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An Analysis of Climate Change Caused by the Development and Urban Transformation of Isfahan as a Tourist City

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Abstract

This study examines the impacts of rising temperatures and urban development on the city of Isfahan, with a specific focus on how these changes affect urban centers and tourism. Climate change, characterized by increasing temperatures, poses significant challenges to the sustainability of urban environments. This research explores the consequences of temperature rise on urban form and the subsequent implications for tourism management. By analyzing urban development patterns, particularly in the context of expanding urban areas and their impact on historical centers, the study emphasizes the need for adaptive strategies that can mitigate the adverse effects of climate change. Quantitative method used to analyze meteorological data, and the city's development maps have been analyzed by using GIS. The findings highlight that, with the city's expansion, especially after 2001, the overall temperature has increased, affecting the center of Isfahan. This is primarily due to most of the expansion occurring in the west, which aligns with the prevailing metrological direction.

Keywords: Climate change, Urban Form, Tourism, Isfahan, Historic city.

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1. Introduction

Climate change, as an undeniable reality of the 21st century, has profound and widespread effects on human life and ecosystems. These changes are primarily caused by human activities, such as the burning of fossil fuels, deforestation, and changes in land use. The consequences of these changes include rising temperatures, shifts in precipitation patterns, sea-level rise, and an increase in the frequency of natural disasters like storms and floods. For instance, according to the Intergovernmental Panel of Climate Change (IPCC) reports (e.g., the 2021 sixth assessment report), the global average temperature has significantly increased over the past two decades, and this trend is expected to continue in the future.

These changes not only affect the environment but can also directly affect the structure and form of cities and human communities. Cities, as economic, social, and cultural hubs, are highly vulnerable to climate change. Rising temperatures and extreme weather fluctuations can have serious effects on infrastructure, transportation systems, and public utilities. Tourist cities, which are heavily dependent on natural and cultural attractions, are at heightened risk. These cities face challenges such as a decline in the quality of life for residents, negative impacts on public health, and a reduction in tourist appeal due to climate change (UNWTO, 2019).

In this context, the city of Isfahan, as one of Iran's most important tourist destinations, is heavily affected by climate change. With its rich history, unique architecture, and cultural attractions, Isfahan is a popular destination for both domestic and international tourists. However, climate change could lead to problems such as drought, increased pollution, and the degradation of urban infrastructure, which in turn would affect the experience of tourists and the sustainability of the tourism industry.

This article examines the impacts of climate change on urban form and the associated challenges for tourism. First, through a case study of the city of Isfahan, it will analyze how climate change affects urban structure, infrastructure, and public spaces. The next section will focus on the specific challenges faced by the tourism industry, including pollution, overcrowding, and the effects of temperature on tourist experiences. Finally, the article aims to offer solutions to manage these challenges and enhance sustainability in tourist cities like Isfahan.

Considering these impacts and challenges, the goal of this article is to explore the relationship between climate change, urban form, and tourism, and to propose innovative strategies for creating sustainable and climate-

resilient cities. It looks to identify practical solutions that, while preserving tourism attractions, also help mitigate the damages caused by climate change.

2. Literature Review

Climate change significantly impacts historic cities and cultural heritage sites, leading to various challenges and necessitating adaptive strategies. Understanding climate risks to heritage must be part of planning and policy decision-making processes to increase the resilience and sustainability of both social and built environmental systems (Quesada-Ganuza et al 2023).

Developing and developed cities often face various challenges that differentiate them from other types of urban areas. Isfahan, recognized as the second most developed city in Iran, has undergone significant transformations throughout its history. One of the most pressing changes in recent years is the impact of climate change, which has manifested visibly in the city. The effects of climate change, influenced by shifts in urban form and infrastructure, are particularly evident in Isfahan. Understanding climate risks to heritage must be part of planning and policy decision-making processes to increase the resilience and sustainability of both social and built environmental systems .

Rafieian and Sheikhi (2015) discuss the specific climate-related challenges facing Tehran, such as air pollution, urban heat islands (UHIs), water scarcity, and flooding. These challenges highlight the urgent need for effective adaptation and mitigation strategies. Similar to Tehran, rapid urbanization and population growth in Isfahan exacerbate these issues, making integrated planning critical. The authors emphasize that without proactive measures, the consequences of climate change could significantly impact urban livability and sustainability. Sodoudi et al. (2014) explain that the UHI effect occurs when urban areas experience significantly higher temperatures than their surrounding rural areas, primarily due to human activities, extensive concrete surfaces, and reduced vegetation. In Tehran, this effect is intensified by rapid urbanization, population growth, and limited green spaces—conditions that also apply to Isfahan. The increase in temperature not only affects the local climate but also poses health risks to residents and strains energy resources, particularly during the summer months. Hunt and Watkiss (2010) emphasize that cities are particularly vulnerable to climate change due to their dense populations, infrastructure,

and economic activities. The concentration of people and resources in urban areas creates heightened risks associated with climate impacts, making cities critical focal points for adaptation efforts. Additionally, Spennemann and Graham (2007) highlight that historic areas are especially vulnerable to the impacts of natural disasters, such as floods, earthquakes, and wildfires. These events can cause significant damage to the physical fabric of cultural heritage and disrupt the social and economic structures of communities. Chow and Brazel (2011) demonstrate that xeriscaping is an effective strategy for mitigating the urban heat island effect, contributing to a sustainable urban form and addressing the challenges posed by climate change in desert cities. Their research advocates for integrating such practices into urban planning to enhance resilience and promote environmentally friendly landscaping solutions .

The integration of climate change adaptation into urban planning is crucial for cities like Isfahan. All the discussed literature indicates that cities, particularly historical ones like Isfahan, will suffer greater losses in the face of climate change if this issue is not addressed. Failure to implement effective strategies could lead to significant degradation of urban environments, loss of cultural heritage, and adverse impacts on the quality of life for residents. Therefore, the development of comprehensive climate action plans that prioritize sustainability and resilience is essential for safeguarding urban areas against the increasing threats posed by climate change.

2.1. Climate Impacts and Urban Form

Climate change can significantly influence the structure and layout of cities. Urban form, which includes the physical arrangement of buildings, transportation networks, and public spaces, plays a crucial role in how cities experience and adapt to climate variations. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events can affect urban infrastructure, public health, and the overall livability of a city (IPCC 2023). The IPCC (2021) has clearly shown that climate change, driven by human activities such as greenhouse gas emissions, has caused a global rise in temperatures, negatively affecting many urban infrastructures and planning systems. This temperature increase can also impact public health, leading to a rise in heat-related illnesses and thermal stress,

particularly in regions unprepared for such temperature changes. Studies by Hamin et al (2022) have shown that cities, as economic and social hubs, are more affected by these changes than rural areas. The direct consequences include reduced economic efficiency and a decline in quality of life.

In recent decades, climate change has had a significant impact on weather patterns across various regions, especially in arid and semi-arid areas like Isfahan. Rising temperatures, changes in precipitation, irregular rainfall patterns, and frequent droughts are among the consequences of these changes that have posed serious challenges to the city of Isfahan. These dry and semi-dry regions are more quickly affected by climate change compared to other areas. The current urban form of Isfahan, shaped by development over the past few decades, contradicts the region's climatic conditions, and this expansion in various directions has contributed to an increase in temperature in the area, according to meteorological data. In cities like Isfahan, these impacts are clear in the pressure on water resources, increased pollution, and the strain on energy systems, all of which are interconnected with the city's urban form. Fallmann and Emeis (2020) advocate for a holistic approach that integrates climate studies into urban design to create resilient and sustainable cities that can thrive despite the challenges posed by climate change. By doing so, urban environments can enhance their attractiveness to tourists while also addressing pressing environmental issues. The design and functionality of urban spaces must adapt to these changes to ensure sustainability and resilience. The changes occurring in the city of Isfahan have led to significant alterations in its climate, and these climatic changes, in turn, impact the city. Sudden rainfall, rising temperatures, and variable weather conditions can affect the infrastructure of the historical and central parts of the city, potentially causing detrimental effects on its tourism industry and historical heritage in the future. The current state of development and urban form of the city of Isfahan holds special significance in planning for addressing the emerging climate changes .

2.2. Impact on Infrastructure

Climate change poses significant threats to urban infrastructure, which is crucial for the functioning of cities. In Isfahan, rising temperatures, increased flooding, and droughts can degrade critical infrastructure such as roads,

bridges, water supply systems, and sewage networks. Changes in precipitation patterns can lead to water scarcity, putting stress on existing water supply systems. The city of Isfahan is currently facing a water crisis. According to research by Shahraki and Fadaei (2019), climate change has led to a reduction in both surface and groundwater resources in the region. Decreased precipitation and frequent droughts have affected urban water supply systems, making it increasingly essential to reassess water resource management. This situation negatively impacts various urban sectors, including historical buildings and green spaces, worsening the city's water crisis. There is a critical need for urban planners and policymakers to recognize and address the vulnerabilities of urban infrastructure to climate change (Mastrorillo et al., 2016). Prolonged droughts reduce water availability, making it challenging to meet the needs of the population and tourism.

Extreme weather events, such as heavy rains and floods, can damage transportation networks, including roads and public transport systems, disrupting connectivity and accessibility. This affects not only daily commuting but also the movement of tourists, which is vital for the local economy. Increased heat can also strain public utilities, including electricity supply and cooling systems, leading to power outages and a decrease in the quality of services. This is particularly critical in a city like Isfahan, where high temperatures can significantly affect residents' comfort and well-being.

The impacts of climate change on infrastructure in Isfahan underscore the importance of adapting urban planning and development to enhance resilience against climate-related challenges. As one of Iran's important tourism and economic hubs, Isfahan relies heavily on its urban infrastructure, including transportation networks, water supply systems, and wastewater management. With the increasing intensity and frequency of natural disasters caused by climate change, the city's infrastructure is at serious risk of damage. Mastrorillo and colleagues (2016) emphasize that urban infrastructure, particularly regarding floods and storms, requires reinforcement and optimization. For example, intense and sudden rainfall can put pressure on sewage systems, leading to urban flooding that disrupts daily life and causes significant economic losses. Marschtz et al. (2020) argue that climate policies must take historical events and local cultural identity into account. They suggest that understanding local and historical

narratives can improve climate policies and community involvement in urban planning, enhancing the management of climate-related risks.

The role of historical infrastructure in the center of Isfahan faces development challenges, and in the event of climate changes such as flooding, many historical infrastructures will also be put to the test. The key question is whether Isfahan's development plans ensure compatibility between modern and historical infrastructures. If this has not been considered, historical infrastructures will suffer the most damage during environmental crises. It is essential that, as one of Iran's major historical cities, Isfahan's historical infrastructures align with its modern infrastructures to ensure resilience.

2.3. Consequences of Urban Development

Climate change resulting from urban development negatively affects natural ecosystems and green spaces. UN-Habitat (2020) emphasizes the need for cities to implement green public spaces that are resilient to climate change to mitigate the adverse effects of global warming. In Isfahan, where extreme temperatures are common during hot seasons, the development of such spaces could significantly improve residents' living conditions and alleviate climate impacts. Historically, Isfahan had abundant green areas, but urban expansion has reduced these spaces, harming the city's environment.

One significant consequence of climate change is the alteration of land use patterns in large cities. Zarifian et al. (2021) highlight that temperature and precipitation changes increase pressure on urban land. In Isfahan, this has led to a reduction in agricultural land on the outskirts and an expansion of residential areas, increasing population density and straining urban planning efforts. Bulkeley and Betsill (2010) stress that revising urban policies to account for climate change is essential, calling for a shift from traditional governance to multilevel governance to improve climate action. Emphasizing the integration of climate considerations into urban planning, advocating for compact and sustainable urban forms, and promoting stakeholder engagement, this can provide a comprehensive approach to addressing the challenges posed by climate change in urban environments (Hanzl and Osmond 2020).

Marschutz et al. (2020) argue for recognizing local narratives in building urban climate resilience. Engaging communities in planning can help

develop effective, context-sensitive adaptation strategies. For Isfahan, the historical urban fabric offers valuable insights into how the city previously adapted to its climate challenges. A key question is whether modern Isfahan's center and outskirts function cohesively in addressing climate issues. Urban development typically results in more impervious surfaces, such as roads and buildings, exacerbating problems like stormwater runoff and the urban heat island effect. These factors worsen flooding and increase urban temperatures, placing stress on the city's infrastructure. In Isfahan, integrated land-use strategies are urgently needed to address climate resilience, sustainable development, and the preservation of green spaces.

Isfahan's historical sites are also at risk due to urbanization. Encroaching urban development threatens cultural heritage, making careful planning essential to protect these sites while accommodating growth. Strategic urban planning is needed to balance development with environmental sustainability and cultural preservation. Promoting green infrastructure, such as parks, green roofs, and urban gardens, can enhance the city's climate resilience. These solutions provide environmental benefits and improve quality of life by offering recreational spaces and reducing urban heat. Establishing policies that focus on sustainable development, resource conservation, and climate adaptation is necessary to guide urban growth in alignment with environmental goals. Continuous monitoring of climate impacts and the effectiveness of urban management strategies is also essential for timely adjustments.

Cities like Isfahan need to reassess urban management approaches to address climate challenges. Eslamian et al. (2017) highlight that climate change poses significant risks to tourism in the Zayandeh-rud River Basin through its effects on hydrological variables and natural attractions. The World Bank (2010) recommends moving toward climate-resilient policies, including infrastructure resilience, natural resource management, and green urbanization. Implementing these measures will mitigate the negative effects of climate change, fostering a more sustainable and resilient city. The tourism industry will also be affected by climate change in Isfahan. Scientific studies suggest that cities should upgrade infrastructure, adapt urban development patterns, and adopt sustainable approaches to minimize the impact on cultural and tourist heritage areas. By understanding vulnerabilities and economic consequences, cities can implement effective

adaptation strategies to safeguard their infrastructure and tourism industries against climate challenges (Gohari et al., 2014).

Sustainable urban development and responsible tourism can work together to create resilient cities. Dodge and Gentry (2019) highlight the importance of adopting sustainable practices to mitigate climate impacts while addressing the vulnerabilities of tourism. Stancu et al. (2017) emphasize the need for proactive climate adaptation in cities, involving stakeholders to ensure sustainable development for future generations.

3. Research Method

This research employs a descriptive-analytical approach, focusing on the impacts of climate change on urban form and the associated challenges in the touristic city of Isfahan, based on the analysis of meteorological data. The study primarily relies on quantitative data, including climate variables such as temperature, precipitation, and humidity, sourced from meteorological stations and climate models.

Document analysis involved reviewing scientific articles, government reports, and materials related to climate change and historical data. Statistical software was used to analyze the climate data, with an emphasis on identifying trends, correlation patterns, and statistical relationships between climate variables and urban changes. In addition, GIS technology was applied to process climatic data and map vulnerable areas, facilitating spatial analysis of climate change impacts across various parts of the city.

The research specifically examined Isfahan as a historical city with a rich heritage, where major tourist attractions are concentrated, to assess how climate change affects these areas compared to other parts of the city. Descriptive and inferential statistical methods were used to analyze the quantitative data, helping to identify significant patterns and impacts. Despite some challenges, such as limited cooperation from respondents and restricted access to certain data, the research methodology enabled a comprehensive analysis of climate change's effects on urban form and tourism management. The findings aim to contribute to more informed urban planning and policymaking, particularly in addressing climate-related challenges in tourism management.

The diagram below illustrates the steps of the research based on the Saunders model. Data collection, digitization, the use of remote sensing

data to analyze climatic data, and calculating the monthly averages of each climatic variable formed part of the study's methodology. The use of 30-year statistical data and the analysis of their trends, based on urban development maps, provided evidence of temperature changes and shifts in urban form.

The research took a deductive approach, with no researcher interference in the data, evaluating cases from the general to the specific. The results of this approach are observable and verifiable within the urban environment.

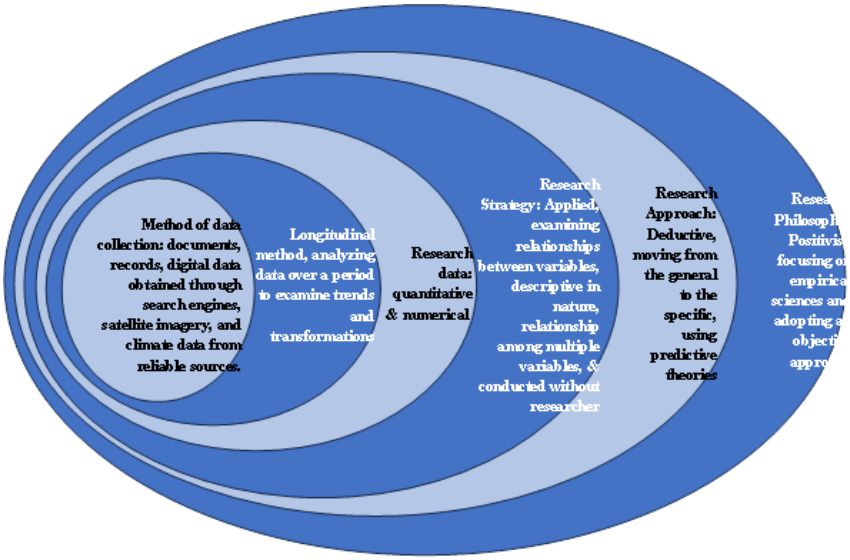

Diagram 1.steps conducting in research based on the Saunders Model.

4. Result

Studies indicate that the city of Isfahan has undergone significant and widespread development in various directions over the past years, particularly since 1984. Studies indicate that the city of Isfahan has undergone significant and widespread development in various directions over the past years, particularly since 1984. Map 1 illustrates the overlay of Isfahan's map from 1923 onto images of the city from 1984 and 2016. This image shows how the expansion of Isfahan over approximately 100 years has occurred in both scale and

dimension. Additionally, the deep blue area at the center is the confluence of the Zayandeh River and Chaharbagh Street, which has still been unchanged throughout these years. The central core of the city, including the historic fabric of Isfahan from the Safavid era, has been preserved, with urban expansion occurring around this central core, to the west.

From the map, between 1923 and 1984, a period of 60 years marked in yellow and orange on the map, the city's expansion was logical and directed eastward, which can be attributed to agricultural and gardening activities on the city's outskirts. However, from 1984 to 2016, during a period of approximately 32 years, urban growth significantly accelerated to the west, particularly with the connection to Khomeini Shahr in the northwestern region, which has the highest population in the province after Isfahan. This expansion in the Isfahan plain has completely transformed the conditions and exacerbated multiple changes, including climate change.

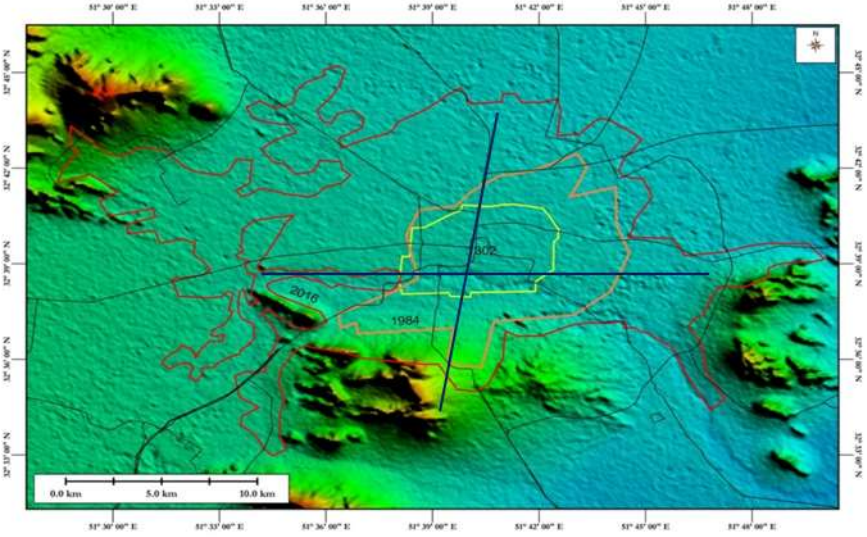

Figure 1. Alignment of the geo-referenced map and the city boundary lines in the years 1923 (yellow), 1984 (orange), and 2016 (red) (Researcher, 2021).

Investigations revealed that the city's type of development in various geographic directions has significantly influenced the increase in ambient temperatures, particularly around the year 2000. Studies show that the expansion of the city, especially towards the west, has led to

challenges in altering the temperature conditions in the region. It is important to note that the climatic systems in the area have a west-east orientation; thus, despite urban development towards the west, the city center, which includes the historical fabric, is more vulnerable to climatic changes, especially rising temperatures.

Statistics show that temperatures in the Isfahan region and its surroundings have been rising and are directed toward the center. As one looks back to the years prior to 2001, a more stable environmental temperature condition can be seen between the warm and cold seasons. Specifically, according to the prepared charts, the level of heat during the summer and the difference in winter temperatures have become more pronounced, saying that the climate in these two seasons has kept balanced conditions (as shown in Tables 1 and 2).

Table 1. Average temperature in the cold months before and after 2001 at Isfahan Airport Station (30-year period from 1990 to 2019).

Cold Months	Before 2001	After 2001
10 (October)	14.10	**16.66**
11 (November)	8.77	**7.99**
12 (December)	3.48	**3.34**
1 (January)	1.99	**1.93**
2 (February)	4.81	**4.98**
3 (March)	9.04	**10.53**

Table 2. Average temperature in the warm months before and after 2001 at Isfahan .Airport Station (30-year period from 1990 to 2019)

Hot Months	Before 2001	After 2001
4 (April)	15.04	**15.23**
5 (May)	19.79	**21.16**
6 (June)	26.11	**26.88**
7 (July)	28.00	**29.48**
8 (August)	27.36	**27.67**
9 (September)	22.46	**23.14**

In Table 1, which pertains to the weather station at Isfahan Airport, the increase in temperature during the cold months, particularly in October, has risen by more than 2 degrees Celsius. Additionally, with the onset of warmer temperatures in February and March, the average

temperature has changed noticeably between 0.1 to 1.5 degrees.
Table 2, which includes average temperature data for the warmer months at Isfahan Airport, shows a significant rise in temperatures during June, July, and August, with an increase of up to 1.5 degrees. The reasons for the temperature differences in the warmer months of the year and their increase have a significant correlation with urban development. The sudden rise in temperature between March and April shows that the onset of the warm season in the Isfahan region is occurring closer to the colder months of the year. In fact, the number of cold months in this region is decreasing. Therefore, the pleasant seasons for tourism in Isfahan are also diminishing, which has a direct relationship with urban development and, so, climate change.
If the overall temperature in a city like Isfahan is on the rise, we will gradually see an increase in temperatures across multiple microclimates within the city, leading to an increase in the number of urban heat islands. Microclimates can depend on various urban spaces, while urban form, development patterns, topography, geographic location, and various other natural factors significantly influence the region's climate. The factors affecting microclimates and the overall climate of a city are related, and each affects the other. Therefore, areas of the city that contain historical fabric, even if they undergo minimal development, will still be affected by changes in the climate and microclimate surrounding them.
As urban development in Isfahan has progressed, urban centers, which primarily include historical fabric, have become increasingly distant from the city's periphery. This distance has resulted in factors such as wind, precipitation, and even pleasant temperatures, which typically infiltrate the city from the west, reaching the city center with diminished quality over time, thus affecting the urban centers of Isfahan. As this distance increases, it is natural that the city center benefits from less favorable climatic conditions. It is important to note that Isfahan, found to the east, is also influenced by its proximity to the central deserts of Iran and differing climatic conditions, contributing to the rise in temperatures, especially during the warmer months. Since around the year 2000, the increase in temperature, coupled with urban development, has created a situation that poses challenges to the possibility of restoring better climatic conditions in these areas. The lack of access to suitable weather from the west and

the pressure from desert conditions infiltrating from the east have placed the center of Isfahan in serious challenges due to urban development. Through firsthand visits and discussions with those who work in the center of Isfahan, it becomes clear that they have been enduring much harsher conditions over the past decade compared to before.

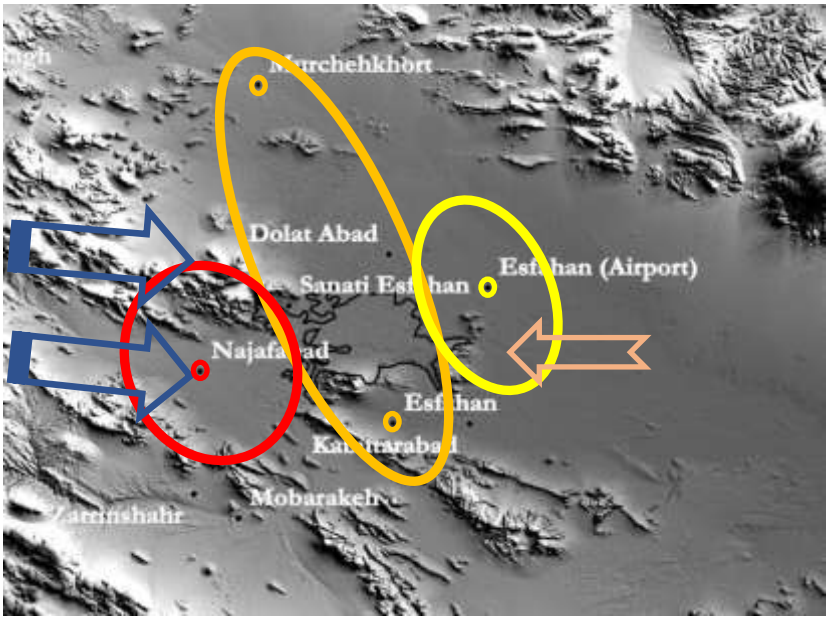

Figure 2. Location of the meteorological stations in question and representation of temperature conditions at each station, along with the influx of temperatures from the west and east into the center of Isfahan (Researcher, 2021).

Beyond the physical impact of these changes, such as rising temperatures, on historical sites in these areas, the situation also poses challenges for tourism, reducing the duration of visits to these historical-cultural centers. Map 2 clearly illustrates how the expansion of the city in various dimensions, particularly towards the west, where climatic influence occurs has affected the city center and allowed warm air from the eastern regions to infiltrate. The red lines show higher temperatures at the meteorological stations, showing how this

influx affects the city center. The red lines are hot temperatures at the weather stations, the orange lines depict lower temperatures but still influenced by the west and east, and the yellow lines show lower temperatures affected by the higher temperatures from the east. As shown in the map, the center of this map and Isfahan is under the pressure of rising temperatures from both the west and east. This issue is expected to have serious implications for the city center of Isfahan in the coming years. Consequences that often impact the quality of life of its residents. The higher the environmental temperature, the more destructive its effects on historical environments, both physically and chemically, as well as on the quality of preservation and visitation conditions. These aspects can be well monitored and objectively studied.

5. Discussion and Conclusion

The urban expansion of Isfahan over the past century has significantly altered both its physical landscape and its climatic conditions. Particularly, the rapid growth observed between 1984 and 2016, particularly toward the west, has led to a substantial rise in ambient temperatures, resulting in the development of urban heat islands. This phenomenon, characterized by localized areas of increased temperatures, has had direct implications for the city's microclimates and overall environmental stability.

Analysis of temperature data reveals a marked increase in both winter and summer temperatures post-2001. For instance, the average temperature during cold months, especially in October, has risen by over 2 degrees Celsius. Similarly, warmer months such as June, July, and August have also seen increases of up to 1.5 degrees. These changes suggest that the onset of warmer seasons is now occurring closer to the colder months, leading to a reduction in the duration of pleasant weather, which is crucial for tourism. The historic core of Isfahan, while largely preserved, has become increasingly vulnerable to these climatic shifts. The westward expansion of urban areas has effectively created a barrier that limits the influx of beneficial climatic elements, such as cool winds and precipitation, which typically come

from the west. As a result, the city center is left exposed to the arid conditions of the eastern deserts, exacerbating the challenges posed by rising temperatures. This increasing distance from the city's periphery has resulted in the degradation of climatic quality that was once favorable to the urban center. The implications for tourism are significant, as the historical and cultural sites in Isfahan, which attract visitors, are now subject to harsher climatic conditions, potentially diminishing the overall tourist experience. This reduction in pleasant weather not only threatens the longevity of these sites but also poses economic risks, as fewer visitors may choose to explore the city during increasingly hotter months .

The research highlights the critical interplay between urban development patterns and climate change, emphasizing the need for sustainable urban planning strategies that account for climatic realities. Addressing these challenges will be vital to preserving Isfahan's rich cultural heritage and ensuring its viability as a tourist destination in the face of a changing climate. Sustainable practices, such as increasing green spaces, enhancing urban resilience, and improving environmental management, will be essential to mitigate rising temperatures and protect the historical core from further degradation.

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Conflict of interest

The author declares that there are no conflicts of interest regarding the publication of this article. All research was conducted in compliance with ethical standards, and there are no financial or personal relationships that could be construed as influencing the work reported in this manuscript.

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