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The Orientation of Village, the Most Important Factor in Rural Sustainability in Cold Climate (Case study: Masuleh and Uramantakht)

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Abstract

The rural fabric of every village is affected by both human interventions and environmental factors. Also, climate and nature can both influence the village structure. In other words, the climatic and vernacular architecture of rural areas are mutually interrelated, and the villages have to adapt to their environment to survive, provide welfare, and prevent the immigration of villagers to cities sustainably. A very important factor in the sustainability of vernacular buildings is the orientation of rural buildings and the possibility of using solar and wind energy, an issue that has been considered by vernacular builders throughout history. Limited sources of energy and reliance on renewable energy have made the inhabitants design and build their vernacular buildings according to climatic conditions to reduce energy consumption. In this regard, the proper orientation of the buildings to prevent energy loss is of particular importance. This study tries to discuss the factors influencing the orientation of rural housing. The vernacular architecture and the proper orientation of houses in Masuleh (Gilan province, north of Iran) and Uraman Takht (Kurdistan Province, west of Iran) villages are also discussed. The possibility of using key factors of vernacular architecture principles in similar climates is also discussed. Energy simulations with the Honeybee plugin are used as a tool for optimization orientation. Honeybee runs simulations with Energy Plus through Rhino and Grasshopper software and visualizes results by the Ladybug plugin. For the finding best orientation, the parameters which related to building energy performance defined in honeybee plugin such as windows size and location, wall U-value, glazing construction U-value, glazing g-value, cooling and heating set-point. After energy modeling of building for the case study, the energy simulation has been conducted with Energy Plus engine and the Ladybug plugin visualized the results.

Keywords: orientation, sustainability, energy, rural vernacular architecture

1. Introduction

Sustainability is a concept in ecology and refers to actions that are not in conflict with the continuation of life processes and ecosystems. Sustainability for human beings is a process of long-term prosperity and encompasses environmental, economic, and social aspects. In fact, sustainability can guarantee the superior quality of architecture and ideation [1]. The term “sustainability” was first coined in 1986 by the World Environmental Development Committee as "Meeting the present's needs without compromising future generations' ability to meet their own needs". More sustainability aspects are introduced annually to offer better strategies to the world [2].

The principles of sustainable architecture have been observed in many vernacular buildings and dwellings. Vernacular architecture has unique features, including aesthetics and environmental features, energy conservation strategies, and adaptability to climatic conditions. Sustainability in architectural sciences and achieving sustainable development in architecture is possible[3]. Some sustainable architecture principles can be seen in the vernacular architecture of Iran villages, such as using local materials, natural heating and cooling measures, and using water and plants properly [4].

In general, the building's orientation follows the natural land topography, wind and sunlight direction, and architectural requirements such as providing private and quiet space. Therefore, it is the architect's responsibility to face the buildings toward the sun for maximum use of sunlight and heat and meet the inhabitants' psychological requirements [5]. The vernacular architecture and regional planning in the mountainous cold and humid climate of Iran, especially Masuleh and Uramanat Takht villages, is a good example of environmental design and harmony with the environment. The inhabitants of these two villages have provided successful architectural solutions for constructing the buildings and organizing the whole village despite all threatening natural disasters. To create a sustainable environment for human life, the builders of Uramanat region and Masuleh village have come up with a special vernacular architecture and rural planning principles that not only conserves the environment but also conserves the environment and enriches t In these areas, the materials of the native hardliners were mostly clay and mud. Single-walled windows and wall thickness vary from 40 to 80 due to a lack of facilities. In this region, due to the mountainous nature of the region and the low living conditions of the people to use maximum electrical appliances, the direction of the building to use more sunlight to use light and heating the building is one of the most critical factors in the formation of the village. Despite being located in two different areas, the architectural style of the two villages is the same. Therefore, this research studies the main architectural features that have led to the creation of similar rural sustainable fabric in these two villages.

The vernacular architecture and rural patterns of Masuleh and Uramant have been shaped based on a thousand years of experience. They have found solutions to utilize solar, and wind energy, and they know who to rely on renewable sources of energy without destroying the natural environment. These villages have created comfort by using minimum amount of fossil fuels, orienting the buildings and villages toward the sun, using appropriate and renewable materials, building according to the land topography and slopes, and merging buildings with the natural mountainous environment to offer "sustainability". However, regarding the current modernization processes, reducing energy consumption and using clean energy sources, especially wind and solar energy (which are directly related to the use of renewable energy in rural housing), are less considered. Therefore, studying the causes of choosing a specific orientation in Uraman Takht and Masuleh villages is further scrutinized. The study results can be used to design and construct new buildings in areas with climatic characteristics.

This study tries to recognize the reasons for the orientation of buildings in Uramanat and Masuleh areas in Iran. Moreover, this research attempts to determine the impact of vernacular architecture on reducing the consumption of fossil fuels and using natural sources of energy. Studying the vernacular architectural patterns in these areas and understanding the practical use of building orientation in rural housing can lead us to achieve sustainability and meet the human requirements, like the past.

Today, villagers tend to modernize their life due to the urban influence (stimulated by the media and the modern transportation system that quickly connects the villages to the cities). This has led them to use modern construction systems and materials (that might not be in harmony with the regional environment) and use typical building plans, disregarding the climatic conditions. This has led the researchers to further scrutinize the architectural patterns of the region and look for the reasons behind the formation of such settlements in the past. These architectural patterns have become significant once again since they have a history of more than a thousand years. The vernacular design solutions have been able to reduce the use of fossil fuels (by using renewable sources of energy) for a very long time. Therefore, recognizing the principles of vernacular architecture in today's rural development is vital for reducing fossil fuel consumption in these areas.

An important principle of vernacular architecture that has been accentuated in the past is building orientation in rural areas. This paper tries to deeply scrutinize the reasons for the specific orientation of rural regions and the impact of such a measure on reducing energy consumption.

1.1 Research Background and factors affecting sustainability in architecture

"Sustainability" as a new branch of architectural and urban studies has been deeply studied. Numerous researches have been conducted in the context of building orientation, some of which are as follows(table 1):

Table 1. Research Background

Research result	Research title	Name of authors
Sustainable architecture and vernacular architecture are discussed, the fundamental principles of vernacular architecture that have led to sustainability are introduced	The relationship and role of vernacular architecture in achieving and creating sustainable architecture	Rahmani, Aliraza
It has studied the identifying symbols of Islamic architecture in Uramanat region of Kurdistan and the influence of Islamic beliefs on the formation of architectural identity.	Recognizing the original identity of Persian architecture and urban planning based on the symbols of Uramanat architecture	Alaei, Ali; Bagheri, Fatemeh
Using the role of natural energy in natural ventilation and investigating the combined role of both natural and artificial energy systems in indigenous settlements	The evaluation of vernacular settlements in Gilan province based on bio-sustainability principles	kasmayi

2. Materials and Methods

A descriptive study provides more insight into the current situation and helps decision making during the research process. It can also help to answer research questions and find the relation between the research factors [6].

Regarding the research aim, which is "the building orientation in the villages of Uramanat and Masuleh for achieving sustainability and optimization", the research data is collected through library and field studies (figure 1). The present is based on a descriptive-analytical research method, which deals with various factors affecting building orientation and energy consumption in rural areas.

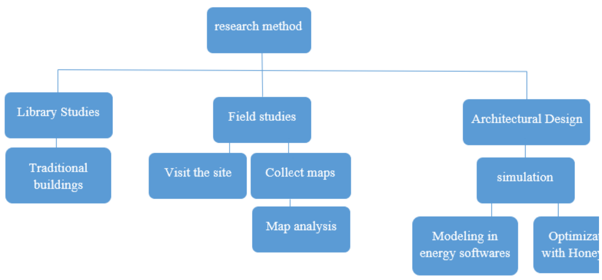


Figure 1: Hierarchy of research methods

2.1 Sustainability

Sustainable development[1] is a multidimensional concept [7], considered the mystery of sustainability [8].

In fact, sustainable development is "Meeting the needs of the present without compromising the ability of future generations to meet their own needs" [9].

The concept of sustainable development existed even before the beginning of this century. It is a social and environmental process to meet human unlimited needs while conserving the environment. The concept was officially unveiled in 1987 with the publication of the Brundtland Report at the World Commission of Environment and Development. Launched by the United Nations, the Commission defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [10].

This definition of sustainable development determines two ideas. Not only does this definition accept the concept of needs, especially basic needs such as food, clothing, and shelter for human life, but also it considers other needs that provide a comfortable and moderate way of life. Moreover, it embraces the concept of adapting technological resources and social organizations with the environment's ability to meet current and future needs [11].

2.2 Sustainable Architecture

Sustainable development is a process that can be repeated. Sustainability is a concept increasingly considered as a value. There is a focus on the process as well as the end product. Sustainable architecture recognizes that while the product may wear out over time, the process remains, or it can then be repeated [12].

The principles of sustainability in a building are as follows:

- Principle 1: Energy conservation

The building should minimize the consumption of fossil fuels.

- Principle 2: harmony with the climate

The building should be designed to adapt to the climate and energy resources available at the construction site.

- Principle 3: Reducing the use of new sources of energy

The building should be designed to reduce the use of new sources of energy as much as possible. It should be used as a new source for new constructions in the future.

- Principle 4: Meeting the needs of residents

In sustainable architecture, meeting the mental and physical needs of residents is of particular importance [13].

- Principle 5: Adapting to the site

The building should be gently blended with the site and be in harmony with its surroundings.

- Principle 6: Totalitarianism

The whole principle of sustainable architecture must be embodied in a complete process that leads to the creation of a healthy environment[14].

2.3 Factors affecting the sustainable architecture in cold regions of Iran

The cold regions of Iran have an average air temperature of more than 10 degrees Celsius in the warmest months of the year and a minimum temperature of fewer than 3 degrees Celsius in the coldest months of the year. These areas have long, cold winters. During several months of the year, the land is covered with snow. Regarding the extreme cold in these areas, maximizing the use of sunlight, controlling temperature fluctuations, maintaining heat and preventing cold winter winds is essential for achieving sustainability in residential environments [5].

Other influential factors for achieving architectural sustainability are the following:

2.3.1 Vegetation

In addition to visual beauty, vegetation is one of the most economical ways to control environmental conditions and reduce energy consumption in buildings and even cities. In fact, vegetation prevents the harmful effects of the sunlight on the building in the summer and protects the building from the extreme cold of winter. A good vegetation design can:

- Reduce energy consumption in summer and winter
- Help control noise pollution and air pollution
- Protect the building against cold winter winds and sharp summer sunlight[15]

2.3.2 Form of the building

Due to the extreme cold in these areas, buildings are recommended to be built in cubic forms to control the winter heat better. (Kasmaei, 2005). The buildings should be designed to benefit from the sunlight in the extreme cold. The buildings in this climate have: 1- an introverted design with a central courtyard, 2- a porch and a small courtyard, 3- specific building plan, form and orientation, 4- small rooms with low ceilings, 5- small apertures 6- relatively thick walls, and 7- flat roofs [16].

2.3.3 Materials

In cold regions, materials that are good absorbers of solar energy are mostly used in the building exterior, especially if they have dark coloring. The equatorial facing walls are vast, and buildings are oriented toward the south to maximize sunlight exposure [17]. Local materials that are adaptable to the environment (such as stone, wood, etc.) are usually used in buildings to lower energy consumption and minimize costs [18].

2.3.4 *Orientation*

Orientation is of great significance in achieving sustainable building. Many factors are involved in finding the best building orientation, based on which the rural areas are shaped. These factors are 1- the sun path, 2- the wind direction and intensity, 3- slope and topography, and 4- religious factors such as Qibla direction[19].

2.3.4.1 *The sun path*

In cold climates, houses should not cast shadow on each other. Street and sidewalks should also be wide to escape shadows. The sun should shine on streets directly and buildings and streets should not be in shadow. Because in cold seasons, it causes frost and causes casualties for the villagers. In these areas, due to the mountainous and cold weather, the direction from southeast to southwest, which is the path of the sun, is very important, and preferably the buildings are inclined to the direction where the sunlight is shining[19].

2.3.4.2 *Wind direction and speed*

Direction, speed, and amplitude are the essential characteristics of wind. In fact, the winds have different features. They are also affected by several geographical factors; for instance, mountains can affect wind direction and large water surfaces can affect the wind temperature. The wind speed increases in plains, and decreases in hilly areas (figure2). Today, the data on the wind direction speed, and amplitude are used and studied in many cases, such as the urban and rural fabric, the airport runway, the location of polluting industries, the location of building window, the construction of windbreaks, and so on. (ibid)

Furthermore, narrowing the streets can reduce airflow and reduce the ambient temperature during the day. Airflow should be minimized in public spaces such as squares [20]. Therefore, studying the effect of wind on urban design is essential in these climatic conditions.

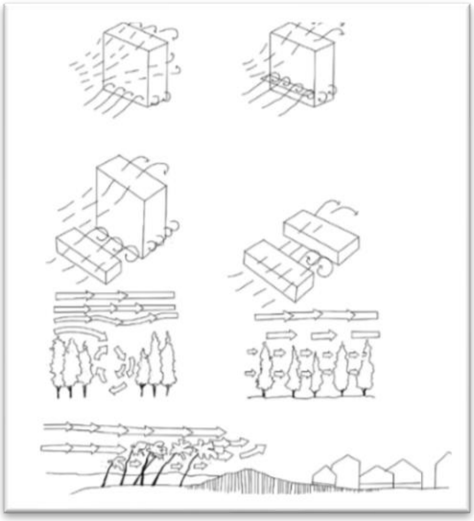


Figure 2. The wind speed reduces over a rough terrain and vegetation [19].

2.3.4.3 *Slope and topography*

In mountainous areas, the slope and natural topography of the land have a great impact on rural fabric orientation. In these areas, buildings should not be constructed at hilltops or low lands (due to the high risk of floods). Southern slopes are more preferred in this climate due to their great exposure to sunlight. Usually, the equatorial-facing slopes are more preferred due to maximum solar absorption [15]

2.3.4.4 *Qibla*

According to some beliefs, the rural fabric is created according to climatic conditions disregarding cultural and religious beliefs. However, the recent studies on the rural fabric of villages in Iran and mainly mountainous areas of the west part of the country reveal that religious and cultural beliefs greatly influence rural areas [21]. For example, efforts have been made to direct many villages in the city of Kurdistan in Iran toward Qibla, despite the direction of slope and topography. It is considered a religious value to face buildings toward Qibla. In addition, the Qibla direction in Iran (southwest), benefits from a great level of exposure to the sunlight [18].

As can be seen, figure 3 illustrates an overview of Factors affecting the sustainable architecture in cold regions of Iran.

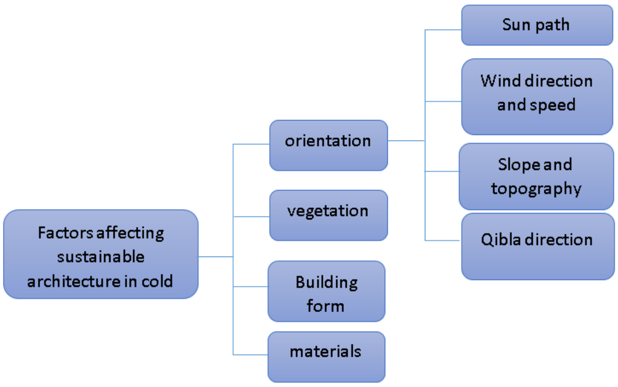


Figure 3. Factors affecting sustainability in Architecture

2.4 *Case studies investigation and simulation process*

Orientation studied as an important factor in the formation of mountainous villages - Uramanat (Uraman Takht) and Masuleh Villages. These areas have stepped rural fabric on a steep slope so that the roof of a lower house serves as the courtyard of the upper house. The house walls are made without mortar or with the use of mud. Multi-story buildings are rarely found in these two villages, and due to the mountainous nature of the area and scarcity of land, houses are built small.

2.4.1 *Uraman Takht Village*

Uraman Takht, a village in Uramanat district of Sarvabad city in Kurdistan province, is located 65 km southeast of Marivan city and 141 km south of Sanandaj, the center of Kurdistan province. Located at an altitude of 1054 meters above the sea level, this mountainous village has a cold climate. Although the weather is delightful in spring and summer, people experience a very cold and long winter each year. In some cases, the snow might block the access roads for a few days. Uraman (Uraman Takht) village is located in Uramanat mountainous area at south Kurdistan and north Kermanshah (figure4) [22].

Figure 4. Uraman Takht village, located on the mountain slopes with a stepped architecture. (Uraman Takht village, 2020) [23]

The buildings of this village are designed with minimum dependence on fossil fuels. Constructing thick walls, small openings, orienting the buildings toward the south to use sunlight, creating vestibules at the entrances, etc. are some measures of vernacular architecture in this area to energy [24].

Buildings are designed to use available natural sources of energy. The building form and location, as well as the interior spaces, should be designed to improve the level of comfort and reduce the consumption of fossil fuels by having proper thermal capacity and resistance. Extending the village on the mountain skirts, orienting towards the south to maximize exposure to sunlight, extending the rural fabric on the main slope and along the access routes, building flat roofs, using the minimum number of surfaces in the constructions, choosing the best form and placement and etc. are the most significant architectural measures in this village (ibid).

Orientation in Uraman Takht village: This village has very cold winters that begin from the beginning of September until the end of April. Therefore, it is necessary to use maximum sunlight, maintain heat, and prevent cold winter winds in residential environments. The solar energy and heat and the natural features of the land have had a decisive factor in establishing and developing this village .[23]

Massive construction and attached buildings are more appropriate for cold climates. The external walls that separate the indoor and outdoor space also result in temperature time lags for more than 8 hours. They act as integrated thermal insulation.

The buildings have an east-west orientation, therefore the longer side of the building faces south, and the exposure to sunlight is maximized. According to the climate of Sanandaj city, the best building orientation is to rotate the building 30 degrees toward the southeast or rotate it between 15 to 45 degrees southeast [17].

Most residential areas are located near a narrow valley having slopes over50%. The main facade of the buildings faces south and southeast to benefit from the sunlight. In many cases, one side of the valley is allocated to residential constructions, and the other side is allocated to horticultural land. The main rural fabric is located in the middle of mountain skirts, and the houses face the south. Not to mention, in terms of house material, In Uraman Takht, due to the mountainous nature of the region, the primary dwellings are usually built on sheepfold. This part, in addition to basement, are formed a complex looking like a semi-terrestrial state on two bases. Not to mention, The walls of the houses that are built in this mountainous area are made of dry-stone method. These walls are made without the use of mortar and by placing stones that have been prepared for this purpose. The stone needed to build houses is often supplied from the mountains around the village, and in other parts of Marivan city, stone walls have been stacked with mud mortar [22].

The traditional architecture of the buildings, the effects of which can be seen in the current situation of the village, has been in perfect harmony with the unique climatic and topographic conditions of the region, as well as the living conditions of the people. After reaching the completely solid ground, people fill the inside of the foundation with stone, then raise the wall of stone by 2-3 meters. After finishing the dry-stone method, it is time to execute the roof, for which purpose wooden beams with a diameter of 15 to 21 cm are put up all over the wall. Having errected the roof, simultaneously, they use sycamore, mulberry, oak, and willow wood. The dimensions of the openings were also small in the past due to weather factors, about 1 * 0.7 meters. Handles made of walnut and mulberry wood were also used in the windows [21].

2.4.2 Masuleh village

Figure 5. Masuleh village and the stepped architecture. The roof of the lower buildings functions as the courtyard of the above building, (Masuleh village, 2020)[25].

The city of Masouleh is located on a steep mountain slope at the farthest west side of Gilan province. In addition to having a north-south slope, the villagers have created an east-west slope. This history of the village stretches back for more than 800 years. Masuleh is located between the cities of Rasht, with a mild climate, and Zanjan, with a cold climate. As a result, the climate in this village is a combination of cold and mild humid climate. Masuleh has very cold winters and mild summers; however, the summer sun is rather hot in this area. Therefore, balconies are built to induce natural ventilation in summer; nevertheless, they are not used in winters (figure 5).

Due to the cold climatic condition in this area, the solar heat and sunlight exposure is very important for the residents. Therefore, the buildings of this village are located on the slopes that face the south. All buildings of this village use natural ventilation in the summer, and the buildings are designed with a wide and open narrow plan. The buildings are designed to block cold winter winds. Despite the valley shape and mountainous nature of Masouleh in the urban context, it has created a kind of harmony and coexistence between green space and natural environment, architecture and artificial environment, which is one of the important principles of architecture, compatibility with the environment. And along the slope of the mountain facing south and along the topographic lines of the earth [26].

The natural terrain influences the rural fabric of Masouleh. The paths are short and often have many twists and turns. Sloping paths that connect the higher parts of the village to the lower sides often have a slight slope. These paths follow the natural shape of the site, and they are designed as stepped paths or have a relatively slight slope [27].

The best solution to regulate environmental conditions in temperate and humid areas is to use natural ventilation and airflow. In this situation, an extroverted morphology is considered the best architectural buildings form. In order to ensure human comfort in these climates, the buildings are built on higher terrains with many large openings. Balconies are also built to connect the interior and exterior spaces and induce airflow in the building. As a semi-open space, balconies reduce the building temperature and create a pleasant breeze in the summer. Also, they make a buffer zone in winter to reduce thermal transmissions. The rural fabric in Masuleh has created a kind of harmony between the natural green space and the built environment.

In this village, the sloped paths are connected via stone steps to be compatible with the environment. Two types of paths connect the whole village: The few long parallel paths and many stepped short paths that enable the circulation and movement in the village. Another important architectural feature in Mauleh village is the use of rooftops as pathways for the higher levels. Citizens have agreed to use their rooftops as the public pathway(as same as Uraman Takht). In fact, the rooftops serve as public places and sometimes used in social ceremonies and celebrations. The old houses of Masuleh, which are less than 100, are on the National Monuments List. They all have two living areas, the winter part, and the summer part [26].

Winter part: This part is called "Sumeh" in their local language. It is a small room, usually located in the back of the house with poor daylighting. There is a stove in the middle of this room that is used for cooking and preparing food, as well as providing heat [24].

Summer part: The summer part or “Pishkhan” has large wooden windows that open up to nature. These windows are decorated with Islamic patterns and colorful glass. Also, some other houses have a room on the rooftop facing the mountains and enclosed by other parts of the house. According to surveys conducted between 1961 and 1999, unfortunately, about 45% of houses in Masuleh village have been destroyed or are being demolished [18].

Like other villages located in mountainous areas, the rural fabric should not be situated at downhills because when air is cooled along the slopes of the mountain, it becomes heavy and flows downhill. Moreover, there is a high risk of flood in these areas. On the other hand, the northern side of the mountain is always in the shade, and this makes it uncomfortable for the residents. Also, the highest part of the mountainous area is not suitable for a rural fabric due to cold winds and lack of control. Therefore, the best solution is to establish rural fabric in the middle of the mountain skirts and the southern side. The building orientation follows the natural mountain slopes. So, some of the city buildings are facing south, and some are facing southeast to be more exposed to sunlight. The orientation of Masuleh village shows the effect of environmental conditions on the formation of the rural fabric in the cold climate[28].

With regards to materials, The material type used in different parts of the building are various, a combination of clay and wood, and all of which, seemingly, are eco-friendly (colected from local region). The structure is based on a piece of rock and buildings are built on a natural slope of the ground in two or three floors, providing both the architectural compatibility along with the natural topography of the environment and a kind of spectacular view for people in all floors and spaces[25].

The walls are usually made of carcass stone countinuing up to the first floor, and after locating the carcass stone, clay with dimensions of 30 * 30 * 8 cm has been used to continue the wall. Thereafter, carcass stone has been used again under the ceiling. At different distances (about one meter) and to distribute the forces from the ceiling down evenly, coiling or so-called scaffolding, referring to local expression, has been used; accordingly, the type of wood used in that is Mazo. The last material of the roof covering is mud called "Fush" which is poured on the ferns, which with the combination of Fush create a gentle slope in the roof to repel rainwater (ibid).

Tables - lists the thermal properties of the building constructions and table 7 presents the total U-value/R-Value of the Constructions and table 8 shows the properties of the heating, ventilation, and air conditioning (HVAC) system. The thermal properties of the construction materials and windows are based on the specifications of the National Iran code (Mabhas 19) building and previous researches [29][30][31].

Table 2. U/R value of construction

areas	Masouleh		Oraman Takht	
U/R value	U Value (W/m²*k)	R Value (m²*k/W)	U Value (W/m²*k)	R Value (m²*k/W)
Exterior wall	2.32	0.43	2.63	0.38
Interior wall	1.68	0.14	1.86	0.53
Ground floor	1.50	0.66	1.5	0.66
Floor	1.12	0.88	1.61	0.62
Roof	2.05	0.48	1.35	0.74

Table 3. U/R value of construction

Window type	Glass	U-Value W/m²*K	SHGC	VT	Frame type	U-value (frame)
Wooden frame Single-glazed glass	6 mm	4.5	0.56	0.7	oak	0.19

Heating and cooling Set points was considered base on Iran National Building Code No.19 (19th Mabhas) respectively 21 and 28 centigrade degree [32].

2.5 *Rhino and Grasshopper - Modeling*

Rhino is a 3D computer graphics and computer-aided design (CAD) application software founded by Robert McNeill et al., An American company, in 1980. The geometry of Rhino. The NURBS mathematical model focuses on producing accurate mathematical representations of curves and free surfaces in computer graphics ,instead of polygon mesh-based applications. (Wikipedia, 2020).

Grasshopper Plugin is a graphical algorithm editor fully integrated with Rhino 3D modeling software, which was released separately in 2007 and Rhino version 6 in 2018 as an integrated with Rhino.

In this research, Grasshopper software version 1.0.007 and its plugins Ladybug version 0.0.69 and Honeybee version 0.0.66 were used as energy modeling and simulation program for building energy analysis. Grasshopper is a visual programming language developed by David Rutton at the Robert McNeill Institute et al. Grasshopper runs in the Rhinoceros Trade program.

Programs are created by dragging the pieces on the screen. The output is connected to these components and then to the input of subsequent components. Grasshopper is mainly used to create productive algorithms. Many grasshopper components create two-dimensional and three-dimensional geometries. Some of them

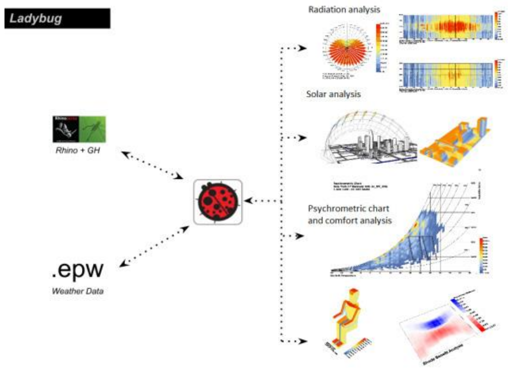


Figure 6. Ladybug plugin workflow diagram

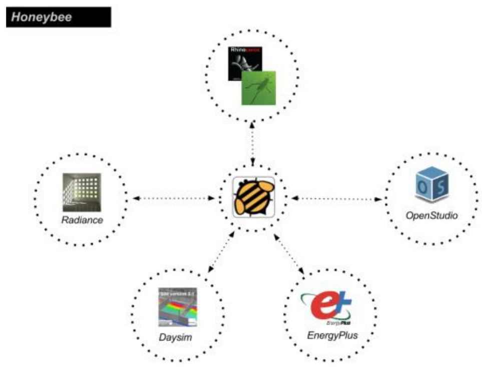


Figure 7. Honeybee plugin workflow diagram

create other algorithms, including numerical, textual, audio and video, and touch applications. "Among students, Rhino, a modeling tool, is known in the world for its architectural design. The Grasshopper environment provides a direct way to design without the need to learn the script. The first version of Grasshopper, called Explicit History at the time, was originally Released September 2007. Grasshopper is an algorithmic graphical modeling software integrated into the default version of Rhino Ladybug and Honeybee Open Source Plugins for Grasshopper to help Designers for Energy Modeling written in Grasshopper (figure 6).

2.6 Design Process in Honeybee Software

Honeybee supports the basic settings of the energy system. The analysis process in Honeybee is based on the standard values of Energy Plus. It is applied to a geometric parametric mass, which is created in Rhino with the help of Grasshopper plugin and connected to a honeybee zone by "Massing To Zones" component.

In the following, a honeybee module is created and time schedules, thermostat and system set points are re-applied to the Honeybee zone. A thorough energy model requires fine-tuning. The "Solve Adjacencies" component is used to determine the boundary conditions. Components "EPConstruction" and "EPMaterial" are used to define materials. The default air conditioning system in Honeybee zone is "ideal air load system", which actually includes a "air Economizer" air recovery system. The thermal energy analysis is performed by "Run_Energy_Simulation" component. Since the output results generated by Energy Plus are not applicable by default, the results are read and interpreted using the "Read_Result_dictionary" component. This process and analysis in the Honeybee environment is completed by examining a simulation in this research.(figure 7)

2.7 Weather data

For building energy simulations complete weather information of the city is required. This information includes dry temperature parameters, wet temperature, wind direction and speed, relative humidity, number of frost days, sunny hours, percentage of cloud cover and Etc. This information has been obtained using meteorological information simulation from 1991 to 2010 as TMYx epw file by the Meteonorm 7 software version 7.3.3 (figure 8 to 11).

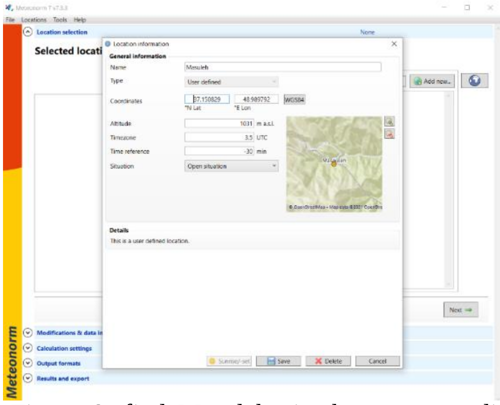


Figure 8. find Masuleh city base on coordination location in Meteonorm

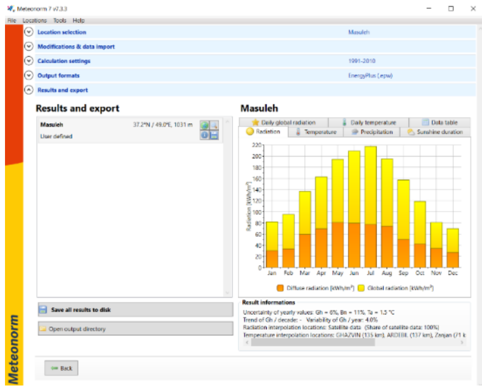


Figure 9. create epw file with Meteonorm for Masuleh

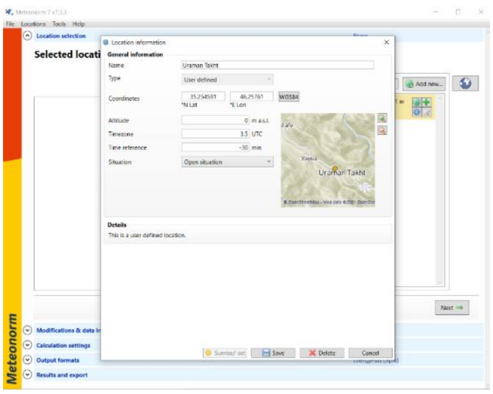


Figure 10. find Uraman Takht city base on coordination location in Meteonorm

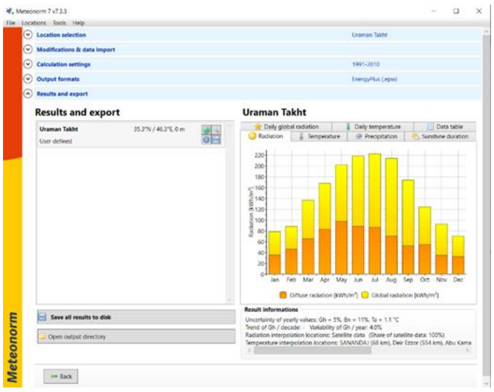
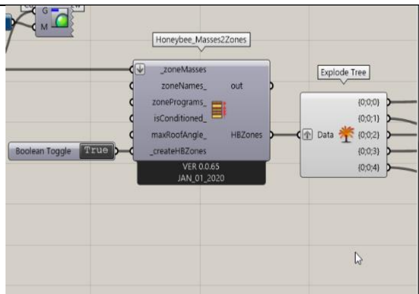
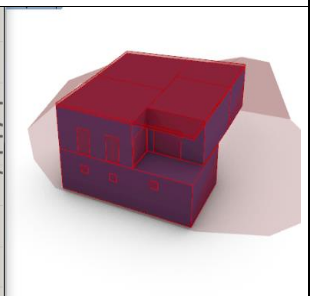
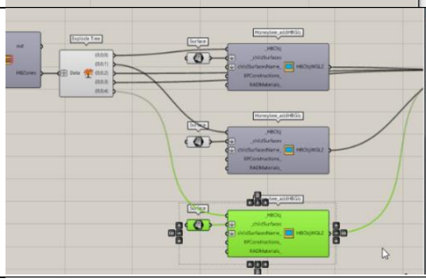
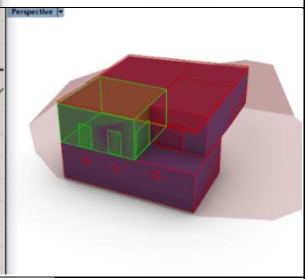
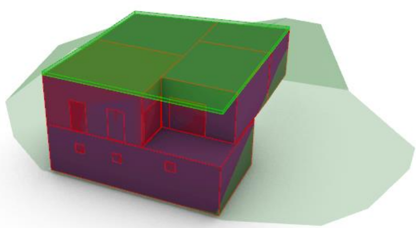
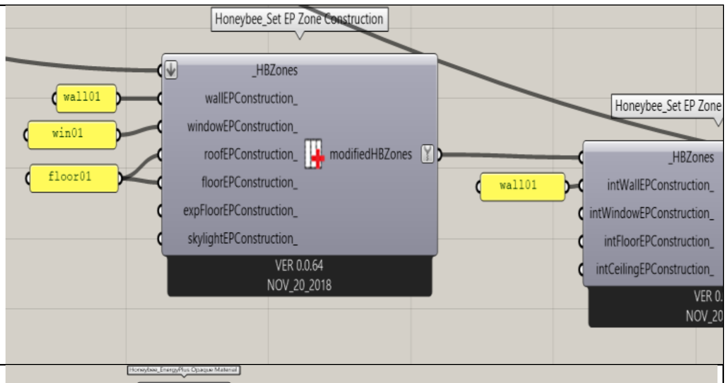
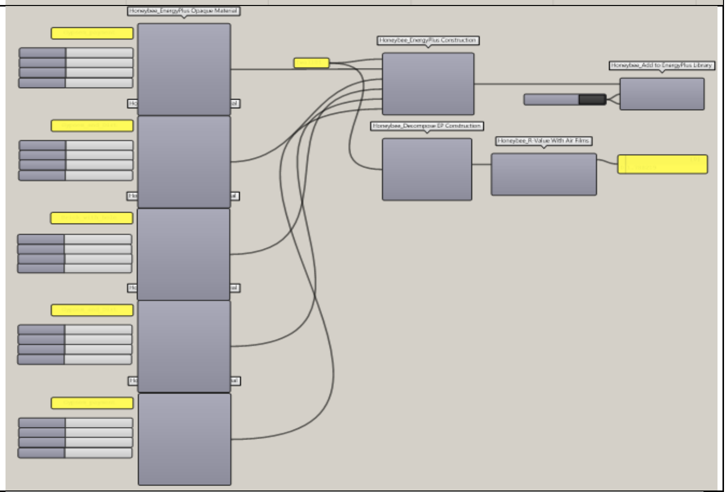
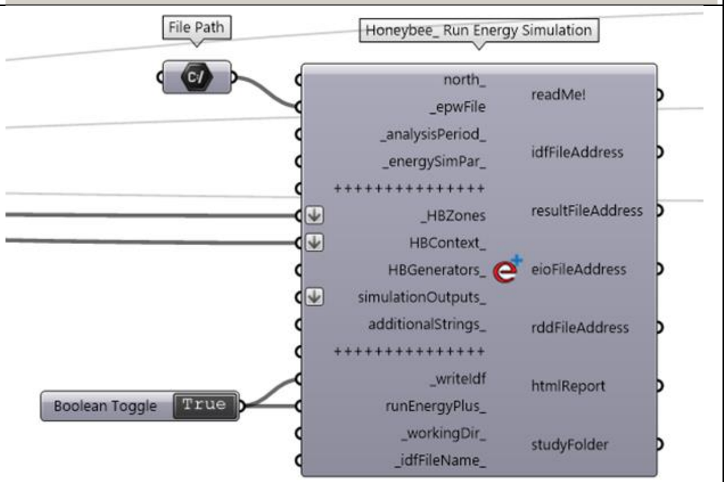


Figure 11. create epw file with Meteonorm for Uraman Takht

The first building to be examined is a sample building built in the Masouleh area (table5).

Table 5. project process of Masouleh

Steps	description	Figures
1	First, the workflow in Rhino is modeled and each space is converted into a thermal zones in the form of a Brep.	 
2	In the next step, each space is selected separately, and openings are applied to each space.	 
3	In the next step, the overhang topographies are added to the mass.	

4	Building materials are made according to their thermal characteristics and are defined by components in the building.	
5	The walls' characteristics are applied to Honeybee zones (thermal zones).	
6	Finally, the information given to the model and the components are analyzed in Energy Plus engine and the energy analysis is performed and returned to Honeybee. The thermal properties of each material are defined and added to Honeybee library. Therefore, the thermal characteristics of the wall and roofs are defined by putting the material layers together in the form of a construction and adding them to Honeybee library.	
7	The downloaded weather data is added to the epw section.	
8	Thermal zones are included in the HB_zones section and shadows are included in the HB context section.	

3. Resault & Discussion

For this project, different orientation angles are analyzed in section North. These analyses are related to the orientation of the building towards the north and the total energy consumption per unit area for each case analyzed. The results can be seen in the following diagram.

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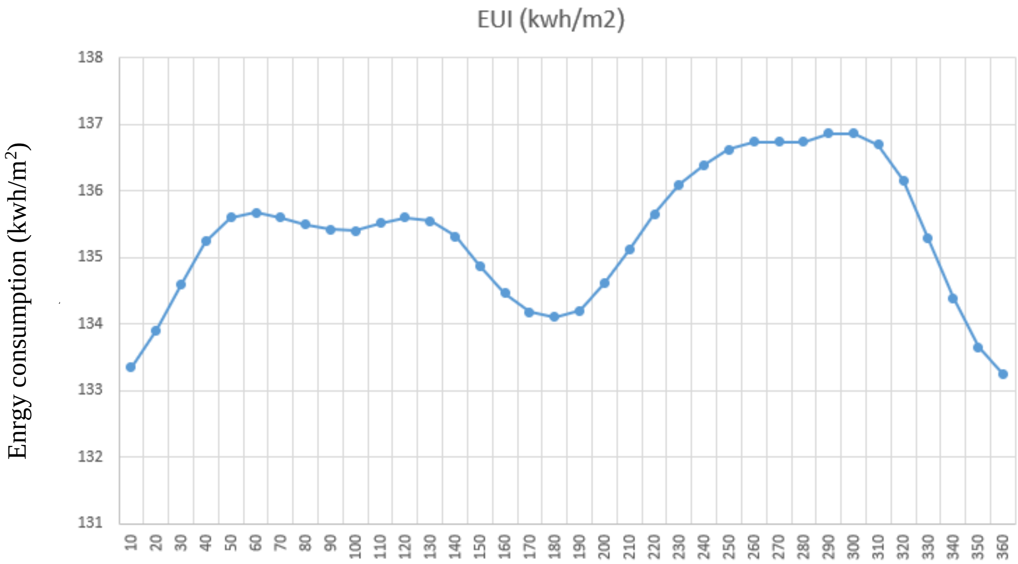
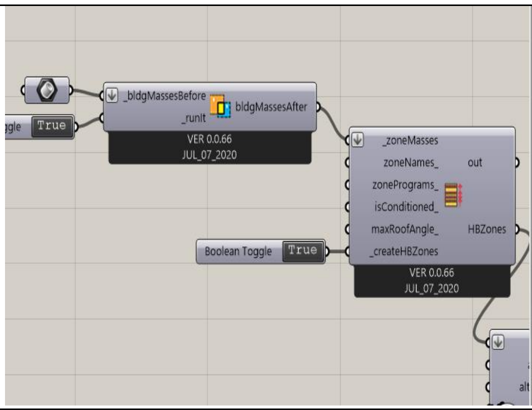
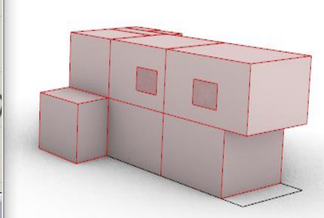


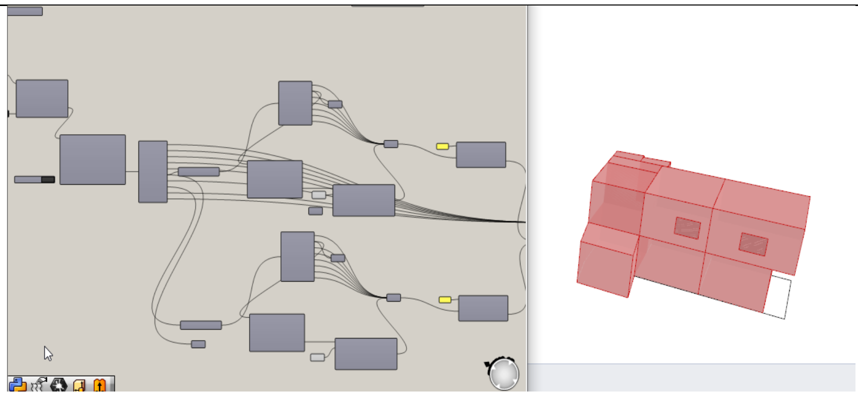
Diagram 1. Building orientation in degrees

According to the Diagram1, the 0 or 360 degree, which determines the building orientation toward the south, results in the least energy consumption of 133.25 kWh/m2. However, it should be noted that the difference between the lowest and highest energy consumption is 2.63%.

The next sample building, located in Uramant area, undergoing the same changes as the building in Masouleh, and the simulations were performed in these steps (Table 6).

. Table 6. project process of Masouleh

Steps	description	Figures
1	First, the building mass is modeled in Rhino software and each space is changed into a thermal zone in the form of Brep.	 

2	Other simulation steps are like the previous steps in the sample building in Masouleh.	

With a slight difference compared to the previous analysis, the results of this analysis showed that building orientation toward 170 degrees is the best alternative. Also, orienting toward zero degrees is a good alternative. However, it is impossible to rotate the building 170 degrees, since the north part of the building is connected to the mountains. Therefore, zero or 360 degrees is the best angle to minimize energy consumption(Diagram 2).

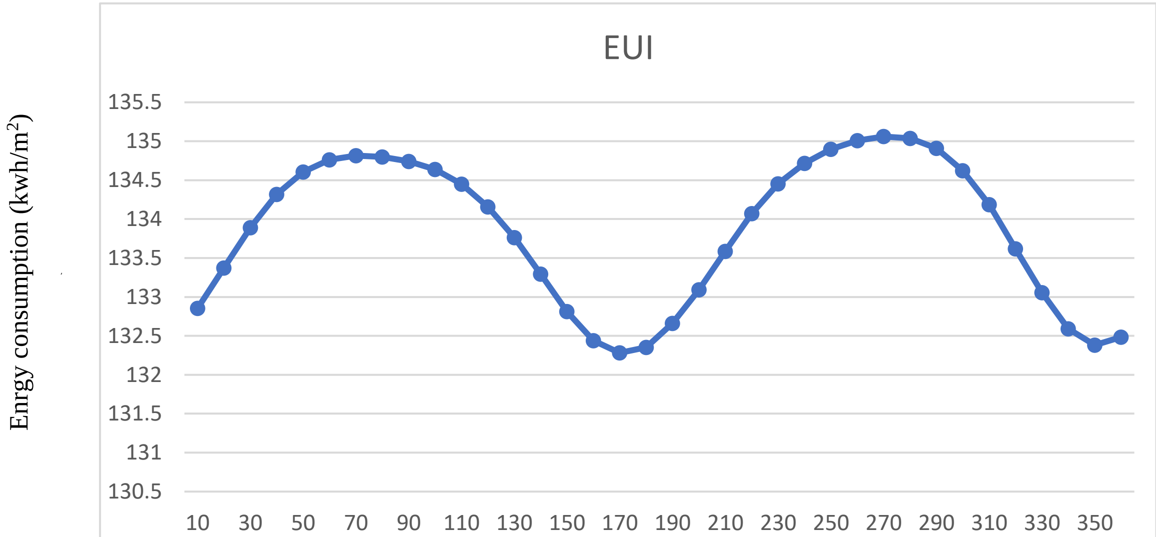


Diagram 2. Building orientation in degrees

Finally, the analyses are performed in more closer steps, and the energy consumption for every 2 degrees of building orientation was calculated to get a more accurate result for differenr orientation angles. The final results reveal that 170 degrees orientation leads to minimum energy consumption (although building energy consumption for different orientations from 0 to 360 degree is calculated, the acceptable angle should be in a range between 0 and 90 or 270 to 360 degrees due to the mountain slopes). The energy consumptions are slightly different for the angles shown in the figure below, and all can be considered the desired angle. The final alternative is selected regarding climatic conditions such as wind and access, etc.

4. Conclusion

As aforementioned, the summers are mild, and winters are cold in the two villages of Uramanat (Uraman Takht) and Masouleh,Of course, Oramanat is a bit colder. As a result, the techniques of vernacular architecture to reduce energy consumption and achieve sustainability are similar. Using natural sources of energy and proper building orientation in these areas (as the most important factor for achieving sustainability) are of utmost importance in the formation of the village. The research findings can be generalized in similar climatic conditions to make the architectural environment more sustainable. The findings of the building orientation in these regions can be mentioned as follows:

1. On the one hand, the buildings of Masouleh and Uraman Takht villages are built into the slope, rather than on hilltops to avoid the low temperature and higher wind speed (the wind is restrictive in this climate). On the other hand, building on downhill areas is more prone to being affected by a flood. It is also difficult to access the water in these areas. Therefore, only agricultural and horticultural lands and are located in lower areas, which are also visible to all villagers. Thus, the best alternative is shown in Figure 12.

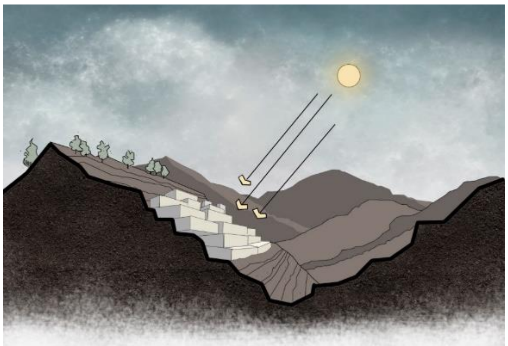


Figure 12. The proper location of the buildings is in the middle of the mountain slopes.

2. To create good thermal conditions inside the building, the main facade should face the south. Although the solar radiation on southeast and southwest sides of the building are more invariable, they are warmer than the south façade in summer and cooler in winter. The east and west sides of the building are warmer than the south, south-east, and south-west sides in summer. Like in other cold regions, the ideal solution is to receive maximum sunlight during the year.

3. In sloped areas, the village should have a stepped form in the middle of the mountain skirts to benefit from sunlight and avoid shading other buildings , as can be seen in figure 13 . The main door and windows of the building should face the south for maximum exposure to sunlight.

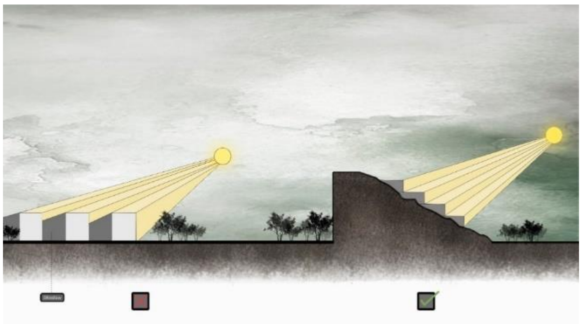


Figure 13. The effect of land slope on shading on other buildings

4. In cold and mountainous areas, the slope is of great importance; the lower the slope, the lower the temperature difference in the two different parts of the village (Figure 14). It is important to select and expand the village on the less sloping areas in very cold areas.

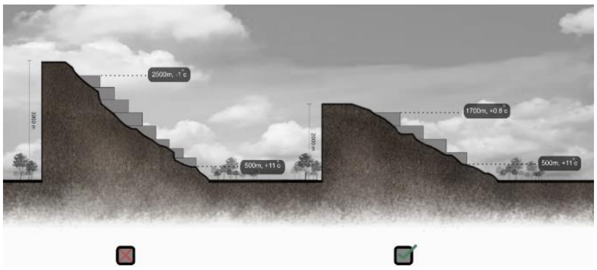


Figure 14. As the slope increases, the temperature difference between the two points of the village will also increase.

5. The main paths are opposite the wind direction, and they follow the shape and form of the land. The access paths should be planned so that they have a medium width, and they should have a north-south or east-west axis. Creating access paths with a specified direction is due to:

- "Creating sunny paths
- Reducing shadows in the paths, especially in the south, and reducing frost
- Creating warmer paths in the village during very cold periods
- Reducing the impact of winter winds "[15]

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