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Original Research Article

A Study of the Wind's Role in Shaping the Man-made Landscape of Sistan and the Methods of Utilizing and Dealing with it Based on Historical Sources

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Abstract

Problem statement: Almost constant winds blowing throughout the year have always been the main feature of the region of Sistan since ancient times. This climatic phenomenon has had a significant impact on the lifestyle, livelihood, and architecture of the residents of this region and has forced them to devise creative solutions to deal with the harmful effects. However, these people have also developed various techniques and methods to harness the power of this natural force. The creativity of the residents in dealing with and utilizing the winds of Sistan has greatly influenced the built landscape of the region and the lifestyle of its people. Individuals who have visited this land in different periods throughout history have mentioned this influence and have discussed the techniques used by the indigenous people of Sistan in their writings.

Research objective: Using credible historical documents and sources, this study attempts to identify and classify the techniques and methods through which the indigenous residents of Sistan deal with the region's winds. Field studies carried out in Sistan, especially in Sekooheh and Qaleh-no villages, indicate that the local architects of the region implement wind-harnessing techniques in constructing the native abodes of the region even to this date.

Research method: This research was a qualitative study that used content analysis to examine historical texts to find mentions of the influence of the wind on the lifestyle and architecture of the indigenous residents of Sistan and to identify the aim and effect of each technique by interpreting the findings.

Conclusion: The results show that the indigenous residents of Sistan have devised effective techniques to redirect the wind before it reaches their settlements and to utilize this natural phenomenon inside their houses since ancient times. Reviving and modernizing these techniques can help improve the current condition of housing in Sistan.

Keywords: *Wind, Built Landscape, Indigenous Solution, Construction Technique, Sistan.*

Introduction

With its long history of human settlement dating

back to the mythological era of Iran according to the Shahnameh, Sistan has been mentioned many times in the travelogues, diaries, and records written by tourists, advisers, and business owners

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who have traveled to and around Iran .In addition to discussing the social ,cultural ,and economic aspects of the lives of the residents of Sistan ,these historical texts mention the climatic conditions of this land and their impact on the lifestyle of the region’s residents. These historical sources mention the winds blowing almost continuously throughout the year as one of the main climatic features of Sistan .For example ,a foreign adviser who had traveled to Sistan about 110 years ago has suggested that if a land is to be named “the land of the wind”, Sistan is the most suitable candidate (McMahon, 1906). These continuous winds have fundamentally affected the lives of the residents of Sistan and have played a significant role in the formation of the built landscape of the region. Contemporary field studies show that the wind is no longer being properly utilized as an energy source in the architecture of Sistan despite its history of use in the region’s past .Therefore ,this study attempts to identify the techniques once commonly used in the vernacular architecture of Sistan to harness the wind and to revive these techniques .To this end, it attempted to find the answer to the following questions:

- 1 -What is the impact of the wind on the life and housing of the indigenous residents of the Sistan region?
- 2 -What techniques do the indigenous residents of the Sistan region use to deal with and harness the power of the wind in their lives?

Research background

Considering that the role of the wind in shaping the built landscape of Sistan has not been researched before ,only the studies which have examined the use of the wind in the contemporary vernacular architecture of Sistan are discussed in this section. Najarsaligheh (2003) studied the relationship between the physical characteristics of Zabol City and the direction of the prevailing winds in the region .He found that the canalization effect of the streets that are parallel to the prevailing winds of Zabol increases the wind speed .He also reported

that the circulation effect of the streets that are perpendicular to the prevailing winds of Zabol result in the accumulation of windblown sand grains and environmental pollution .Fazelniya et al .examined the manner of adaptation of the physical-structural development of Tombaka Village in Zabol City with the direction of the region’s sandstorms. They argued that the houses were built southward in the old part of the village with some openings in the northern walls to let the gentle cool air enter the indoor space (Fazelniya, Kiani, Khosravi & Bandani, 2012). Heidari & Davtalab (2020) measured the speed of the wind in the indoor space of a native abode in Sistan that was equipped with Kharkhona (a native technique to cool the indoor air) and compared the results with the human comfort conditions of another abode not equipped with Kharkhona to determine the optimal wind speed for achieving thermal comfort. They concluded that Kharkhona is an effective means to naturally modify the wind speed toward optimum conditions in the native abodes of Sistan (Heidari & Davtalab, 2020). Sartipipour (2009) and Razjouyan (2009) reported that the residents of Sistan managed to establish pleasant and natural ventilation inside their houses by piling up moistened thorn bushes behind the windows that face the region’s winds .Memarian et al .analyzed the impact of the wind on the natural ventilation of the native abodes of Qaleh-no Village in Sistan using computational fluid dynamics (CFD). They analyzed the behavior of the wind inside each type of room in the native abodes of the region and concluded that NE-SW rooms which utilize natural ventilation elements have the highest efficiency for harnessing the wind (Memarian, Mohamad Moradi, Hosseinalipour, Heidari & Doudi, 2017).

Research methodology

Based on the architecture research frameworks developed by Groat & Wang (2005) and considering the interdisciplinary nature of architecture ,this study was designed and developed using historical documents and writings .This research is essentially

a qualitative study that seeks to identify and categorize the indigenous techniques and methods devised by the residents of Sistan to deal with and use the winds of the region. The methodology involved content analysis and examination of historical and geographical documents, travelogues, and similar texts authored by Iranian and non-Iranian individuals, which describe Sistan in different historical periods.

Theoretical foundations

The local architects of Sistan have developed various methods to utilize the wind for creating natural ventilation in the indoor spaces of the region's native abodes. Some of these methods are also used to cool the indoor temperature. However, these architectural techniques have been largely forgotten in the contemporary rural architecture of Sistan, which is modeled after urban housing. The most important of these techniques are as follows:

• Kolak

The indigenous residents of Sistan refer to the windcatchers of their houses as Kolak. Kolak is a rectangular protrusion in the middle and the end of the house's domed roof, which faces the prevailing wind of the region. After entering a house's Kolak, the wind changes its direction and flows into the interior space of the house through a 20 × 20 cm opening located at the top of the domed roof and provides natural ventilation. The combination of the windcatcher tower and the dome, which are built at a certain height from the flat section of the roof, greatly contribute to the achievement of thermal comfort in Sistan (Tavassoli, 2002). Fig. 1 shows the position of a Kolak relative to the domed roof and the room of an indigenous house in Sistan.

• Dorche

In the vernacular architecture of Sistan, the honeycomb-like openings built in the walls that face the prevailing wind of the region are called Dorche. A Dorche built in the NW wall of a house allows the wind to directly enter the room, which effectively cools down the indoor air during the hot seasons



Fig. 1. A kolak in Qaleh-no Village (right); A graphic representation of how the wind enters the room (left). Source: Heidari, 2015.

of the year. Dorches are used to regulate the indoor temperature of the native abodes in Sistan (Fig. 2).

• Kharkhona

Due to the 120-day winds of Sistan, the native residents of the region build and use a structure locally referred to as Kharkhona (also known as Kharkhaneh) to convert hot air into humid air (Fig. 3). The function of this architectural element is similar to that of a water-based air conditioner. The wind flows through the moistened thorns and its temperature decreases. Then it enters the room and modifies the indoor temperature toward thermal comfort.

Discussion

• Sistan's geography and climate

Located in the east of Iran, Sistan borders Afghanistan from the north and east, Zahedan City from the south, and the Lut desert and Birjand City from the west and northwest (Butorabi, 1977). The plain of Sistan is a part of the vast plain of Helmand, most of which is located in Afghanistan and a small section of which is located in Pakistan (Akbari, 1987); (Fig. 4).

Numerous historical texts describe the climatic characteristics of Sistan throughout different periods. In "Historical geography of Sistan: traveling with travelogues", Sir Henry McMahon¹ is quoted as saying if land is to be named the land of the wind, Sistan is the most suitable candidate. According to McMahon's explanation, the wind upsets one to the point of exhaustion; on the other hand, the blowing of this wind in Sistan is a kind of blessing, because it kills insects and reduces the heat of Sistan (Ahmadi Karviiq, 1999).

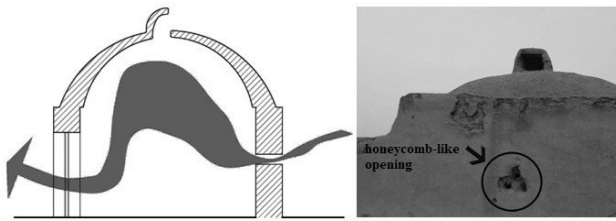


Fig. 2. A Dorche in Sekooheh Village (right); A graphic representation of how the wind enters the room through Dorche (left). Source: Heidari, 2015.

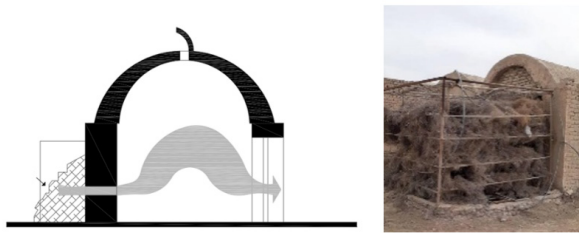


Fig. 3. An indigenous hut in Sekooheh Village (right); A graphic representation of how the wind enters the room through Kharkhona (left). Source: Davtalab & Heidari, 2020.

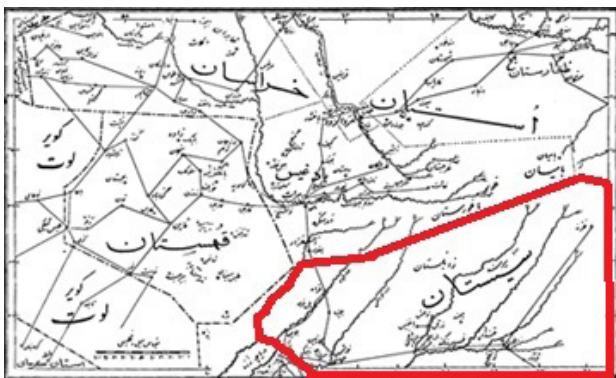


Fig. 4. A map of Sistan around 1900. Source: Afshar Sistani, 1991.

In “Kitab Al-Masalik wa Al-Mamalik” authored in the 10th century, Abu Ishaq Ibrahim Ibn Muhammad Al-Farisi Al-Istakhri describes the climate of Sistan and says “Sistan is a warm city. It has palm trees and no mountains; there is no snow during winter and the violent wind blows constantly” (Al-Istakhri, 1968, 194).

In his travelogue, Muḥammad Abul-Qasim Ibn Ḥawqal reports that “the land of Sistan is salty and sandy and the climate is hot. The trees are palm and there is no snow; it is flat land with no mountains and the closest mountains are in the region of Farah². Violent winds constantly blow in Sistan (Ibn Hawqal, 1966).

In its description of Sistan’s climate, a book titled “History of Sistan” authored by anonymous individuals states that “the north wind constantly blows there as does the morning breeze and the understanding and mind of its people are better than those of the people of other regions because of this temperate climate” (Bahar, 1935).

In “The lands of the eastern caliphate: Mesopotamia, Persia, and Central Asia from the Moslem Conquest to the time of Timur”, Guy Le Strange³ (1958) describes the climatic conditions of the Sistan region and reports that the city’s land is salty and sandy and it has palm trees. Violent winds blow continuously and move the sands around in a dangerous way which often overwhelms the whole villages and ruins the cultivated sections.

In his travelogue, Arnold Henry Savage Landor⁴ (1999) mentions the 120-day winds of Sistan and reports that these winds blow from north to south and that if these winds stop blowing in Sistan, the climate will become unhealthy considering the condition of water supply in the region. Landor also says that without these winds, life would become impossible during summer and that the climate is very healthy because of these winds.

In his travelogue about the 120-day winds of Sistan, Sir Percy Molesworth Sykes⁵ (1936) states that, according to the indigenous people of Sistan, the region would have been uninhabitable if these winds did not blow across the land.

In his book titled “Seistan: a memoir on the history, topography, ruins, and people of the country” originally authored in 1910, George Peter Tate⁶ (1983) describes the climate of the region and adds that the 120-day winds affect all aspects of life in Sistan. According to Tate, these winds have great value since, without them, the residents would have to rely on watermills; however, the slope of Sistan’s land is so gentle that there is no cascade anywhere in the region even in the largest canals; as a result, the residents can’t build and use watermills; therefore, only windmills are common in Sistan. Tate also reports that the wind decreases the summer heat,

makes the temperature more tolerable, carries away air pollutants and polluted air, and makes the air healthier.

Based on numerous historical sources some of which were mentioned above, two main factors can be said to have shaped the climate of the Sistan region: Hamoun Lake and the 120-day winds.

1- Hamoun Lake: Hamoun used to be the largest freshwater lake in the world before the recent droughts. The 120-day winds of Sistan blow over the lake and the water cools the air and thus decreases the temperature of the region, which in return improves the living conditions in Sistan. The local architects use certain techniques to direct the wind toward and into the living spaces of Sistan's native abodes.

2- 120-day winds: These winds which blow across the region from early June to early September (hot days of the year) have affected the vernacular architecture of Sistan.

These two climatic phenomena play a major role in shaping the lifestyle, housing, and livelihood of the residents of Sistan. This paper specifically focuses on the latter, namely the wind.

• **Techniques of dealing with the wind in Sistan**

Studies carried out on the mind control techniques used in Sistan can be categorized into two groups: (1) historical sources and (2) geographical researches. [Table 1](#) shows a classification of these studies based on their publication year.

Al-Istakhri has described Sistan and how the wind is used in this region: "A violent wind constantly blows and mills are built to use the wind. The wind picks up sands and moves them from one place to another. When sands pile up near the city, the people gather around to build a wall around the sands using wood and brushwood, higher than the sands. They leave openings at the foot of these walls through which the wind flows to pick up the sands and carry them over the wall and drop them where they cannot harm the people" ([Al-Istakhri, 1968, 194](#)).

Al-Jayhani has also explained the same procedure: "When they want to move sands from one place to

another where they do not fall on cultivated lands, they pile up wood, brushwood and thorn bushes around the sands to the same height. Then, they leave an opening at the foot. The wind flows and picks up the sands and moves them to another place so that their cultivated lands are not damaged" ([Al-Jayhani, 1989, 162](#)).

Ibn Hawqal traveled to Sistan in 331 AH and this allowed him to observe and describe in his travelogue how the indigenous people of Sistan use the wind: "[...] for this reason, windmills are built for grinding wheat. These winds carry sands from one place to another. The local people use the experience of their predecessors, which is based on the principles of geometry, to protect their land from quicksand. [...] I have heard that when the local people want to move sands from one place to another, they build some hills and walls made of wood and thorns near the sands and install an opening at the foot facing the wind. The wind flows in and picks up the sands, forming a whirlwind and moves the sand to where it is intended" ([Ibn Hawqal, 1966, 153](#)).

Al-Qazvini has also explained how the wind is redirected and harnessed by the indigenous residents of Sistan. The residents construct a wall made of wood, brushwood, and thorn bushes around a pile of sand and make a hole at the foot of the wall to relocate the sand pile ([Al-Qazvini, 1994](#)).

The book "History of Sistan" reviews the history of this region between 1053 and 1325 and mentions some characteristics, including the wind, which was unique among Iranian cities at that time: "And they have other choirs as well which they do not shy away from, such as moving sands from one place to another and collecting them and putting them where they want. The sands are a great treasury for them and they stash whatever they want inside the sands and the other benefit is that when they add a little sand to a place, plants grow better there. They also build mills and the wind spins them and grinds wheat. They have also made pulleys to draw water for the gardens and lands where they farm, even if water is scarce [meaning that they use this tool to draw water

Table 1. Historical sources and geographical studies about utilization of the wind energy in Old Sistan. Source: Authors.

Category	Author	Title	Translator/ editor	Year of publication of original work	Techniques for decreasing wind speed before reaching human settlements	Techniques for using the wind inside human settlements
Historical sources	Al-Istakhri (1968)	Kitab al-masalik wa al-mamalik	Iraj Afshar Sistani	951	Using a windcatcher made of wood and brushwood around the sands and leaving the lower section open for the wind to flow through, pick up the sands and carry them off toward the distance	Using the wind to operate windmills and grind wheat
	Al-Jayhani (1989)	Ashkal al-alam	Ali Bin Abd Al-Salam Katib	975	Using windcatchers as explained in Al-Istakhri's book	---
	Ibn Hawqal (1966)	[Travelogue]	Jafar Shoar	977	The people use the experiences of their predecessors, which was based on the principles of geometry, to keep their land safe from running sands / the same method explained in Al-Istakhri's book	Using the wind to operate windmills and grind wheat
	Al-Qazvini (1994)	Asar al-bilad wa akhbar al-ibad	Jahangir Mirza Qajar	1264	Using windcatchers as explained in Al-Istakhri's book	---
	[Anonymous]	History of Sistan	Mohammad Taqi Bahar	1325	The prosperity of Sistan is believed to have come from three acts: constructing dikes, raising walls to stop sands, and seizing corrupt individuals	Using the wind to grind wheat and draw water from wells
	McMahon (1999)	A collection of the historical geography of Sistan	Hasan Ahmadi Karviq	1897	---	The orientation of the buildings is based on the region's prevailing wind
Geographical studies	Sykes (1999)	The fourth journey in Persia	Hasan Ahmadi Karviq	1902	---	Using the wind to operate windmills
	Landor (1999)	In the forbidden land	Hasan Ahmadi Karviq	1903	---	Some techniques for using the wind to create natural ventilation in the houses / using the wind to cool the air via Kharkhona
	Le Strange (1958)	The lands of the eastern caliphate: Mesopotamia, Persia, and Central Asia from the Moslem Conquest to the time of Timur	Mahmoud Erfan	1905	---	Using the wind to grind wheat
	Tate (1983)	Seistan: a memoir on the history, topography, ruins, and people of the country	Hasan Ahmadi Karviq	1910	---	Some techniques for using the wind to create natural ventilation in the houses / using the wind to cool the air via Kharkhona
	Afshar Sistani (1990)	A book on Sistan	---	1990	---	Vernacular housing and the methods of utilizing the wind in the native abodes

from wells when there is a water shortage in Sistan] and they also take great advantage of the wind” (Bahar, 1935, 12). This book also proposes that

the prosperity of Sistan results from three actions: constructing dikes to prevent floods when Hamoun Lake may overflow, raising walls to stop sands from

entering the city and villages, and seizing corrupt individuals.

Raising walls has been frequently mentioned in other historical sources authored by historians, traders, and visitors such as Al-Istakhri (1968), as one of the main techniques used by the indigenous residents of Sistan to deal with the winds and sandstorms of the region. The book “Ajaib Al-Buldan” (748 AH), which is said to have been authored by Abu Al-Muayyid Al-Balkhi, suggests that: “There are lots of sands all around Sistan and the wind blows there and the mills spin by the wind and the people, fearing from the wind, have built dams and walls to prevent the wind from carrying the sand into the cities and villages” (Al-Balkhi, 1974).

Ahmadi Karviq has collected the travelogues of foreign advisers who traveled to Sistan in a book titled “Historical geography of Sistan: traveling with travelogues”. These travelogues frequently mention the techniques used by the indigenous residents of Sistan to deal with and utilize the wind. McMahan, for example, has explained that the indigenous houses of the region are built based on the direction of the region’s winds: “The ancient ruins in Sistan have all been built with a certain angle and the front and back walls of the buildings are perpendicular to the wind while the lateral walls have the same direction as that of the wind” (Ahmadi Karviq, 1999, 388).

Tate also describes the residential fabric of Sistan and reports that the villages of Sistan consisted of a collection of amorphous huts made of mud and straws. According to Tate, windcatchers were built right on top of the domed section of the roofs to allow in the wind. The residents clog up these openings using mud during winter (Tate, 1985) (Fig. 5).

Sykes suggests that windmills existed all over the east of Iran and says Al-Mas’udi (4th century AH) and Ahmad Ibn Rustah (4th century AH) have also mentioned their existence in Sistan. According to Sykes (1936), the Europeans did not know much about windmills back then. Describing his first visit



Fig. 5. The indigenous fabric of Qaleh-no Village in Sistan. Source: Pishdadi, 2014

to the human settlements of Sistan, Sykes reports that he saw 50 windmills constructed in a straight line, each of which had two walls built in parallel and facing the northeast and the prevailing wind.

In his book, Le Strange (1958) suggests that since the wind always blows in Sistan, the residents have constructed windmills to grind wheat and these windmills specifically belong to this region.

Landor (2009) has discussed how the residents of Sistan used the wind in their houses and mentions that the residents constructed an opening at the highest point of the domed section of the roof, which acted as a ventilator device. He also explains how windmills work in Sistan and emphasizes that these mills had the most elaborate design of their kind (Fig. 6).

According to the explanation provided by Landor (2009), the windmills in Sistan did not function vertically similar to those in Europe; rather, the mill, encased by three walls, rotated horizontally. The wind blew into the vertical opening of the mill and spun the wheel. Placed firmly onto an iron pedestal, the wheel started to spin smoothly and gradually gained speed. The mill had two floors. The wheel was on the upper floor and the millstone was on the lower floor. Wheat was guided under the stone via a very simple system made of yarn and a bowl. Landor



Fig. 6. The photo of a windmill in Sistan. Photo: Richard Hewer, 1971; Source: Beazley, Harverson & Roaf, 2013.

(2009) has also reported his observations of the British Consulate building in Zabol City, the capital of Sistan, and has described the indigenous techniques utilized in this building to provide thermal comfort. He goes on to explain that certain measures were taken in the design of the British Consulate building to alleviate the disturbing effects of the north winds that blow during the summer; several huts had been built alongside the northern wall, which was stocked with thorn bushes and two employees regularly sprayed water on the thorns. According to his explanation, the hot wind blew into these Kharkhonas via a special duct. The heat evaporated the water sprayed over the thorns and the wind became cooler and humid. Similar to the air blowing out of an air conditioner, this air entered the room and decreased the indoor temperature. In addition to the Kharkhonas, a windcatcher had been built at the center of the domed section of the roof through which the wind directly entered the room (Landor, 2009). George Peter Tate is probably the most credible British consultant who has provided a more detailed narration of the vernacular architecture of the region in “Seistan: a memoir on the history, topography, ruins, and people of the country”. Describing his place of residence in Sistan, Tate mentions that the drop in the room’s temperature resulting from the Kharkhona was so sharp that it was not comfortable and they had to downsize the opening to half its original size. Tate also mentions the windmills constructed in Sistan as a creative method to harness the

wind’s power. According to Tate, these windmills were a very common sight in Sistan. They were permanent buildings made of mud bricks and were designed in such a way that allowed for maximal use of the winds which blew from a fixed direction or with small alterations (Tate, 1983). In addition, Tate has described the native houses of Sistan in his book. His description of these abodes is considered to be the most detailed and the most comprehensive account of Sistan’s indigenous housing among various historical sources. According to Tate, at the time he was writing his book, each native house in Sistan used to have a ventilation system with a shaft or vertical duct which passed through two walls and opened up into the rooms. The ceiling was often a high dome. The entrance door was installed toward the southeast, i.e., the opposite direction of the region’s prevailing wind. Tate suggests that, based on the available evidence, this clever design was more compatible with the region’s climate compared to the European design. Thick walls and high domed roofs kept the houses cool during summer and the several openings freshened the indoor air in addition to helping the natural ventilation. The vents were the prominent feature of the native abodes in each village (ibid.).

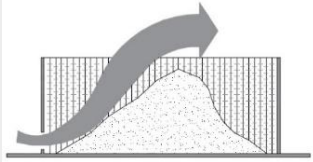
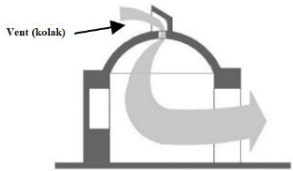
Findings

The residents of Sistan have long shaped and developed their lifestyle, housing, and livelihood based on the region’s climate. They use creative techniques to take benefit from the climatic features of Sistan. These techniques especially help them harness the power of the winds blowing almost constantly in the region. Table 2 summarizes the cases mentioned in various historical sources about how the residents of Sistan use the wind.

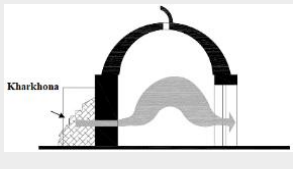
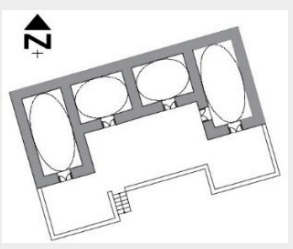
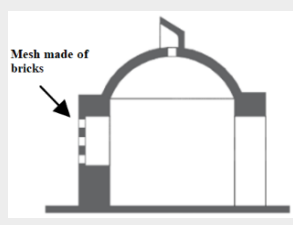
As can be seen in Table 1, various historical sources suggest that the residents of Sistan utilize the wind for various purposes including the following:

- Preventing sands from entering their settlements by constructing dikes, making use of small walls made of wood and brushwood to relocate sands, building larger walls to protect their settlements from the wind, and implementing a suitable direction for the urban fabric
- Grinding wheat using windmills

Table 2. The techniques employed by the indigenous residents of Sistan for dealing with and using the wind based on historical sources. Source: Authors.

Aim	Technique	Historical sources	
Grinding wheat	Building windmills	<ul style="list-style-type: none"> - Al-Istakhri (1968, 194): “[...] mills are built to use the wind.” - Beazley and Harverson, 2013 - Tabari (3rd century AH), (1972) - Al-Mas’udi (4th century AH) - Ibn Rustah (4th century AH) - Landor (2009) - Al-Balkhi (1974): “[...] the mills spin by the wind.” - Le Strange (1958): Since the wind always blows in Sistan, the residents have constructed windmills to grind wheat. - Sykes (1944) - Tate (1983): Everyone uses windmills in Sistan. - Ibn Hawqal (1966, 153): “[...] for this reason, windmills are built for grinding wheat.” - Dameshqi (8th century AH, 1978) - Bahar (1935, 12): “They also build mills and the wind spins them and grinds wheat.” 	
Preventing sands from entering settlements and damaging cultivated lands	Building sand-stopping walls	<ul style="list-style-type: none"> - Al-Istakhri (1968, 194): “If they do not use tricks to relocate the sands [...]” - Al-Balkhi (1974): “[...] and the people, fearing from the wind, have built dams and walls to prevent the wind from carrying the sand into the cities and villages.” - Ibn Hawqal (1966, 153-154): “It stretched away from the city 18 parasangs, not in the wind’s direction and so changed the wind’s direction away from the city.” 	---
	Building walls made of wood and brushwood around sands for relocating them using the wind	<ul style="list-style-type: none"> - Al-Jayhani (1989, 162): “[...] they pile up wood, brushwood and thorn bushes around the sands to the same height.” - Al-Istakhri (1968, 194): “[...] the people gather around to build a wall around the sands using wood and brushwood, higher than the sands.” - Ibn Hawqal (1966, 153): “[...] they build some hills and walls made of wood and thorns near the sands.” - Al-Qazvini (1994): Redirection of the wind via piling up woods and brushwood around the sandhill - Bahar (1935, 12): “[...] such as moving sands from one place to another and collecting them and putting them where they want.” - Ibn Hawqal (1966, 153-154): “It returned to the sands that had spread all over the city and scattered them to another wind.” - Forbes⁷(1955) 	
	Using the principles of geometry	<ul style="list-style-type: none"> - Ibn Hawqal (1966, 153): “The local people use the experience of their predecessors, which is based on the principles of geometry, to protect their land from quicksand.” 	---
	Suitable urban fabric	<ul style="list-style-type: none"> - Ahmadi Karviq (1999, 388): “The ancient ruins in Sistan have all been built with a certain angle.” 	---
	Building walls around the city	<ul style="list-style-type: none"> - McMahan (1906): The villages and locales have walls to protect them from the wind 	
Stashing valuables		<ul style="list-style-type: none"> - Bahar (1935, 12): “The sands are a great treasury for them and they stash whatever they want inside the sands.” 	---
Improving cultivated soil by adding some sands		<ul style="list-style-type: none"> - Bahar (1935, 12): “[...] and the other benefit is that when they add a little sand to a to a place, plants grow better there.” 	---
Accessing water	Building Wind-operated pulleys	<ul style="list-style-type: none"> - Bahar (1935, 12): “They have also made pulleys to draw water for the gardens and lands where they farm.” - Beazley et al. (1392): Horizontally-rotating pulleys are used to draw water 	---
Natural ventilation	Building vents and windcatchers on the roof	<ul style="list-style-type: none"> - Landor (2009): There is a vent on the highest point of the dome - Landor (2009): There is a windcatcher at the center of the domed roof - Tate (1983) 	

Rest of Table 2.

Aim	Technique	Historical sources	Image
	Using Kharkhona	- Landor (2009): Several Kharkhonas are built alongside the northern wall of the house, each with a depth of four feet - Tate (1983)	
	High domed roof	- Tate (1983)	---
	Direction of the entry door	- Tate (1983): The entry door of the indigenous houses of Sistan are installed toward the southeast, opposite the direction of the region's prevailing wind. - The plan on the right displays a U-shaped indigenous house in Samani Village in Sistan. All entry doors open toward the southeast.	
	Building bowl-like vents on top of the domed roof	- Tate (1983): The domed roofs have vents as well which are similar to the glass of bathrooms and the skylights of the room are built on the highest point of the dome.	---
	Using the Fakhr-o-Madin pattern for windows	Tate (1983): The space inside the frame of the windows is blocked with heavy bricks.	

- Stashing valuables inside sandhill created by the wind
- Extracting groundwater using wind-operated pulleys
- Improving arable soil by a controlled flow of the wind toward fields and adding a small amount of sand to the soil
- Creating natural ventilation using Kolak, Dorche, and Kharkhona

Conclusion

The findings of this study showed that the techniques used by the indigenous residents of Sistan to deal with the wind are divided into two categories:

- 1) Techniques used to control the wind, dust, and sands before reaching their settlements
- 2) Techniques used to harness the wind's power inside their settlements and living spaces

Various studies have indicated that the indigenous residents of Sistan have devised certain techniques to prevent wind-blown sand into their settlements

by building walls made of wood and brushwood, implementing a proper orientation in their settlements' fabric, and constructing protective walls around their villages. They also use the wind to operate windmills, stash their valuables in sandhills created by the wind, improve their cultivated lands by directing the wind toward these lands and adding a certain amount of sand to the soil, build wind-operated pulleys to access the region's groundwater and create natural ventilation using vents, windcatchers, Kharkhonas, and domed roofs. The current climate-related problems that the residents of Sistan face today, such as strong winds, sandstorms, and water shortage, are not much different from the past. As such, studying the tried-and-true techniques used by the indigenous residents of Sistan in the past can help the current residents and experts better deal with these problems. Currently, the architecture of the Sistan region has two

types: (1) The vernacular architecture, which is a remnant of the past and in which maximal use of the wind's power is observable. Many residents of the region still dwell in abodes constructed using this type of architecture, which is based on the climatic characteristics of the region and uses natural resources to provide comfort. (2) The new architecture, which is based on urban housing models and in which climate-related principles have been ignored. These indigenous techniques can be revived, modernized, and improved to help the current residents suitably respond to the conditions of the region and fulfill their needs – a subject that future studies are recommended to focus on.

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The authors declare that there is no conflict of interest in conducting this study.

Endnotes

1. In January 1903, a delegation led by Colonel Sir Vincent Arthur Henry McMahon arrived in Sistan on behalf of the United Kingdom to make decisions about the water of Helmand and to resolve the Iran-Afghanistan dispute over the river. This delegation stayed in Sistan for more than three years to complete its mission and left Iran in June 1905 (McMahon, 1999).
2. Farah is one of the three rivers that flow into the Helmand. The river is dry for the better part of the year but there are often some puddles in the river's bed. The water can also be accessed by digging down a few meters (Ahmadi Karviq, 1999).
3. Guy Le Strang (1854-1933) was a famous British orientalist who lived in Iran from 1877 to 1880, concurrent to the reign of Nasser Al-Din Shah. During this period, he studied Persian language, history, and geography.
4. Arnold Henry Savage Landor (1865-1924) was a British archaeologist and geographer who traveled to Sistan and Baluchistan in 1901.
5. Sir Percy Molesworth Sykes (1867-1945) served in the Indian Army during 1892 and became familiar with the Persian language. He went to Iran two years later and set up a British consulate in Kerman Province. In 1898, he established a consulate in Sistan.
6. George Peter Tate (1856-???) was a British authority, surveyor, archeologist and historian. He traveled to Sistan with Sykes in 1901. On his second travel to Sistan between 1903-1905, he was a member of McMahon's arbitration board, which resolved the dispute between Iran and Afghanistan over their borders in Sistan.

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