The relationship between climate and energy in vernacular architecture in central Italy

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ABSTRACT: Traditional architectural typology has local characterization. The region climate can change within short distances. Architectural typology models have been changing in relation with local climate and depending on the construction materials availability. In this paper we describe three vernacular architecture typology buildings, inside a valley, in the centre of Italy. There are three micro areas in the valley: plan, hill and mountain. Each of them is characterized by slightly different parameters of temperature, rainfall and windiness, and different construction materials. The architectural model (called centre Italian vernacular architecture) is the same but there are some differences related to local climate.
In this paper we describe the relation between local microclimate (*temperature, wind and solar radiation*), physical characteristics and architectural energy forms. This process highlights how the architectonic model changes to satisfy energy balance.

Keywords: typology architecture, form and energy, comfort

1. INTRODUCTION

The study of building typologies gives information about the relationship between climate and architecture.

Many factors have always influenced architecture, such as methods of construction and local availability of materials.

Other aspects directly linked with climate are also the presence of arcades, porches, window dimensions and the ratio between surface and volume. This is quite obvious for vast homogenous climate areas.

In northern countries with typical cold weather, buildings are more compact than in areas with a milder climate.

Victor Olgyay has firstly analysed these aspects.

Three different buildings located within a micro-geographical area in central Italy and their construction and architectonic forms are compared.

The relationship between energy consumption in winter regime, microclimate, and architectonic shapes (dispersing surface) have been studied and analysed.

2. THE MICRO AREA TERRITORIAL

2.1 The valley

The valley is located in centre of Italy and is created by the river Marecchia that springs in the Apennine Mountains and flows into the Adriatic Sea.
The valley comprehends three different areas: plain, hills, and mountains.

The relation between energy demand, climate and architectural design of three different farmhouses will be considered in this study.

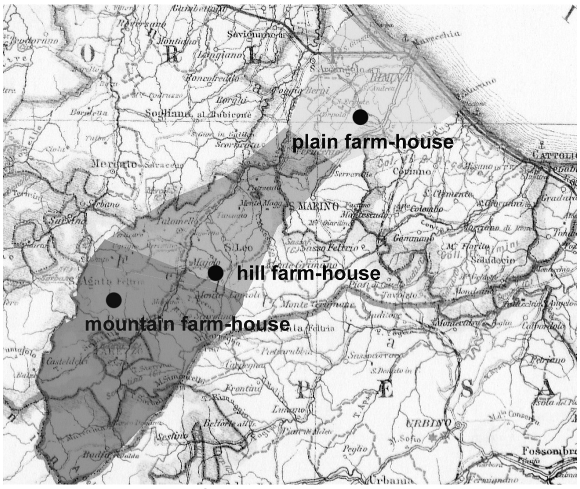

Figure 1: the Valley of Marecchia with three area and farm-house

2.2 Climate and orography

The climate reference considered in this work is Day Degree.

Day Degrees is related with local annual average minimum temperature, according to the Italian standard.

Area(place)	latitude longitude	altitude (a.s.l.)	Day Degree	Average minimum temperature
Plain (*Rimini*)	44°4' N 12°33' W	235 m	2139	-2°C
Hill (*Novafeltria*)	43°53'N 12°12'W	883 m	2294	-5°C
Mountain (*S.Agata*)	43°51N 12°12' W	961 m	2563	-5°C

3. THE BUILDING TYPOLOGY OF FARMHOUSES.

The buildings are normally utilised as residence as well as for agricultural activities.
The ground floor is used for agricultural activities: stables, wine cellars and deposits.
Besides, the first floor is used for human activity: bed rooms, kitchen and living room.
The calculation of the energy dispersions is referred to the first floor.
A porch (portico) is located on the ground floor of the farmhouse located in the plain. It protects from the sun during the summer and from wind in winter. The porch is orientated towards south.
The portico and the hall protect the stairs inside the building that lead to the first floor.
The windows are all of small dimensions. They are south and north oriented. Besides they are small and tall with reporting in the wall. Brick-tiles are the construction materials for structure wall, whereas wood tile for horizontal structure and roof.

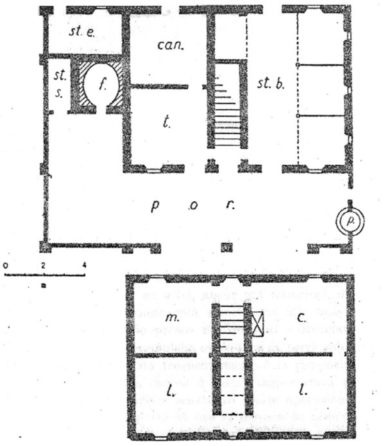

Figure 1: Plain farm-house
a= entrance anst=anti-stable c=kitchen, ca=fruit deposit, can = wine cellar, car=farm cart deposit, d=deposit, f=oven, l=room, log=porch, m=store, p=well, sc=stair, st.b=cow stabs, st.e.=horse stabs, st.s=pigs stable

Plain farm-house	Geometry	Thermo-physic Parameters (Transmittance)
Wall East-West	33,90 m^2	1,18 W/m^{2}K
Wall North/South	24,75 m^2	1,18 W/m^{2}K
Roof (wood structure and tile)	93,20 m^2	1,861 W/m^{2}K
First floor (living area)	93,20 m^2	2,09 W/m^{2}K
Window typology 1.	(0,60x1,70)xn.°2= 2,04m^2	4,42 W/m^{2}K
Window typology 2	(0,80x1,70)xn.°4= 5,44 m^2	4,42 W/m^{2}K
Height (first floor)	3,00 m	
Volume	279,60 m^3	

Table 1. Plain farmhouse geometry and transmittance characteristics

The *hill farmhouse* is more compact, without porch. The kitchen and stabs windows are protected from winter winds.
The farmyard is small and the ground floor surface is reduced.
The construction material for the house is stone (limestone and sandstone) for the structural walls. The horizontal structures, the floor and roof, are made of wood beam. The stairs that lead inside the building at the first floor is external. Kitchen and living room are in a central position.

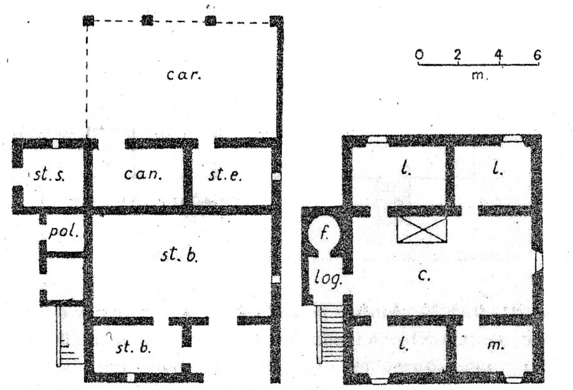

Figure 2: Hill farmhouse

Hill farm-house	Geometry	Thermo-physic Parameters (Transmittance)
Wall East-West	38,25 m^2	2,52 W/m^{2}K
Wall North/South	30,30 m^2	2,52 W/m^{2}K
Roof (wood structure and tile)	128,77 m^2	1,861 W/m^{2}K
First floor (living area)	128,77 m^2	2,09 W/m^{2}K
Windows	(0,80x1,50)xn.°5= 6,00m^2	4,42 W/m^{2}K
Height (first floor)	3,00 m	
Volume	386,31 m^3	

Table 2. Hill farmhouse geometry and transmittance characteristics

The mountain farmhouse has a compact structure similar to the hill farmhouse, except for porch and stabs in ground floor. The windows are smaller. The stairs are inside the building wrapped.

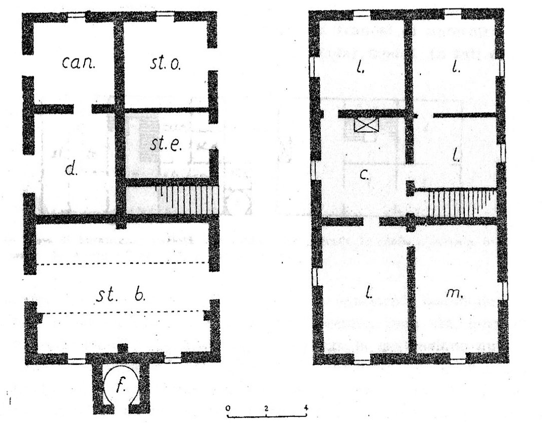

Figure 3: Mountain farm-house

Hill shack	Geometry	Thermo-physic Parameters (Transmittance)
Wall East-West	50,55 m^2	2,52 W/m^2K
Wall North/South	27,45 m^2	2,52 W/m^2K
Roof (wood structure and tile)	154,17 m^2	1,861 W/m^2K
First floor (living area)	1554,17 m^2	2,09 W/m^2K
Window 1.	(0,85x1,10)xn.°5= 9,35 m^2	4,42 W/m^2K
height (first floor)	3,00 m	
Volume	462,51 m^3	

Table 3. Mountain farmhouse geometry and Transmittance characteristics

4. CALCULATION MODEL TO EVALUATE THE ENERGY DISPERSION IN WINTER REGIME.

The simplified calculation model to evaluate the energy dispersion in winter regime has been made according to the Italian Law and European Directive, with reference to Italian Law 10/91 and DM192/2005, calculated following UNI EN 832.2001 standard.
Annual energy dispersion, expressed in kWh/year and kWh/m^2 year, is evaluated with two different methods, namely *Casaclima* and *Provincia di Milano* (province of Milan) calculation models.

In this model only the wrapper energy dispersions without ventilation dispersion are considered.

	A (m^2)	U (W/m^2K)	A*U(W/K)	t (°C)	Q (W)
Walls					
Wall North	24,75	1,180	29,21	25,00	730,13
Wall South	24,75	1,180	29,21	25,00	730,13
Wall East	33,90	1,180	40,00	25,00	1000,05
Wall West	33,90	1,180	40,00	25,00	1000,05
Windows					
Kind 1	2,04	4,420	9,02	25,00	225,42
Kind 2	5,44	4,420	24,04	25,00	601,12
Roof	93,20	1,861	173,45	25,00	4336,13
Horizontal Floor	93,20	2,090	194,79	8,00	1558,30
Thermal dispersions (10% Qd)			50,66		935,48
		tot A*U	**590,37**		
					$\sum Q\,(W)$
Total Heating Dispersions					**11.116,8**

Heating Annual Dispersion		DD	A*U		**Q year**
	0,024	2139,0	590,37	**30307,42**	kWh/year
				325,19	kWh/m^2 year
Dispersing surface (m^2)	**296,22**			**U average**	**1,1084**

Table 4: Example table for Energy dispersion calculation - Plain farmhouse.

With:
U=Transmittance (W/m^2K)
DD= Day Degrees

$$Q\,(W) = A*U*)t \qquad [1]$$

$$Q_{year} = A*U*DD*0{,}024 \text{ [kWh/year]} \qquad [2]$$

$$U_{average} = \frac{\sum A*U}{\sum A} \qquad [3]$$

For each architecture typology, this model has been used.

5. COMPARATION OF THE CALCULATION RESULTS

The following parameters have been compared:

- Day Degree, which summarizes the climatic area characteristics,
- Total dispersing surface (wall, floor and roof),
- U average (Transmittance average),
- Heating Dispersion Wrapped,
- Heating annual dispersion [kWh/year] and [kWh/m2 year]

It is also interesting to compare the same values respectively with the increasing value between hill and plan typology (%H/P), between hill and mountain typology (%H/M) and between plain and mountain typology (%M/P):

	DD	S/V	U average
Plain	2.139,00	1,059	1,108
Hill	2.294,00	1,007	1,527
Mountain	2.563,00	0,984	1,394
%Increment			
% H/P	7,25%	-31,24 %	37,78%
% H/M	11,73%	-18,37 %	-8,69%
% M/P	19,82%	-43,87 %	25,80%

Table 5: Comparison Day Degrees and geometry

	Heating dispersions	kWh/year	kWh/m2 year
P	11.116,80	30.307,42	325,19
H	19.136,35	53.226,10	413,34
M	20.896,40	66.240,63	429,66
% Increment			
%H/P	72,14%		27,11%
%H/M	9,20%		3,95%
%M/P	87,97%		32,13%

Table 6: Comparison result value

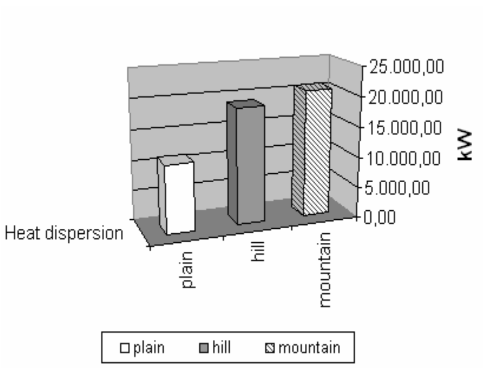

Figure 4: Heat dispersion

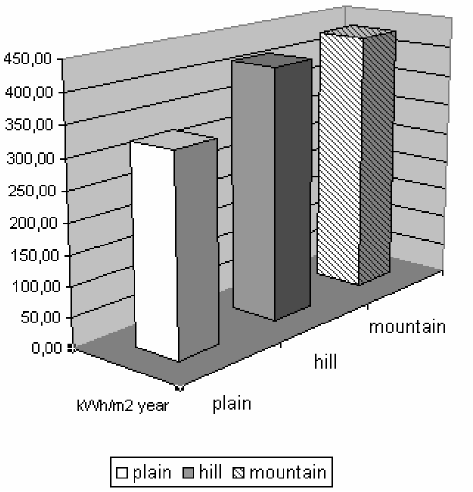

Figure 5: Annual Energy Dispersion (kWh/year)

Energy dispersion increases in mountain, where the climate is more severe and therefore the heating period is longer in relation with Day Degrees.

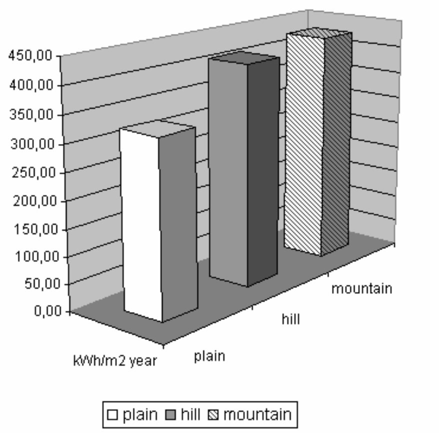

Figure 6: Annual Energy Dispersion (kWh/year)

The dispersion differences are smaller, referring to energy consumption at square meter.

Comparing the increase of energy consumption with the increase of Day Degrees for each area we have the result reported in fig.7

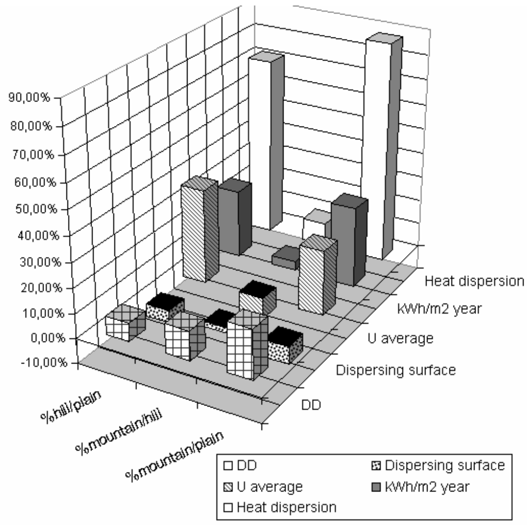

Figure 6: Increment comparison

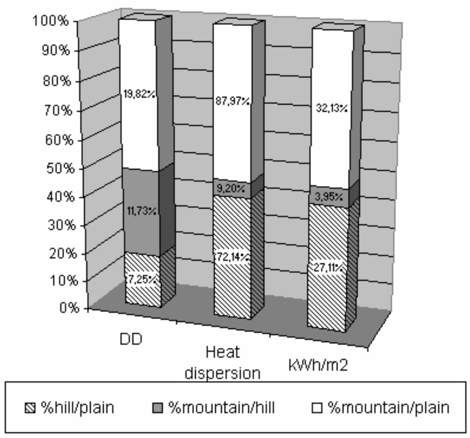

Figure 7: Increment comparison (Day Degrees, Heat Dispersion and kWh/m^{2}year consumption).

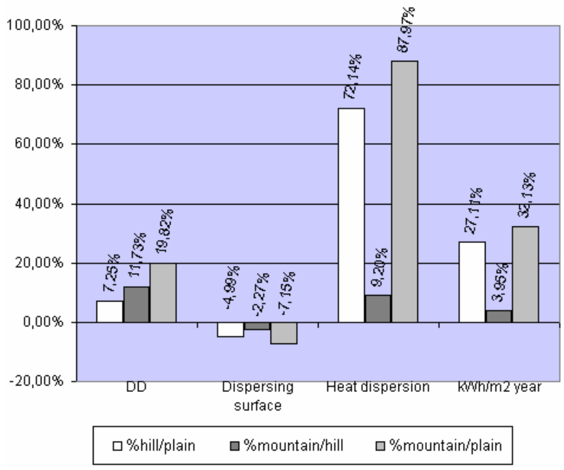

Figure 8: Increment comparison (Day Degree, dispersing surface, Heat Dispersion and kWh/m^{2}year consumption).

As shown in figure, the increase of 7.25 % of Day Degrees between Hill and Plain farm-house, leads to a reduction of approximately 5% of dispersing surface and it involves an energy dispersion (referred at square meters-kWh/m^2year) increase of 27.31%.
Comparing mountain/hill the Day Degrees increase of 11.73% with a reduction of only 2.27% of dispersing surface, and only the 3.86 % of increase of energy dispersions (in kWh/m^2year).
At last comparing mountain/plain, Day Degrees increase of 19.82% with a reduction of only 7.15% of dispersing surface, and the 32.13% of increase of energy dispersions (in kWh/m^2year).

6. CONCLUSIONS

The results of this analysis highlight that architectural design and typology are strictly connected with microclimate also considering a micro geographic area.
Constructions materials and typology that improve energy performance are therefore preferred.
The building typologies analysed in the paper represent historical typologies for each zone. They have been chosen because they represent models of vernacular architecture in this area, as they were archetypes, and therefore historical representatives.
These typologies were developed as a result of various factors, included clime, which have lead to these architectural typologies.
The purpose of this study was therefore to determine the influence of the clime factor in the changing of different architectural forms. In this paper we have emphasized the different architectural form in relation with climate difference. During last centuries and during the lives of these three typologies, many factors related with form, material, structure, etc. have changed due to material resources, economic resources, orography of sites, local technologies and, last but not least, result of climate.

7. REFERENCE

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