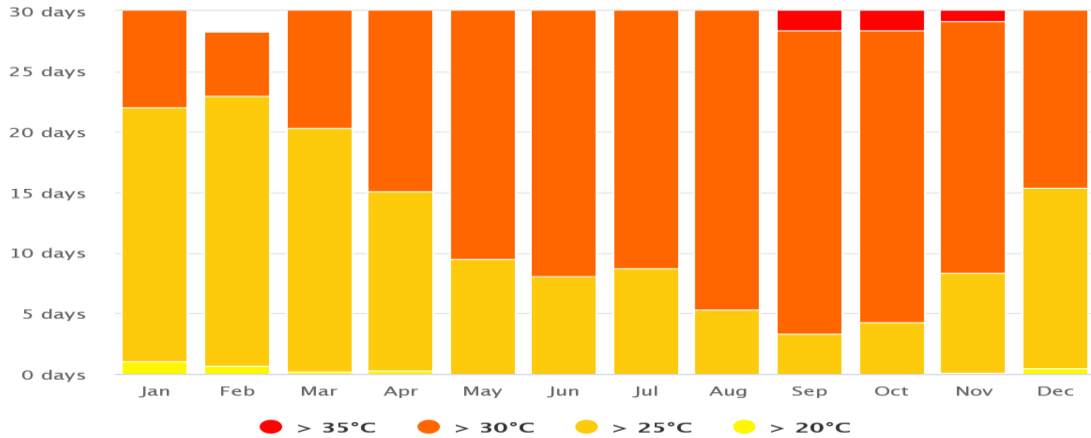

Figure 3. Maximum temperatures

The diagram for Jakarta indicates the number of days per month when the wind attains specific speeds. A noteworthy example is the Tibetan Plateau, where the monsoon generates consistently strong winds from December to April and relatively calm winds from June to October (19).

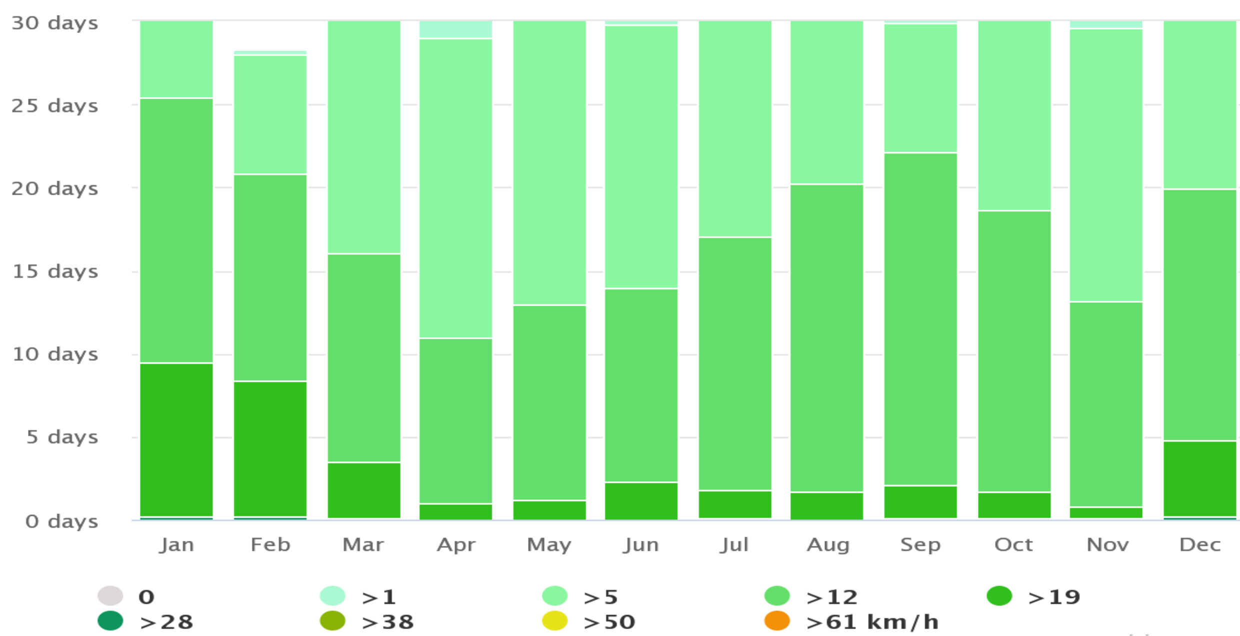

Figure 4. Wind speed

The wind rose for Jakarta displays the number of hours per year that the wind blows from specific directions. For instance, SW represents wind blowing from the South-West to the North-East. Cape Horn, the southernmost land point of South America, is known for its solid west winds, making east-to-west crossings particularly challenging, especially for sailing boats (19).

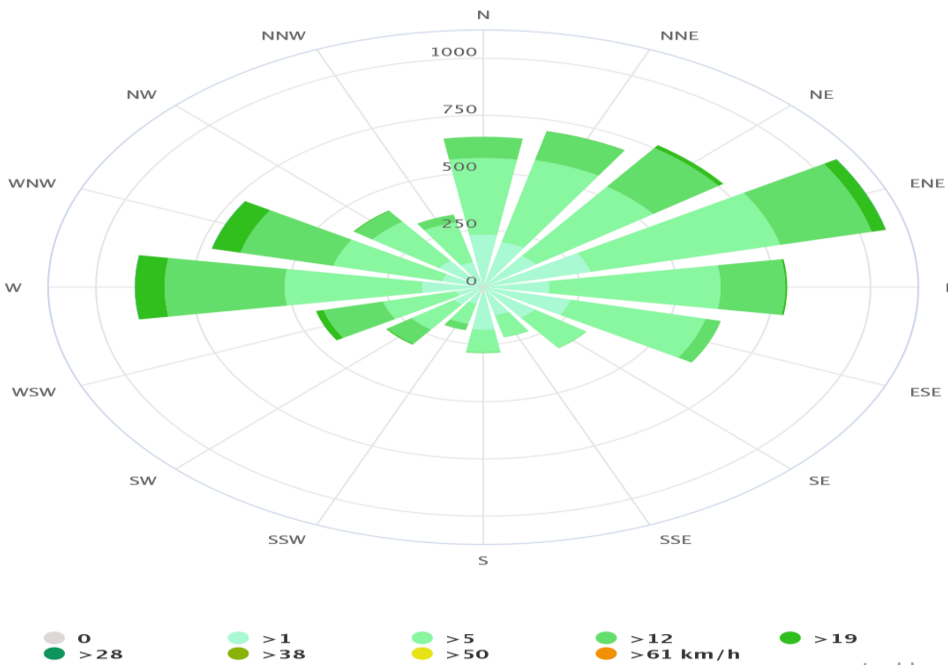

Figure 5. Wind rose

Table 1. The global descriptive statistics for the climatology variables

Variables	Minimum	Maximum	Mean	Std. Deviation (SD)
Temperature minimum (°C)	27.00	28.80	27.96	0.55
Temperature maximum (°C)	32.20	37.20	33.74	1.13
Temperature average (°C)	29.30	31.00	30.11	0.50
Humidity average (%)	69.00	78.00	74.21	2.70
Duration of sunlight (hour)	7.30	9.60	8.42	0.79
Maximum wind speed (m/s)	4.00	9.00	5.89	1.15
Minimum wind speed (m/s)	1.00	3.00	2.42	0.61
Confirmed cases (total cases)	15*	-	-	-

*Cases of Monkeypox in Jakarta on October 27, 2023

Based on **Table 1**, there were 15 cases of Monkeypox reported in Jakarta. This indicates that Monkeypox has spread to Jakarta. Further, descriptive statistics of meteorological variables recorded from October 1 to October 19, 2023, are as follows Minimum confirmed temperature: Mean 27.96°C, Standard Deviation (SD) 0.55, Minimum 27.00°C, Maximum 28.80°C; Maximum temperature: Mean 33.74°C, Standard Deviation (SD) 1.13; Average temperature: Mean 30.11°C, Standard Deviation (SD) 0.50; Average humidity: Mean 74.21%, Standard Deviation (SD) 2.70; Duration of sunlight: Mean 8.42 hours, Standard Deviation (SD) 0.79; Maximum wind speed: Mean 5.89 m/s, Standard Deviation (SD) 1.15; Minimum wind speed: Mean 2.42 m/s, Standard Deviation (SD) 0.61.

DISCUSSION

Climate change is expected to lead to significant shifts in the occurrence and distribution of infectious diseases, potentially posing serious health risks to human populations in regions previously unexposed to these illnesses. As global temperatures rise and weather patterns become more erratic, the prevalence of certain viruses is anticipated to increase, particularly in areas where environmental conditions have historically limited their spread (22, 23). This is due to the fact that many infectious agents, including viruses, thrive under specific climate conditions, and changes in temperature, humidity, and precipitation can create new habitats for disease vectors such as mosquitoes and ticks.

Temperature is a key environmental factor influencing virus stability, vector life cycles, and the dynamics of zoonotic disease transmission. Research indicates that MPXV remains more stable in cooler environments, whereas high temperatures tend to accelerate its degradation on surfaces (21). As global temperatures rise due to climate change, the geographic distribution of MPXV may shift toward cooler regions, such as temperate zones that were previously unaffected.

Additionally, rising temperatures can alter the behavior of reservoir animals, particularly rodents, which play a crucial role in the MPXV transmission cycle. A study by Sklenová et al. (2023) found that rodents tend to migrate to cooler habitats as temperatures increase, potentially shifting disease transmission patterns and elevating the risk of human infection in previously low-risk areas (24) .

Environmental humidity also significantly impacts the stability and spread of MPXV. High-humidity environments can prolong the virus's survival on surfaces, thereby increasing the likelihood of transmission through indirect contact. Laboratory studies have demonstrated that MPXV persists longer in environments with high relative humidity, heightening the risk of disease spread in tropical regions with substantial rainfall (25).

Conversely, excessively low humidity can cause virus-laden droplets to dry out, potentially reducing the effectiveness of airborne transmission. However, under certain conditions, dry air may enhance transmission risk through microaerosols, as observed in epidemiological studies of other diseases with similar transmission mechanisms (26)

High rainfall can further create environmental conditions that support the proliferation of reservoir animals and vectors involved in MPXV transmission. Research suggests that increased rainfall promotes vegetation growth and expands food availability for rodents, subsequently boosting their populations and increasing human contact risks (27)

Moreover, excessive rainfall can affect human mobility and contribute to poor sanitation conditions, ultimately increasing the likelihood of MPXV transmission through both direct and indirect contact. Extreme shifts in rainfall patterns driven by climate change may lead to flooding, further facilitating the spread of zoonotic diseases, including monkeypox, into previously unaffected regions.

Projections for the end of the 21st century indicate that the average annual global temperature could rise by as much as five degrees Celsius. This warming trend will be accompanied by significant shifts in precipitation patterns, with tropical regions, especially in Africa, experiencing increased rainfall, while areas farther from the equator will likely see a decrease in precipitation. Additionally, evaporation rates are expected to rise across most continents, leading to more intense and frequent droughts in some areas while exacerbating flooding in others. These shifts will not only influence the transmission of waterborne and vector-borne diseases but also increase the likelihood of extreme weather events, which can disrupt health services and hinder efforts to control outbreaks (28-31).

The impact of these climatic changes is expected to be most severe in regions with limited infrastructure and healthcare capacity, potentially exacerbating health disparities. Furthermore, the increasing seasonality of rainfall in many parts of the world could create conditions that favor the breeding of disease vectors during specific periods of the year, leading to more concentrated and unpredictable outbreaks. This highlights the urgent need for global cooperation in climate adaptation strategies, particularly in the health sector, to prepare for and mitigate the potential public health consequences of climate change.

Jakarta, the capital of the Republic of Indonesia, is not only the center of government but also serves as a key entry point for the country, with many people arriving through Soekarno-Hatta International Airport. The city experiences significant population mobility, both domestically and internationally, largely due to its strong economic appeal. As the hub for business, industry, and commerce in Indonesia, Jakarta attracts people from across the country and beyond, seeking economic opportunities. This influx has driven rapid population growth and high rates of urbanization, making the city a dynamic yet densely populated urban center.

As of October 27, 2023, the Jakarta Health Department reported 15 confirmed cases of Monkeypox, with one recovery recorded in August 2022. Among the 14 active cases, the PCR positivity rate stands at 44 percent. Most of these individuals exhibit mild symptoms, and transmission in nearly all cases was linked to sexual contact. The patients are all male, aged between 25 and 50 (32). The urban environment and high population density in Jakarta, combined with the continuous inflow of people, contribute to the risk of infectious disease spread. The mobility of the population, especially within close-knit social networks, has facilitated the transmission of Monkeypox, highlighting the challenges that metropolitan areas like Jakarta face in controlling outbreaks of zoonotic diseases.

In light of these factors, Jakarta's health authorities are intensifying surveillance and public health campaigns aimed at raising awareness about Monkeypox, with a particular focus on preventive measures and early detection. The city's role as a gateway to Indonesia makes it especially important to implement effective screening and containment strategies to prevent the wider spread of the virus within the country.

This research identified the climate conditions conducive to the development of Monkeypox in Jakarta. In October, climate data for the city showed a minimum temperature of 27.96°C, a maximum temperature of 33.74°C, and an average temperature of 30.11°C. The average humidity level was recorded at 74.21%, with the duration of sunlight ranging from 7.30 to 9.60 hours per day. Additionally, wind speed varied, with the maximum mean wind speed reaching 4.00 m/s and the minimum mean wind speed at 2.42 m/s.

These climate variables are critical in understanding how environmental factors influence the spread of the Monkeypox virus (MPXV). For instance, high humidity levels, typically above 80%, have been found to slow down the transmission of certain viruses like influenza (32). In regions like Oceania, when relative humidity exceeds 80%, the daily average of confirmed cases has been found to decrease to approximately 0.28 cases per day (18, 22, 33). This suggests that variations in humidity may also play a role in the spread patterns of MPXV.

Arotolu, Temitope Emmanuel, et al. (2022) identified five key factors that influence the suitability model for Monkeypox disease transmission. These factors included precipitation in the driest areas (47% contribution), the lowest December temperature (7% contribution), and the highest March temperature (3% contribution). Their model demonstrated a high predictive accuracy, with an Area Under the Curve (AUC) score of 0.92 and a low standard deviation of 0.009, indicating its reliability in identifying regions prone to Monkeypox outbreaks (33).

These findings underscore the importance of integrating climate data into predictive models for disease outbreaks, particularly in urban environments like Jakarta, where population density and mobility can further complicate transmission dynamics. As climate conditions shift, it will be essential to continuously monitor how temperature, humidity, and other factors influence the spread of Monkeypox and to adapt public health strategies accordingly.

Limitation of study

In Indonesia, there is no periodic or continuous reporting of monkeypox case data within specific time intervals. Due to this irregular reporting, it is impossible to analyze trends in case changes or conduct an analysis of correlations between particular factors that may be associated with the spread of the disease. This research constitutes basic research on the climate and monkeypox disease. Within this research, some aspects have not been investigated. Factors such as urbanization, geography, economics, lifestyle, and behavior are not included or deeply analyzed. This means that the potential influence or correlation between these factors and the spread or characteristics of Monkeypox has not been thoroughly studied or is not the primary focus of the research.

CONCLUSION

This study highlights the significant role of climate factors, particularly temperature and humidity, in the transmission of Monkeypox in Jakarta. While the Monkeypox virus has not been proven to reproduce in the air, the findings indicate a correlation between climate conditions and the increase in cases, aligning with previous research. These findings have important public health implications, particularly for disease prevention and control strategies. Integrating climate data into surveillance systems can enhance early response efforts to case surges. Governments and health agencies are advised to develop adaptive, evidence-based policies, including early warning systems and increased monitoring during periods with climate conditions that favor disease transmission. Given the increasing intensity of climate change, environmental-based mitigation strategies are becoming more urgent. A multisectoral approach involving health institutions, governments, and other stakeholders is essential to reducing the future risk of Monkeypox outbreaks.

AUTHOR'S CONTRIBUTION STATEMENT

The authors declare no conflict of interest

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AUTHOR CONTRIBUTIONS

[RT, DSE] was instrumental in the conceptualization and design of the study. [RT, DSE] was also responsible for data collection and analysis, and writing the initial draft of the manuscript. [AA, NN] contributed to the development of the methodology and data validation, and made critical contributions to the revision of the manuscript. [AA, NN] was also involved in the development of the theoretical framework and data processing. [SY, RT] was responsible for the overall supervision and oversight of the study. [SY, RT] also critically reviewed the manuscript to ensure the accuracy and clarity of the reported results. All authors contributed substantially to the drafting of the final manuscript, read and approved the manuscript prior to publication.

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