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The Impact of the Site and the Local Climatic Conditions on the Design of the Forums in Roman Cities

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ABSTRACT

This research explores the principles that Romans adopted for the selection of locations for the city's public places, particularly the forums. It attempts to identify how contextual characteristics strongly influenced Roman urban space as well as buildings design. This study supposes a relationship between environmental factors, such as solar orientation and wind patterns, and the forum's urban design. This study suggests that this could be attested throughout the checking of both parameters' impact within a set of forums located in various cities from the south and north of the Mediterranean Sea. It constituted a database of thirty-five (35) forums located in various geographic locations among this study area. Using a systematic analysis and comparison, the results demonstrate that, even within different climatic contexts, Roman planners largely respected Vitruvius' principles, particularly in terms of aligning forums to prevailing winds and optimizing solar exposure. This investigation's outcomes highlight the ingenuity of Roman urban planning in terms of appropriate balanced response between the environmental requirements and the functional needs inside the public spaces. This research work contributes to understanding how climate, topography, and Vitruvius' recommendations crossed to shape the Roman cities' public spaces.

1. INTRODUCTION

The forum existed in all the Roman cities and was their main focal point. This is due to its functional role but also because of its symbolic and political significance. In fact, all the public life activities were concentrated there [1]. However, its design is not limited to providing the practical needs of public gatherings but also articulates the societal and ideological values of the Roman world. The forum's design embodied political consensus and community belonging as well as fostering collective identity through cultural and religious expression. These dual roles of functionality and symbolism were integral for the forum's given prominence in Roman urban planning [2]. The Roman forum is generally organized as a set of various buildings. The most important among these buildings are the temple, the basilica, and the curia arranged around an open-to-sky square. This latter, known in Latin as the '*area*', was the place where all kinds of events occurred, including political activities (demonstrations, major declarations, etc.) and commercial activities (buying and selling, markets and auctions). It was also often the scene of bloody and cultic events (torture of slaves, funeral banquets, and collective prayers in times of crisis). Oppositely, the forum was also the place for the celebration of many joyous events such as the usual religious ceremonies, feasts and processions [3]. It must be emphasized that legal prohibitions ensured that the forum remained an open space, accommodating the full spectrum of civic life [4]. This openness made it a physical and symbolic epicenter, where the dynamics of Roman society were both enacted and observed. According to Vitruvius, the Romans located the forum immediately after defining the layout of the city's main streets [5]. However, it is possible that the Roman builders adapted the spatial characteristics of the forum to the natural constraints and particularities of each geographical and physical environment [6].

This research work aims to know how the Roman builders undertook such adaptation in respect of the various constraints specific to the different contexts included in the Roman Empire. Consequently, and as a first step, several cases of forums in North African and European cities were selected as a study corpus. The undertaken analysis considers the specific climatic and topographical constraints of the places where the study corpus objects are located. The geometric layout of the forum (longitudinal and transversal axis) is examined in relation to the slope of the terrain, as well as the prevailing wind direction and the path of the sun, both individually and in combination. This made it possible to define a set of categories of forums that totally or partially share these examined characteristics.

2. LITERATURE REVIEW

The Roman urban space, namely the forum, evolved from

its first appearance in the Italian cities to the towns conquered during the vast expansion of the Roman Empire. Throughout this era, these latter areas' forums always referred to the Italian cities' forums as well as to the imperial ones (Figure 1).

It seems that the Roman forum has origins steeped in both practicality and mythology. As the myth recounts, the twins Romulus and Remus were abandoned at birth and nurtured by a she-wolf in the wild—a story symbolizing Rome's resilience and connection to nature [7-9]. However, throughout the years, the forum that was established as a market and was gradually transformed into a public space surrounded by luxury shops [3].

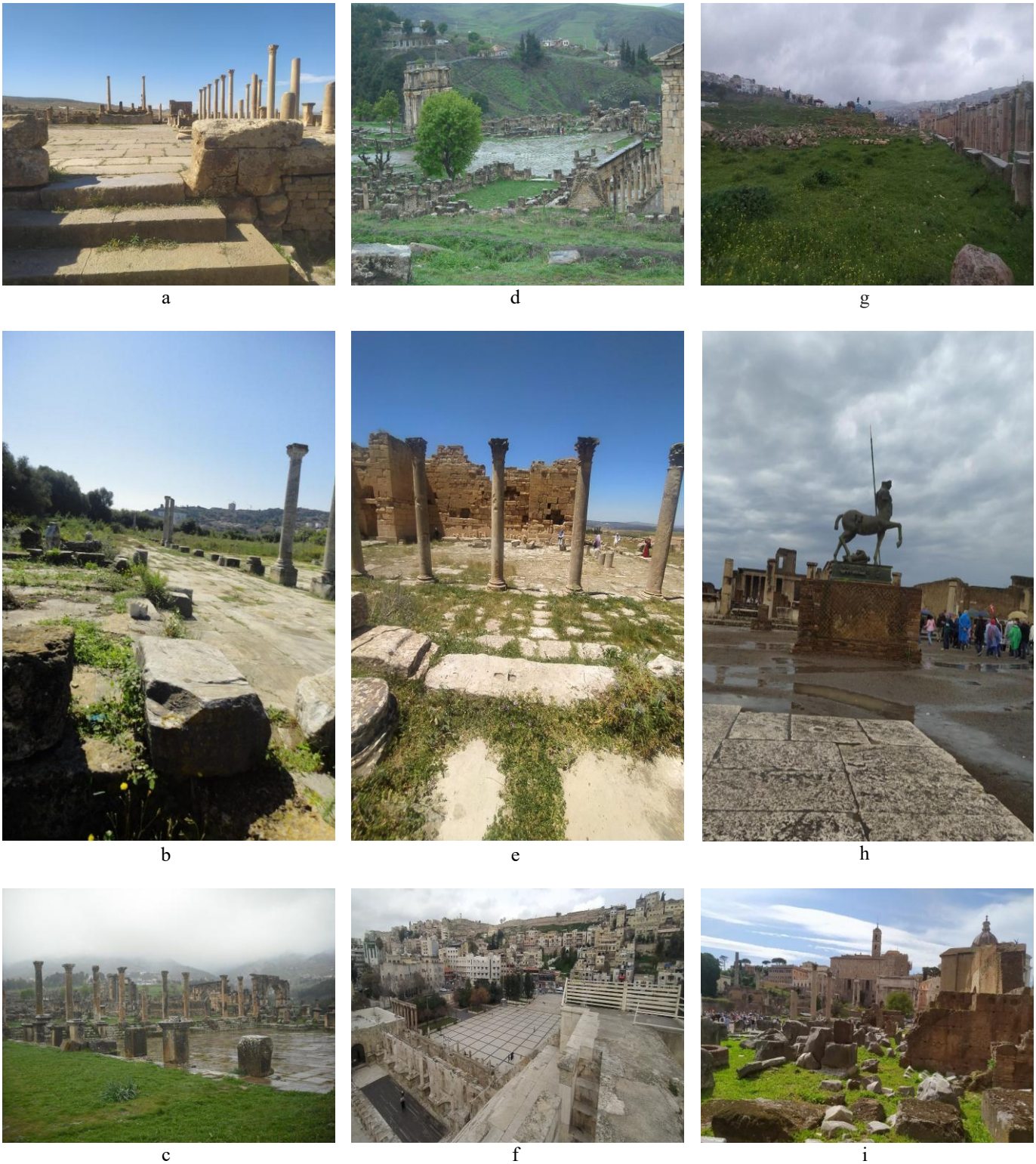

Figure 1. Pictures of Roman forums: a. Timgad forum; b. Hippo regius forum; c. Djemila forum (01); d. Djemila forum (02); e. Madauros; f. Philadelphia (Amman) forum; g. Gerasa forum (probable location [7]); h. Pompeii forum; i. The forum of Rome

Source: Authors

Appearing between 54 BCE and 117 CE, the Imperial forums of Rome were designed along nested axes; the longitudinal axis of each new forum being perpendicular to the longitudinal axis of the previous forum. Such an axes-based system created a dynamic movement in the city center [10].

Outside Rome city, the Italian towns and Roman provinces forums could be categorized into distinct typologies in respect to their architectural and functional characteristics.

According to Gros [11], four main types of forums could be identified: i) The Comitium that is an earliest type characterized by a ring-shaped space reserved for electoral meetings, ii) The first forums, in Italy, presented a temple dominating the square, with a basilica positioned along a perpendicular axis, hence emphasizing the centrality of religious and administrative activities in urban life, iii) The tripartite Scheme based forum was the most common case in the Roman provinces including a basilica bordered the square transversely and a temple located on the opposite side, and iv) The provincial forums including some buildings devoted for regional administrative functions in addition to those found in the Italian cities [11].

Regarding the key factors governing the choice of location for cities, Castra and public spaces, including forums, within Ancient Rome. Indeed, previous studies highlighted several factors potentially impacting the location of public buildings on the orientation of the forum.

García Quintela et al. [12] identify two astronomical referred models for Roman cities: i) alignments around the equinox, and ii) those corresponding to seasonal markers from Celtic tradition [12]. During the reign of Augustus (27 BCE–14 CE), the main public buildings, including forums, were oriented toward specific points of the horizon where sunrise or sunset is observed on specifically important dates [13, 14]. Despite their symbolic value, these astronomical considerations were not the unique dominant factors. Effectively, Rodríguez-Antón et al. [15] highlighted that both sites' topographical and environmental characteristics widely prevailed in the planning process. Roman surveyors gave priority to the site's characteristics, climate, and strategic advantages that ensured the place's functionality and defense [15]. Vitruvius also underlined the necessity to harmonize urban layouts with practical realities, balancing symbolic alignments with environmental pragmatism [5].

2.1 Climatic factors

In his book of 1939, Vinaccia [16] informs about the Romans' remarkable ability to incorporate environmental considerations into urban design, reflecting their capacity for practical and climatic urban planning [16]. Giovagnorio et al. [17] further emphasized that Roman urban planning was rooted primarily in the site's practical concerns, particularly the direction of local winds and the path of the sun, rather than ideological or religious principles [17].

Adam [18] examined the orientation of towns and centuriations and revealed that northwest-southeast alignments often deviated from theoretical guidelines. His findings suggest that Roman surveyors made practical adjustments to accommodate local conditions [18]. For the case of Italian Roman cities, Vinaccia [19] revealed that many urban plans deviated by approximately 30° from the north-south axis in order to mitigate the effects of cold northern and northwestern winds while avoiding the damp, unhealthy southeastern winds. Additionally, such orientations ensured that sunlight reached all four sides of buildings, providing enhanced lighting and thermal benefits [19]. Further, El Alami [20] notes that diagonal alignments allowed structures to maximize southern sun light exposure while minimizing northern less sunlit one, thus reflecting the Romans' preference for practicality over rigorous cardinal alignments [20].

Although Romans frequently used pragmatic approaches to manage natural factors, they display remarkable similarities and crossings with other civilizations in their consideration of the sun as a symbolic element.

A study on the city of Petra, a Nabatean city, known for its strong Romanization, revealed that numerous buildings, including the famous Al-Kazneh and the theatre, were oriented in a specific way in relation to the sun. The designers adopted three solar principles: i) they oriented some building towards the sunrise or sunset at a specific time of day, (ii) they aligned others with a key reference point on the horizon, and they arranged others so that the sun's rays penetrate the interior spaces at particular times to highlight significant elements [21].

The incorporation of the sun into the design and orientation of monuments is an ancient tradition common to many ancient civilizations.

In Greek civilization, knowledge of solar geometry was highly developed. For instance, a study demonstrates how sunlight enters the Parthenon (Greece) and completely lights up the statue of Athena at 6:07 am on 22 August, the day dedicated to the goddess Athena [22].

In Ancient Rome, the most illustrative example of solar design principles is the Pantheon. The rotunda was illuminated and heated through a zenithal oculus, which directed sunlight downward [23]. The dimensions of the rotunda were precisely calculated so that during autumn and winter, sunlight would traverse the upper half of the building, tracing an arc from east to west [24]. These observations indicate a sophisticated understanding of solar dynamics as well as demonstrate the Romans' ability to integrate environmental knowledge into their architectural designs.

Besides, these ancient Roman cities' urban grid patterns were ingeniously designed to shield streets from the chill of winter winds while promoting cooling ventilation during the summer months. This has been concluded from the analysis of fifteen (15) Roman-era cities in Italy [17].

In the northern part of Khanga, one of the five main oases in Egypt's Western Desert. A series of Roman buildings are scattered across the landscape. A study has revealed that the orientation of the various components of this vast and complex site corresponds to the prevailing local winds. It seems that the designers followed a modified version of Vitruvius' principle adapted to the desert: their orientation is based on the wind, but their purpose is to harness it, rather than avoid it in order to mitigate the summer heat [25]. This is consistent with a study conducted by Burch and Prat [26] investigating climate adaptation in Roman Architecture through the analysis of ancient authors' writings: Pliny the Younger, Columella, Cato, Palladius, Varro and Vitruvius. They concluded that the Romans adapted to the climate in two main ways: the first was to choose the appropriate location for the building by situating it in specific places that mitigated climatic factors. The second was to orient the building correctly in order to obtain the appropriate amount of light depending on its function. In addition to these two approaches, the Romans were skilled in the use of building materials, enabling them to build structures

that endured through time [26].

2.2 Topography's constraints

Numerous examples of forums confirm that the Romans consider the topography's constraints for the urban layout of their cities. The first approach is mainly related to the forum's setting. The latter must be carefully chosen to ensure accessibility and/or enhance visibility. In some cases, the forums were built upon an elevated setting allowing the domination of their surroundings, as in Terracina (Italy), Augusta Bagiennorum (Italy) and Glanum's (France). Such strategic placements emphasized the forum's civic importance and visual prominence, often extending its influence beyond the city boundaries [4, 27].

Differently, builders took advantage of topographical features to plan the civic buildings that made up the forum, often even exploiting the configuration of the cliffs to erect the forum temple, as at Augusta Raurica, where the temple occupies a dominant position within the complex. The city of Djemila (Cuicul) illustrates perfectly the topography's constraints considered by the planners in terms of site's landform potential for the buildings' choice of siting and layout. Its forum (Djemila 01) is located on a high place of the city and is visible from the surrounding countryside. The Capitol was raised on a massive slope with its temple raised on double platforms. Similarly, its severe square (Djemila 02) is a complex surface surrounded by numerous civic monuments, punctuated by the raised mass of the Septimus Severus temple [4].

From the building's point of view, the Romans used cryptoporticus in the layout of the forums, consisting of vaulted galleries. These serve to support one of the elements of the square in order to compensate for uneven ground and/or to enhance the height of the monumental center, as seen in the forum of Minturnae [27]. Another way to adapt to the topographical features of the forum's site is to exploit the differences in level to emphasize key visual axes and create a distinction between the square and the adjacent streets [28].

Unfortunately, there is a lack in terms of theoretical information about the tangible way Roman planners adapted to the topography of the site. And although the downstream and/or upstream, as well as parallel and/or perpendicular to the slope, settlements are easily detectable on the ground, the relationship to the topography of the place remains latent and the relationship to the contour lines characterizing the slope of the settlement land are mainly deduced and did not remain to any textual and/or graphic fundamental recommendations.

2.3 Vitruvian recommendations

In De Architectura (Book V, Chapter I), Vitruvius mainly recommended the morphological characteristics for the forum as follows: i) the forum's shape should be rectangular, ii) its area have to be related to the population of the city, and iii) its central square's width should be equal to the two-thirds of its length, hence ensuring a harmonious and functional layout.

Also, Vitruvius indicated that the forum should be at the crossing point of the city's primary streets, the Cardo and the Decumanus. Nevertheless, he did not specify whether the forum's longitudinal or transverse axes must be parallel or perpendicular to these main streets [5]. It must be remembered, here, that Vitruvius' recommendations have been mainly intended for Roman cities in Italy. However, they constitute a planning and building reference for Roman human establishments later built in the various provinces of the Roman empire.

3. THE STUDY CORPUS

The study corpus's components were selected by means of an extensive literature review related to Roman town planning. The selection process has been undertaken in two consecutive stages. The first one consisted of compiling an inventory of the forums located in the Roman cities across Europe and North Africa. For the first continent, twenty (20) forums were selected that are located in the cities of the United Kingdom (Silchester and Wroxter), Germany (Colonia Ulpia Traiana and Trier), Italy (Alba Fucens, Cosa, Ordona, Ostia and Pompei), France (Bagacum, Glanum, Lugdunum and Ruscino), Switzerland (Augusta Raurica), Spain (Baelo Claudia, Augusta Emerita and Empuries), Romania (Sarmizegetusa) and Croatia (Zadar).

For North Africa, the study considered fifteen (15) forums throughout the Roman cities from Libya (Leptis Magna and Sabratha), Morocco (Colonia Iulia Valentia Banasa, Sala Colonia and Volubilis), Tunisia (Bulla Regia, Dougga, Gigthis, Sufetula), and Algeria (Djemila, Hippo Regius, Timgad and Madauros). Because some cities had more than one forum, e.g., Augusta Emerita, Leptis Magna and Djemila, the total number of cases finally considered in this study is thirty-five (35) forums (Figure 2). It must be noticed that the Sarmisegetuza forum is a distinct case because it includes two public squares with similar characteristics but of different sizes (Figure A1).

The second stage aimed to update and check the forum related previously collected data. It involved examining archaeological plans and cross-referencing them with aerial imagery and Google Earth satellite photographs. It should be noted that actually, and in several towns, there are archaeological plans of forums, while on site, there is no visible trace. For the latter, restituted plans were used. This in-depth approach aimed to include the most possible number of forums while respecting archaeological academic requirements. The descriptive characterization of the selected forums included: i) geographical location, ii) construction date, iii) climatic context, and iv) the topographical nature of their sites (Tables 1-3).

The chronological review of the selected forums revealed that the oldest forums were located in Italy. By the IInd century BCE, this urban space type had spread within Gaul territory. During the first century BCE, this typically Roman urban complex spread throughout Europe, particularly to Germany, Great Britain and the Iberian Peninsula. Most of the forums in Europe were achieved during this era. However, a significant decrease of new forums is underlined during the Ist and IInd centuries CE.

In North Africa, the construction of the earliest forums began in the 1st century BCE and continued until the 3rd century CE. Notably, most North African forums dated to the 1st century CE, reflecting the succeeding stages of Roman expansion from Italy to Gaul, then to North Africa, and finally to other European regions (Figure 3).

Figure 2. Location of corpus forums
Source: Authors

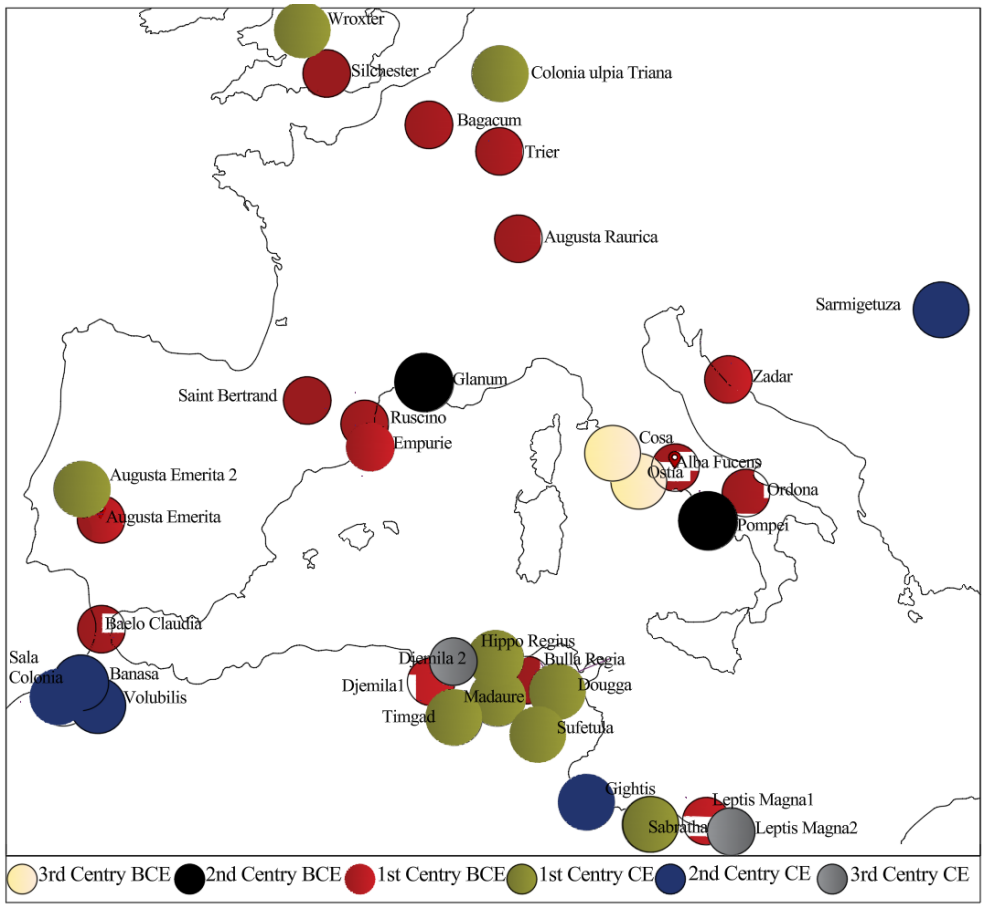

Figure 3. Forum construction dates
Source: Authors

Table 1. Characterization of corpus forums

Forum	Name	City	Country	C.P	Continent
F1	Alba Fucens	Aquila	Italy	1st century BCE	E
F2	Augusta Emerita 01	Mérida	Spain	Augustus Period	E
F3	Augusta Emerita 02	Mérida	Spain	30 CE	E
F4	Augusta Raurica	Basel	Switzerland	43 BCE	E
F5	Baelo Claudia	Bolonia	Spain	Augustus Period	E
F6	Bagacum Nerviorum	Bavay	France	19-15 BCE	E
F7	Bulla Regia	Jendouba	Tunisia	46 BCE	A
F8	Colonia Ulia Valentia Banasa	Left bank of Sebou River	Morocco	2nd century CE	A
F9	Colonia Ulpia Triana	Xanten	Germany	71 CE	E
F10	Cosa	Ansedonia	Italy	274 BCE	E
F11	Djemila 01	Sétif	Algeria	96 BCE	A
F12	Djemila 02	Sétif	Algeria	216 CE	A
F13	Dougga	Téboursouk	Tunisia	54 CE	A
F14	Empuries	Girona	Spain	Augustus Period	E
F15	Gigthis	Médenine	Tunisia	Hadrian's reign	A
F16	Glanum	Saint Rémy	France	102 BCE	E
F17	Hippo Regius	Annaba	Algeria	71 CE	A
F18	Leptis Magna 01	Khoms	Libya	1st century BCE	A
F19	Leptis Magna 02	Khoms	Libya	3rd century CE	A
F20	Lugdunum Convenarum	Saint Bertrand de comminge	France	72 BCE	E
F21	Madauros	Souk Ahras	Algeria	1st century CE	A
F22	Ordona	Foggia	Italy	1st century BCE	E
F23	Ostia	Ostia	Italy	267 BCE	E
F24	Pompei	Naples	Italy	2nd century BCE	E
F25	Ruscino	Perpignan	France	1st century BCE	E
F26	Sabratha	Tripoli	Libya	1st century CE	A
F27	Sala Colonia	Chellah	Morocco	2nd century CE	A
F28	Sarmizegetusa	Hunedoara	Romania	106-107 CE	E
F29	Silchester	Hamsphire	England	30 BCE	E
F30	Sufetula	Sbeitla	Tunisia	69-96 CE	A
F31	Timgad	Batna	Algeria	1st century CE	A
F32	Trier	Trier	Germany	16 BCE	E
F33	Volubilis	Walili	Morocco	150-190 CE	A
F34	Wroxeter	Shrosphire	England	48 CE	E
F35	Zadar	Zadar	Croatia	35-33 BCE	E

Source: Authors

Table 2. Climate characterization of corpus forums

Forum	Name	Orientation	WD 01	A1 01	WD 02	AI 02	WD 03	AI 03	WD 04	AI 04	WD 05	AI 05
F1	Alba Fucens	Q7	41°	78°	224°	83°						
F2	Augusta Emerita 01	Q7	90°	51°	270°	51°						
F3	Augusta Emerita 02	Q7	90°	51°	270°	51°						
F4	Augusta Raurica	Q1	7°	46°	147°	86°	230°	2°	260°	28°		
F5	Baelo Claudia	Q2	271°	60°	60°	29°						
F6	Bagacum Nerviorum	Q8	201°	83°	249°	50°						
F7	Bulla Regia	Q1	322°	74°	221°	27°						
F8	Colonia Ulia Valentia Banasa	Q2	320°	72°	259°	48°						
F9	Colonia Ulpia Triana	Q1	261°	35°	220°	5°						
F10	Cosa	Q8	231°	78°	29°	81°						
F11	Djemila 01	Q7	260°	78°	20°	42°						
F12	Djemila 02	Q2	260°	43°	20°	16°						
F13	Dougga	Q1	322°	71°	221°	30°						
F14	Empuries	Q7	180°	22°	26°	47°						
F15	Gigthis	Q1	58°	16°	270°	19°						
F16	Glanum	Q7	3°	18°								
F17	Hippo Regius	Q7	19°	29°	232°	61°						
F18	Leptis Magna 01	Q7	0°	30°	60°	90°	90°	60°	120°	29°	242°	88°
F19	Leptis Magna 02	Q1	0°	58°	60°	2°	90°	32°	120°	68°	**242°**	6°
F20	Lugdunum Convenarum	Q8	289°	22°	135°	2°	203°	70°				
F21	Madauros	Q7	45°	72°	225°	73°	315°	17°				
F22	Ordona	Q7	316°	1°	330°	14°	78°	58°	101°	37°		
F23	Ostia	Q7	69°	87°	270°	72°	254°	88°				
F24	Pompei	Q7	190°	31°	29°	47°						
F25	Ruscino	Pl	332°	44°	117°	60°						
F26	Sabratha	Q1	120°	57°	151°	89°	302°	60°				

F27	Sala Colonia	Q1	319°	49°	202°	71°		
F28	Sarmizegetusa	Q1	320°	56°	270°	13°	140°	54°
F29	Silchester	Pl	218°	38°	243°	63°		
F30	Sufetula	Q8	0°	62°	270°	31°		
F31	Timgad	Pr	39°	51°	243°	28°		
F32	Trier	Q8	45°	72°	230°	64°		
F33	Volubilis	Q1	314°	50°	224°	34°	180°	79°
F34	Wroxeter	Q8	332°	51°	250°	31°		
F35	Zadar	Q1	68°	12°	119°	49°	300°	63°

Source: Authors

Table 3. Topographical characterization of corpus forums

Forum	Name	Ds/LA	Cl/LA	Slope	Slope Gradient	Top/Wind
F1	Alba Fucens	Pl	Pr	4%	Slight	C3
F2	Augusta Emerita 01	None	None	None	None	None
F3	Augusta Emerita 02	None	None	None	None	None
F4	Augusta Raurica	None	None	None	None	None
F5	Baelo Claudia	Pl	Pr	6.38%	Moderate	C2
F6	Bagacum Nerviorum	None	None	None	None	None
F7	Bulla Regia	No Slope	No Slope	No Slope	No Slope	No Slope
F8	Colonia Ulia Valentia Banasa	No Slope	No Slope	No Slope	No Slope	No Slope
F9	Colonia Ulpia Triana	None	None	None	None	None
F10	Cosa	No Slope	No Slope	No Slope	No Slope	No Slope
F11	Djemila 01	Pl	Pr	7%	Moderate	C3
F12	Djemila 02	Conv/Conc	Conv/Conc	7.14%, 13.6%	Moderate & steep	C1
F13	Dougga	Pr	Pl	4%	Slight	C1
F14	Empuries	Pr	Pl	2.27%	Slight	C2
F15	Gigthis	Pr	Pl	4%	Slight	C2
F16	Glanum	Pl	Pr	6%	moderate	C1
F17	Hippo Regius	No Slope	No Slope	No Slope	No Slope	No Slope
F18	Leptis Magna 01	No Slope	No Slope	No Slope	No Slope	No Slope
F19	Leptis Magna 02	No Slope	No Slope	No Slope	No Slope	No Slope
F20	Lugdunum Convenarum	None	None	None	None	None
F21	Madauros	Pl	Pr	4.5%	Slight	C1
F22	Ordona	Conv/Conc	Conv/Conc	3.7%, 2.28%	Slight	C4
F23	Ostia	Conv/Conc	Conv/Conc	2%, 3.5%	Slight	C4
F24	Pompei	Pl	Pr	1.86%	Slight	C2
F25	Ruscino	Conv/Conc	Conv/Conc	2%, 2%	Slight	C2
F26	Sabratha	No Slope	No slope	No slope	No Slope	No Slope
F27	Sala Colonia	Pr	Pl	8%	Moderate	C2
F28	Sarmizegetusa A	Pr	Pl	3.1%	Slight	C1
F28	Sarmizegetusa B	Pr	Pl	5.55%	Moderate	C1
F29	Silchester	None	None	None	None	None
F30	Sufetula	Pl	Pr	2.7%	Slight	C2
F31	Timgad	Pr	Pl	4.65%	Slight	C2
F32	Trier	None	None	None	None	None
F33	Volubilis	No slope	No slope	No slope	No slope	No Slope
F34	Wroxeter	None	None	None	None	None
F35	Zadar	No slope	No slope	No slope	No slope	No Slope

Source: Authors

4. METHODOLOGY

According to the previously cited criteria, on which the location and the design of the Roman forum are based, each case in the study corpus is analyzed in respect of the following methodological protocol: i) Its position in relation to the Cardo Maximus and the Decumanus Maximus, ii) Its orientation in relation to the sun, iii) The orientation of its longitudinal axis with respect to the direction of the prevailing winds. Results were then analyzed according to the types of climate that characterize each case, using the Köppen classification [29]. iv) The forum's longitudinal axis relationship to its site's Contour lines direction using both Google Earth and topographical maps, and v) Compliance with the forum related Vitruvius' recommendations in terms of dimensions, proportions, and location.

Indicating that, in cases where the longitudinal axis of the square was somewhat ambiguous, e.g., the trapezoidal forums, the general shape of the forum and the arrangement of surrounding buildings were considered in order to deduce its longitudinal axis (Figure 4).

The forum's orientation towards the sun has been identified using a quadrant based-subdivision. These were defined in terms of cardinal and intercardinal points. However, as all the cases were studied in relation to a northern orientation, only four (04) quadrants were taken into account: Q1 (0-45), Q2 (45-90), Q7 (270-315), Q8 (315-360) (Figure 5).

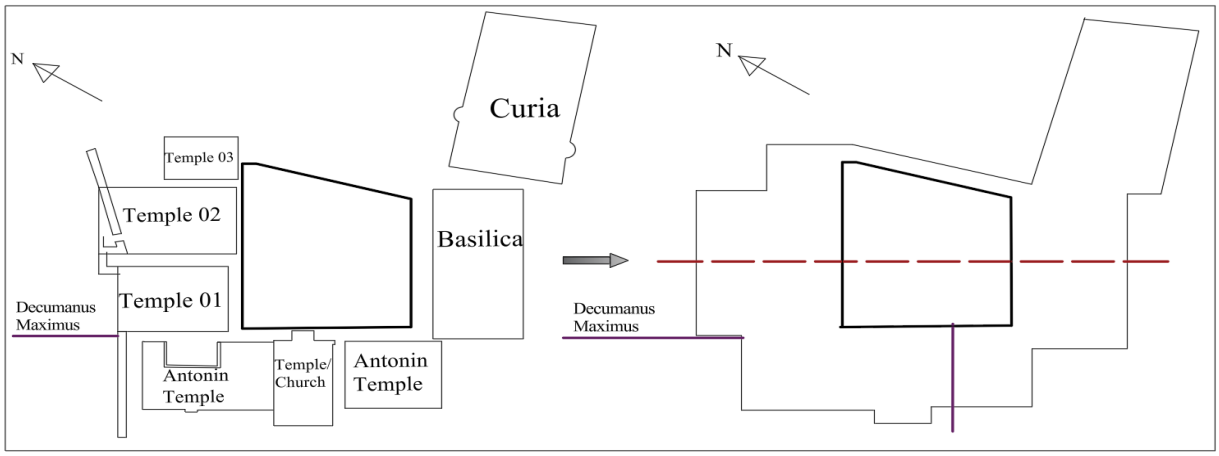

Figure 4. The longitudinal axis considered in the case of irregularly shaped squares (Leptis magna forum (01))
Source: Authors

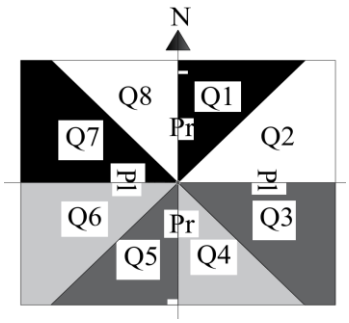

Figure 5. Quadrant diagram
Source: Authors

Besides, the wind data were primarily extracted from the IEM (Iowa Environmental Mesonet) (https://mesonet.agron.iastate.edu/sites/locate.php) database and NOAA (National Climatic Data Centre) (https://www.noaa.gov/). However, due to data less availability for Madauros and Sufetula, it was extracted from Weatherspark (https://weatherspark.com/) and Météoblue (https://www.meteoblue.com/fr/meteo/semaine/blue_%C3%89tats-unis_5286039).

To identify prevailing winds, wind roses based on historical data are used. These were obtained from the collection and analysis of a large amount of wind data. To read the maps correctly, it was necessary to examine detailed climate data for each considered city in addition to monthly wind maps. As an instance, and in order to determine the prevailing winds during the cold season, it was unavoidable to read the Wind roses for four months, namely November, December, January and February. Also, to identify the direction of the prevailing winds during the warm season, the wind roses had to be examined for the months of May, June, July and August. Knowing that sometimes there are winds that blow throughout the year. The collected data's synthesis and the practical simplification of the analytical process have been converted to schematic drawings. These allow for comparison of the angles formed by the wind direction and the forum's longitudinal axis one. Finally, it will effectively identify the cases where the winds were blowing perpendicular to the main axis, parallel or diagonally to it (Figure 6).

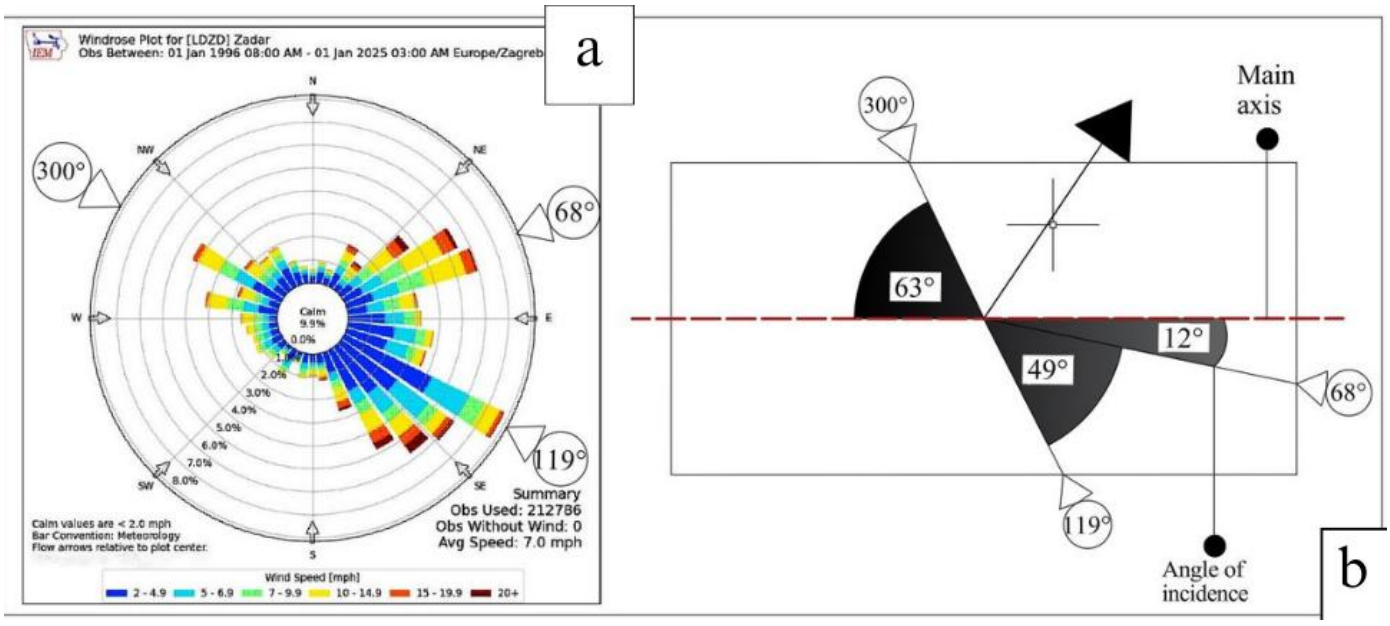

Figure 6. a. Prevailing winds in Zadar; b. Measuring angles of incidence according to prevailing winds
Source: a: https://mesonet.agron.iastate.edu/sites/dyn_windrose. b: Authors

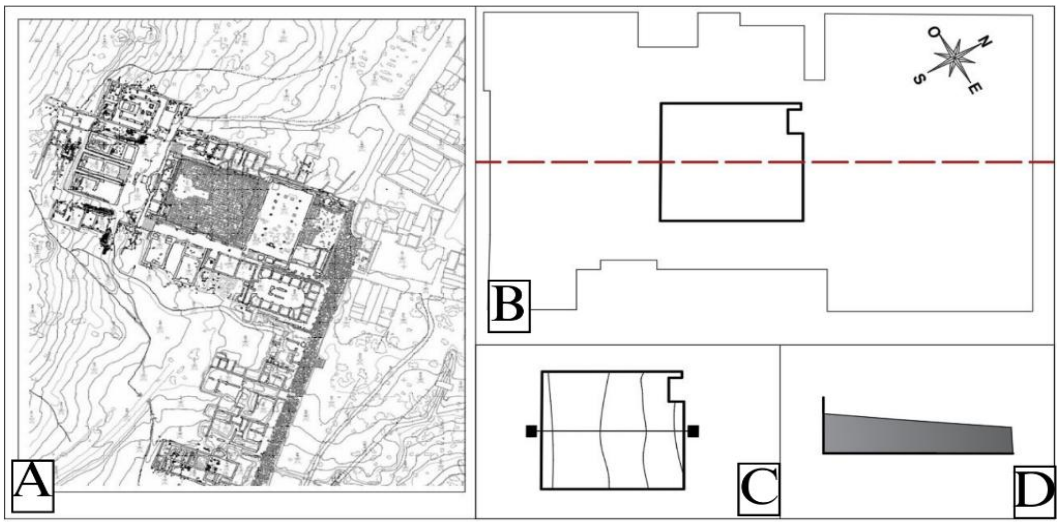

Figure 7. A. Topographic relief of Baeolo Claudia; B. The forum of Baelo Claudia; C. The direction of the slope; D. Topographic profile of the square of the Baelo Claudia forum
Source: A: [30], B: [30], adapted by authors. C: Authors. D: Authors.

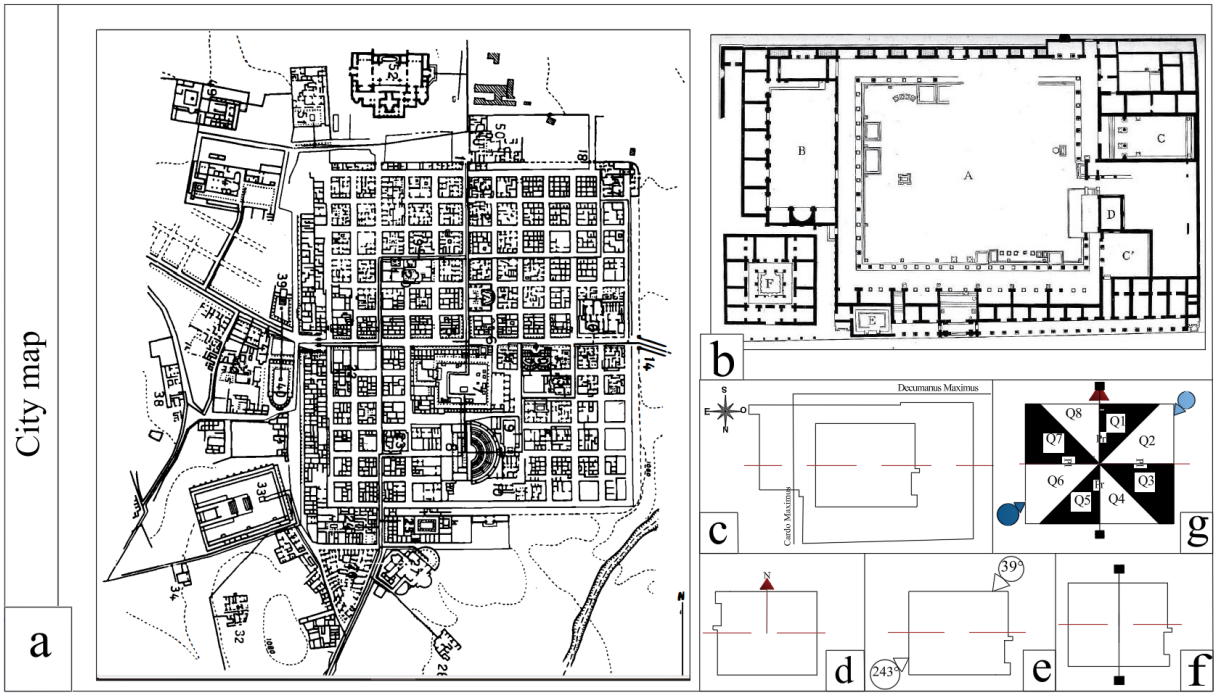

Figure 8. Climatic characterization of the Timgad forum. a. The map of the city of Timgad; b. The map of the Timgad forum; c. Forum location; d. Solar orientation; e. Wind direction; f. Topography; g. Synthesis diagram
Source: a: [27]. b: A. Ballu drawing [31]. c-g: Authors.

To identify the impact of topography constraints the analysis process is based on the reading of the contour line directions. This analysis considered two primary possibilities related to the site topography: i) Parallel Alignment (Pl) when the Contour lines are aligned with the longitudinal axis of the forum, and ii) Perpendicular Alignment (Pr) if the Contour lines crosses perpendicularly the longitudinal axis (Figure 7).

Once each factor has been examined for every case study, all the study corpus' objects were superimposed on a same single diagram in order to analyze them together comparatively (Figure 8). In such a way, this method provides a comprehensive visual framework for discussing the relationships between climatic, topographical, and urban planning factors and their impacts on the studied forums' design.

5. RESULTS

5.1 The forum's location at the crossing between the Cardo and Decumanus Maximus

Within our study corpus, there is a lack of data related to the location of the forum, in relation to the crossing of the Cardo Maximus and Decumanus Maximus, for four cities (Bagacum, Lugdunum, Wroxeter, and Zadar). Thus, these forums were not here considered. The analysis of the forums' locations in the other considered cities reveals several categories of situations.

Firstly, the data reveal that the forum could or not be at the center of the city's urban fabric independently of the present time visible trace of the two main axes. For example, the forum

of Glanum and Madauros's one are centrally located within their urban networks, but no specific information regarding their relationship to the Cardo and Decumanus is available. Differently, nine (9) forums were not located at the center of the urban network illustrating unconformity with the usual crossing place. These cases are those of the cities Bulla Regia, Ordona, Ruscino, Dougga, Sabratha, Sala Colonia, Gigthis, Pompeii and Volubilis.

Secondly, the Forums revealed as clearly located at the Cardo and Decumanus crossing are sixteen (16) and are the following: Alba Fucens, Augusta Emerita 01, Augusta Raurica, Baelo Claudia, Colonia Ulpia Valentia Banasa, Colonia Ulpia Traiana, Cosa, Djemila 01, Empuries, Hippo Regius, Ostia, Sarmizegetusa, Silchester, Sufetula, Timgad, and Trier.

Not located at the main streets crossing but giving on one of them, is the case of the three (3) following ones: The old forum of Leptis Magna (1), the second forum of Djemila (2), Augusta Emerita 2 one. Lastly, the Severan forum of Leptis Magna 2 is located between two crossing streets parallel to the main axes.

These outcomes illustrate the diversity in forum placement, reflecting both adherence to and deviations from the classical planning principles associated with the Cardo and Decumanus (Figure 9).

5.2 The forum and solar orientation

A comparative analysis of the forums' orientations relative to the North highlights consistent patterns across different geographical regions. Most of the forums align with the three following main quadrants: i) Q1, ii) Q7, and iii) Q8.

Which means that the longitudinal lines of these squares are positioned respectively on the following axes: (ENE-WSW), (NNW-SSE), (WNE-ESE).

According to their geographical zone location, more than the third (40%) of European forums are oriented towards the Q7 solar quadrant (NNW-SSE) and the quarter (25%) towards Q8 (WNW-ESE) one whilst approximately half (46%) of the North African cities' forums are located on the Q1 (ENE-WSW).

These outcomes reveal that almost all the analyzed forums deviated from the cardinal directions with different angles (Figure 10, Table 2).

5.3 The forum's shape in relation to the prevailing winds

Based on the angle of incidence between the prevailing wind direction and the longitudinal axis of the forum, the analysis reveals distinct patterns characterizing the relationships of these ancient urban spaces with wind directions. Thus, the corpus of forum studies was classified into three categories.

For the first category (17% of this corpus), the wind blows parallel to the longitudinal axis of the forum (0°–15°). In the second category (68% of the forums studied), the prevailing winds cross their longitudinal axes diagonally (15°–79°). Finally, for just over one-tenth (11.4%) of the forums considered, constituting the third category, the prevailing winds intersect the longitudinal axis of the forum perpendicularly (80°–90°).

Even though they are few in number (2.85% of the total number of forums examined), singular cases highlight the complexity of the relationship between the forum and the wind. Indeed, in Augusta Raurica, the prevailing winds blow in two directions, crossing the forum longitudinally and transversely.

In sum, the third (32%) of the analyzed forums are crossed by prevailing winds either parallel or perpendicular to their longitudinal axes. However, more than two-thirds (68%) are positioned obliquely to the prevailing winds, and then conform to Vitruvius' recommendations.

This trend is particularly obvious in North Africa where a high number (80%) of the forums comply with the latter. Less numerous but so significant is the number of European forums (55%) that are respectful with the same principles. Furtherly, this fact demonstrates the Roman planners' ability of integrating environmental factors into urban design (Figure 10, Table 2).

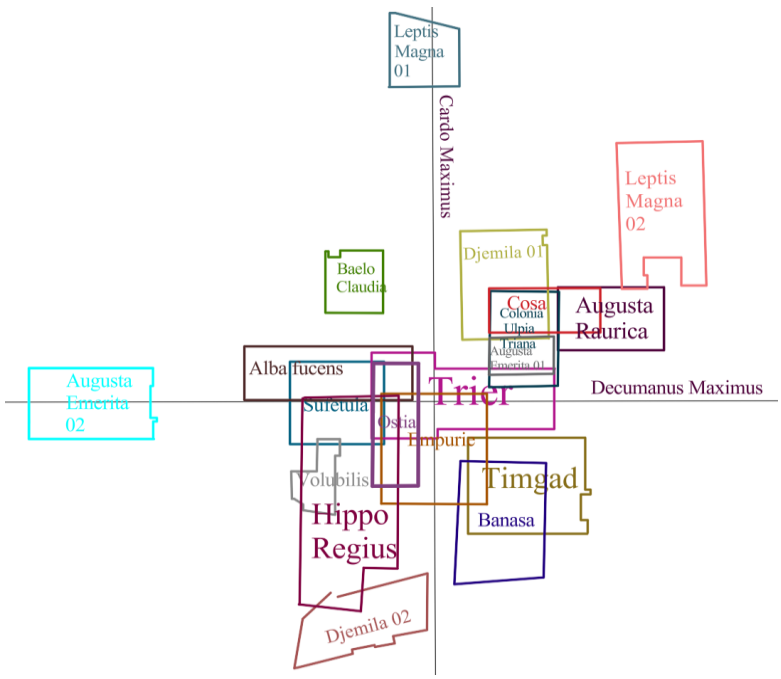

Figure 9. Location of 18 forums in relation to the streets of Cardo Maximus and Decumanus Maximus
Source: Authors

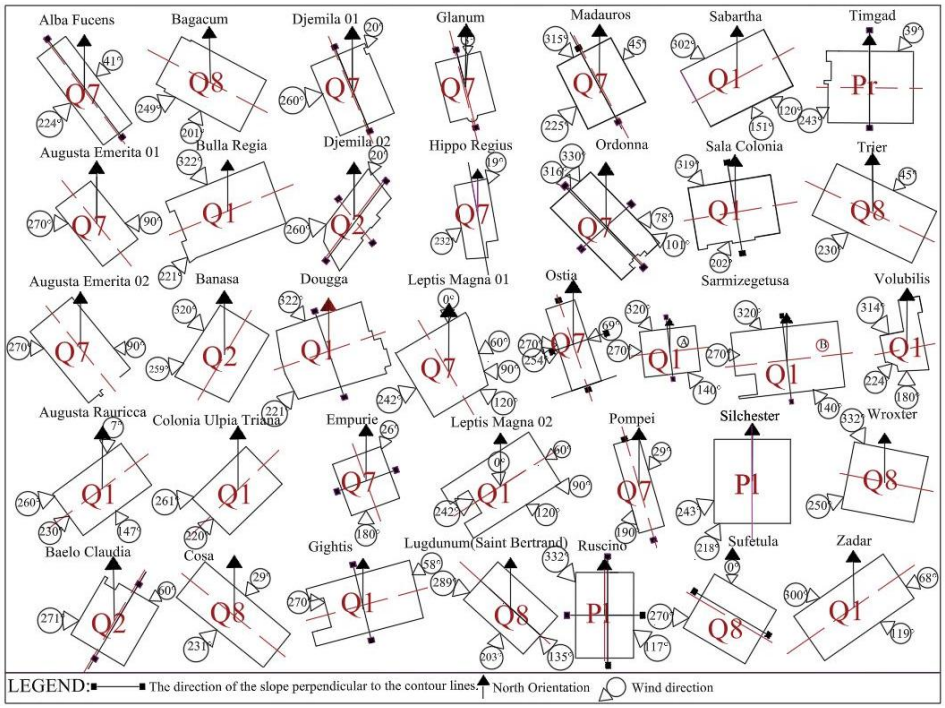

Figure 10. The position of the forum squares in relation to the northern orientation, the prevailing wind directions and the direction of the slope
Source: Authors

5.4 The forum and the impact of the site's topography

The analysis of the forums' topographical characteristics faced the lack of archeological data better informing about such place's site natural properties. In fact, several forums have either disappeared and/or known only through restitutions. The still existing forums are ruins partially or entirely overgrown with vegetation. Among the thirty-five (35) forums studied, the direction of the slope was easily identifiable in twenty-six (26) cases. In nine (09) cases, the terrain was flat without discernible slope. Among the remaining forums, seven (07) were oriented perpendicular to the contour lines, while seven (07) ran parallel. Additionally, three (03) forums were located on concave terrain. Particularly, the forum Djemila (02) was built on a combined sloping terrain. Its inclinations are of 6 m in both transverse and longitudinal directions and complicate furtherly the examination and discussion of its topographical alignment (Figure 10, Table 3).

5.5 The double impact of the site's topography

Topography is a fundamental design factor and its interaction with the wind direction could have an imperative effect on urban spaces. This should occur especially when the slope direction is aligned with the prevailing wind direction. In fact, the interaction between topography and wind can either amplify or mitigate the effects of this latter on the urban space users' practices.

To consider this physical phenomenon, the angle of incidence between the forum's orientation and the topographical curves was calculated for all cases with sufficient data. Apart from the nine (9) forums situated on flat terrain, the corpus' remaining objects were categorized into three groups based on the angle of incidence: i) C1 (< 20°) including five (05) forums, ii) C2 (20°-75°) constituted by eight (08) cases, and iii) C3 (> 75°) illustrated by two (02) cases. In some situations, the intersection of the prevailing winds and the terrain forms angles of incidence one close to 0° and another close to 90°. Consequently, another category, C4, has been added, counting two (02) cases.

Interestingly, it has been revealed that five (05) forums, precisely Djemila 2, Dougga, Glanum, Madauros as well as Sarmizegetusa (A and B), present an alignment between the direction of the contour lines and the prevailing winds. This is concretely illustrated by an angle of incidence approaching 0°. For the major cases of forums, the wind directions were either oblique or simultaneously oblique and perpendicular to the contour lines, with angles typically close to or equal to 45°.

In particular, in Ordona and Ostia forums, the winds formed angles of incidence close to 0° and 90° with the terrain (Table 3).

5.6 Compliance with the forum related Vitruvius' recommendations

The analysis revealed varied levels of compliance with Vitruvius' recommendations within this research's forums study corpus. Specifically, nearly two thirds (62% and 68%) of the examined forums conform, respectively, with Vitruvius' guidelines regarding their placement within the urban grid as well as respectful to his recommendations for their orientation in relation to the wind direction. However, less than half (38%) of the examined forums complied with the recommended length-to-width ratio. It should also be underlined that one square of Sarmizegetusa forum is respectful to Vitruvius' recommendations on proportions and the other are not (Table 4).

The shape criterion was verified and highlighted the major cases (83%) having a rectangular shape. For eight (08) cases (Baelo Claudia, Empuries, Madauros, Sarmizegetusa (A), Silchester, Sufetula, Timgad, Wroxeter), the shape is closer to square due to the fact that the length and the width are almost equal. The remaining forums are of irregular shape.

Table 4. Compliance with Vitruvius' recommendations

Forum	Name	Shape	W/L	Position Vitr	Shape Vitr	W/L Vitr
F1	Alba Fucens	Rectangle	2/6	Yes	Yes	No
F2	Augusta Emerita 01	Rectangle	2/3.39	Yes	Yes	Yes
F3	Augusta Emerita 02	Rectangle	2/3.4	Yes	Yes	Yes
F4	Augusta Raurica	Rectangle	2/3.29	Yes	Yes	Yes
F5	Baelo Claudia	Rectangle	2/2.23	Yes	Yes	No
F6	Bagacum Nerviorum	Rectangle	2/3.29	None	Yes	Yes
F7	Bulla Regia	Rectangle	2/3.25	No	Yes	Yes
F8	Colonia Ulia Valentia Banasa	Trapezoid	Trapezoid	Yes	No	No
F9	Colonia Ulpia Triana	Rectangle	2/2.88	Yes	Yes	Yes
F10	Cosa	Rectangle	2/4.9	Yes	Yes	No
F11	Djemila 01	Rectangle	2/2.57	Yes	Yes	No
F12	Djemila 02	Irregular	Irregular	Yes	No	No
F13	Dougga	Irregular	Irregular	No	No	No
F14	Empuries	Rectangle	2/2.14	Yes	Yes	No
F15	Gigthis	Rectangle	2/3.59	No	Yes	Yes
F16	Glanum	Rectangle	2/2.63	None	Yes	No
F17	Hippo Regius	Irregular	Irregular	Yes	No	No
F18	Leptis Magna 01	Trapezoid	Trapezoid	Yes	No	No
F19	Leptis Magna 02	Rectangle	2/3.44	No	Yes	Yes
F20	Lugdunum Convenarum	Rectangle	2/3.18	None	Yes	Yes
F21	Madauros	Rectangle	2/2.4	None	Yes	No
F22	Ordona	Rectangle	2/3.57	No	Yes	Yes
F23	Ostia	Rectangle	2/5.6	Yes	Yes	No
F24	Pompei	Rectangle	2/7	No	Yes	No
F25	Ruscino	Rectangle	2/2.95	No	Yes	Yes
F26	Sabratha	Rectangle	2/2.95	Yes	Yes	Yes
F27	Sala Colonia	Rectangle	2/2.7	No	Yes	Yes
F28	Sarmizegetusa A	Rectangle	2/3.24	Yes	Yes	Yes
F28	Sarmizegetusa B	Rectangle	2/2.46	Yes	Yes	No
F29	Silchester	Rectangle	2/2.2	Yes	Yes	No
F30	Sufetula	Rectangle	2/2.22	Yes	Yes	No
F31	Timgad	Rectangle	2/2.39	Yes	Yes	No
F32	Trier	Rectangle	2/3.86	Yes	Yes	No
F33	Volubilis	Irregular	Irregular	No	No	No
F34	Wroxeter	Rectangle	2/2.24	None	Yes	No
F35	Zadar	Rectangle	2/4	Yes	Yes	No

Source: Authors

6. DISCUSSION

In order to identify the relationships between the various qualitative variables and the numerous corpus study's objects, the recourse to an objective analytical research is necessary. Thus, the multiple correspondence analysis (MCA) has been used and allowed to identify statistically categories and subcategories sharing similar characteristics within the sample of the studied forums (Table B1 and Figures B1-B5). The performance of the multiple correspondences analysis for allowing this kind of outcomes has been proved by several previous studies considering qualitative variables based samples [32-34].

Findings regarding topography showed that most of the squares were built on flat ground (nine 09 Cases) or were optimally located to avoid slopes, as was the case for six (06) forum squares. The latter are located in various natural sites: i) Gightis and Empuries are situated near the Mediterranean coast on a slightly hilly plain, ii) Dougga is nestled on a hill, iii) Sala Colonia also is on a hill overlooking the fertile plain of BouRegreg, iv) Timgad is situated on a narrow plain at the feet of the Aurès Mountains, and v) Sirmizegetusa is situated on a steep rise in the Orastie mountains. In all these cases, the longitudinal axes run parallel to the contour lines.

However, seven (07) cases were built in the same direction of the slope direction. Three of them were built on plateaus: i) Alba Fucens is situated on a plateau surrounded by the Apennins mountains, ii) Madauros, and iii) Sufetula are also built on high plateaus. In some cases, the sites are rather more complex, such as: i) Djemila which is built on a narrow ridge between two valleys, ii) and Glanum, as well, belonging to a cliff and escarpment landscape. In contrast, Baelo Claudia is located on the coast of the Mediterranean Sea. Likewise, Pompei lies in the countryside near the bay of Naples.

In addition, to enhance understanding of the topographic impact on each square, slopes were calculated by measuring the difference in elevation between two points and dividing by the horizontal distance between them [Slope (%) = (Height difference/Horizontal length) × 100].

For each forum, the elevation related data were extracted from Google Earth software.

The forum squares at Alba Fucens, Madauros, Sufetula, Pompeii, Dougga, Empuries, Gigthis and Timgad were built on gentle slopes of no more than 5%. Those located in Baelo Claudia, Djemila, Glanum and Sala Colonia were built on moderate slopes of between 5% and 10%.

The large square of the Sarmizegetusa forum (B) was built on a gentle slope (3.1%) and the smaller square (A) on a moderate slope (5.55%). The squares of Ordona, Ostia and Ruscino were built on combined gentle slopes, while Djemila 2 was built on two slopes, a steep one (13.6%) and another moderate (7.14%).

Regardless of the topographical characteristics of each site, the results make known that the majority of the squares were placed on flat or slightly sloping ground. Even in cases where the orientation of the contour lines was not strictly followed. However, as discussed above, there was no direct influence of topographical features on the squares. With the exception of a few cases where the terrain was greatly uneven that the slope could not be avoided, such as at Djemila, Glanum and Baelo Claudia.

Concisely, no specific trends were observed in terms of topography, perhaps because the forum squares were intended to be flat and were therefore built on the level ground, either naturally or after leveling. In addition, the Romans were accustomed to interacting with the 'site', organizing structures to reflect symbolic and functional priorities [35, 36]. However, the topographical study also needs to include the buildings and the large urban landscape. This requires an overall examination of the urban landscape and an understanding of the effects of volumes and urban scenography.

The outcomes within concern to the relationship to the sun indicate clearly a major trend in favor of diagonal alignments. Effectively, most of the forums are oriented along the ENE/WSW (Q1), NNW/SSE (Q7), or WNW/ESE (Q8) axes. This trend aligns with Vitruvius' emphasis on optimizing sunlight exposure. Similarly, the analyzed data suggests a deliberate consideration of wind direction in forum design. This also attests to the respect for Vitruvian principles for urban planning that harmonize with environmental conditions [5].

Apart from eleven (11) cases, most of the studied forums are positioned diagonally to the direction of the prevailing winds.

The first group consist of (6) cases: i) two of them (Colonia Ulpia Traiana and Lugdunum) are located in an Oceanic Climate, humid temperate climate (Cfb) [37, 38], ii) two others (Ordonna, Zadar) are located in a Mediterranean climate (Csa) [39, 40], iii) the Sarmizegetusa forum belongs to the humid continental climate (Dfb) [41], and iv) Leptis Magna's 02 square is located in a region characterized by a semi-arid climate (BSh). Respectively, they are aligned with the: i) warm winds, ii) cold winds and humid winds, iii) humid winds, and iv) humid and hot winds.

The second group includes four (04) cases: i) Cosa and Ostia, located within the Mediterranean climate (Csa) [41], are respectively perpendicular to cold and humid winds, ii) Leptis Magna 1 is perpendicular to hot and humid winds, and iii) Bagacum is situated in an Oceanic Climate (Cfb), it is perpendicular to humid winds [42, 43].

Augusta Raurica is a special case because the square is aligned with the wind's main prevailing direction and is also crossed diagonally and perpendicularly by other less current winds. Basel has an oceanic climate (Cfb), where winds come from several directions [44]. However, its climate is moderate and the winds are varying in such a way they could be cool in summer and dry in winter.

In cases where the wind crosses transversely or longitudinally the forum, it is not easy to determine exactly what impact the wind will have. Really, it should be difficult to demonstrate to what extent it is harmful or beneficial. This is due to the fact that several factors can be involved. For example, Ordona, Zadar and Cosa forums experience all cold, wet winds. However, these cases are characterized by the Mediterranean climate. In this type of climate, cool winds play an important role in refreshing the atmosphere during the summer. On the other hand, there are cases located in areas with a cold temperate climate, such as Colonia Ulpia Traiana, Lugdunum and Bagacum which are exposed to hot winds. This is in line with what the former specialists in the study of climate in architecture. Olgyay and Olgyay [45] pointed out yet and recommended that in cold temperate climates, cold winds should be avoided as much as possible, but in warm Mediterranean climates, advantage should be taken from cool winds and sea breezes [45].

Sometimes, under severe climates, winds cannot be avoided when they come from several directions, as in Leptis Magna. The latter is located in a rather harsh climate between the sea and the desert and is exposed to many hot, humid and cold winds [46]. Sarmizegetusa is another example of a harsh climate influenced by altitude and mountainous terrain, characterized by harsh winters and seasonal contrasts.

Most of the study corpus' forums are located within areas with favorable sunlight exposure and minimal wind impact. While it remains uncertain whether these choices were explicitly aimed at controlling climatic factors, the design of these spaces often illustrated optimal and creative solutions in accordance with the local conditions. This adaptability highlights the ingenuity of the Roman planners in balancing practical, aesthetic, and environmental considerations in the forum design process.

In relation to Vitruvius' recommendations regarding the location and shape of forums, it's worth synthesizing by the following (Figure 11): i) Forums respectful of all the Vitruvian criteria (Sabratha, Colonia Ulpia Traiana, Augusta Raurica, Augusta Emerita 1 and even Augusta Emerita 2). It should be noted that the Glanum, Madauros and Worxter cases comply with Vitruvian criteria and are located in the centre of the urban fabric, but there is no sufficient information as to whether or not they are located regarding the intersection of the Cardo and Decumanus, ii) Few contrasting cases of forums not fulfilling any of the Vitruvian criteria such as those of Dougga and Volubilis, iii) Several cases that partially meet his criteria such as the squares of Bulla Regia, Gigthis, Leptis Magna II, Ordona, Ruscino, Sala Colonia, which respect Vitruvius' recommendations in terms of shape and proportion, but not in terms of location within the urban fabric. The cases of Bagacum and Lugdunum meet the criteria of shape and proportion, but there is no precise information on their locations, iv) Numerous forums that meet some of his recommendations particularly in terms of location and shape but are not in respect with the ⅔ rule alike those of Alba Fucens, Baelo, Claudia, Cosa, Djemila 1, Ostia, Sarmizegetusa, Silchester, Empuries, Sufetula, Timgad, Zadar and Trier, v) Many cases, such as Leptis Magna 1, Hippo Regius, Banasa, and even Djemila 2, regardless of the Vitruvian criteria, with the exception of the location criteria alone.

It should be pointed out that in terms of integration into the urban grid. Overall, 21 forums in the corpus align with Vitruvius' recommendation. The outcomes highlight that the greatest number of forums were placed at the intersection of the two main axes, in accordance with Vitruvius' principles. Others, however, were positioned horizontally or vertically along the Decumanus, demonstrating some flexibility in their alignment. It must also be underlined that three forums located in coastal cities, Zadar, Leptis Magna, and Sabratha, were situated near the sea. In Book I, Chapter 06 of his treatise, Vitruvius recommended that markets in coastal cities should be located near the port, a principle that appears to be extended

to the forums of these cities. Additionally, in cities like Djemila and Augusta Emerita, where more than one forum exists, the positioning of secondary forums is justified, further reflecting thoughtful urban planning.

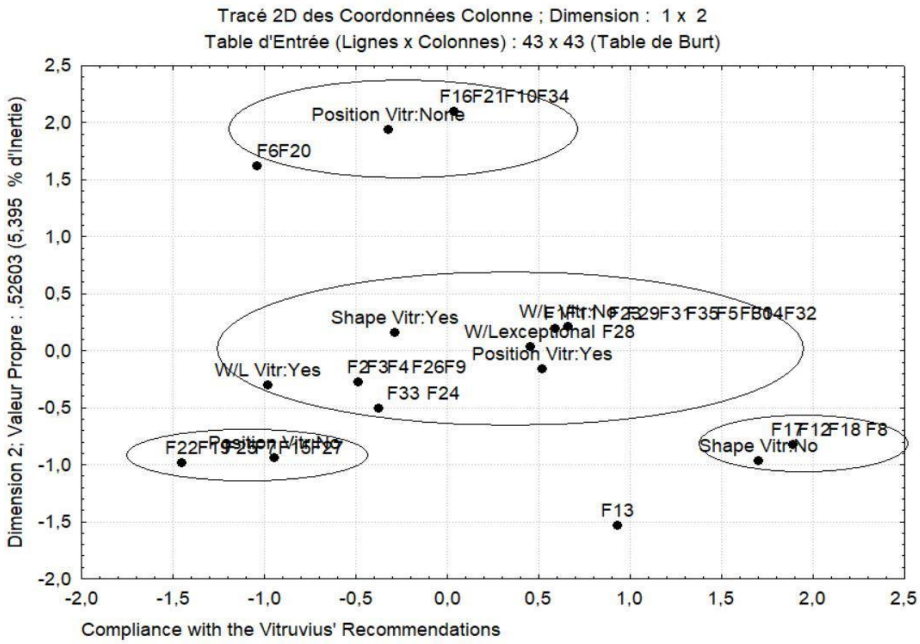

Figure 11. Statistical analysis of the conformity of forums to Vitruvius criteria
Source: Authors

7. CONCLUSION

This research falls within the framework of studies that aim to draw lessons from ancient civilizations. Studying the Romans' urban planning skills and their ability to adapt to the natural environment can contribute to shaping innovative solutions related to sustainable architecture.

This study has examined the design and placement of Roman forums and to what extent they consider the climatic, topographical, and urban planning principles as they were established by Vitruvius as well as how they are revealed by the field itself. This research works aims to the ingenuity of Roman urban design in terms of adaptability to various geographical contexts.

The outcomes demonstrate that Roman planners adhered to Vitruvian principles regarding the placement of forums at key intersections within the urban grid as well as the consideration of the prevailing winds and the sunlight exposure issues. However, variations were observed, reflecting the flexibility of Roman design in adapting to local conditions. For example, while many forums followed the prescribed length-to-width ratio, others deviated due to specific topographical constraints or local needs. This is also illustrated by the case of coastal cities' forums that Roman planners associated with the practicalities of port access hence reinterpreting Vitruvius' principles in order to adapt them to the place 's particularities.

The study also underscores the importance of diagonal alignments in solar orientation, a recurring trend across most of the analyzed forums. These orientations, favoring axes like ENE/WSW, NNW/SSE, and WNW/ESE, illustrate a deliberate strategy to optimize sunlight exposure. Likewise, wind direction played a crucial role in forum design, with many cases aligning obliquely to prevailing winds, consistent with Vitruvian recommendations. These appropriate responses to the climatic constraints reveal an advanced understanding of the environmental design long before modern methods. They additionally constitute a consistent teaching of environmental urban design strategies.

In terms of topography, while most forums were designed for flat terrain, Roman planners exhibited remarkable ingenuity in using natural features as they could. However, this research has certain limitations, such as the extent of detail, the archaeological character of the studied cases and the changeable nature of the climatic factors. Further research work should extend the study corpus to include other sites located in the middle-east and/or in Asia Minor, for instance. In addition, the outcomes could also be extended to: i) explore the forums as a complex of buildings and the location of each building in relation to the central open-to-sky square, and ii) the users way of life within these urban spaces in respect of the local climatic specificities varying both temporally and spatially.

Finally, it should also be interesting to go beyond the current 3D volumetric models virtually reconstructed to the development of a human scale based imaginary scenography illustrating the ambiences within these structuring urban spaces of the Roman cities.

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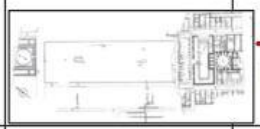
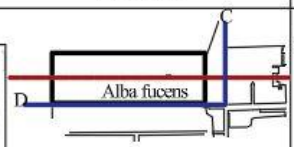
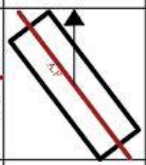
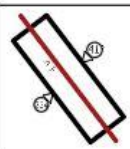
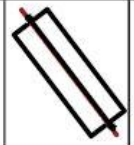
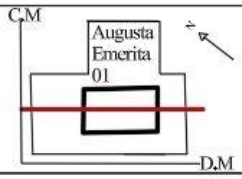
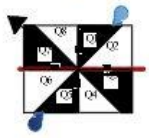
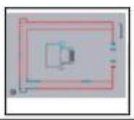
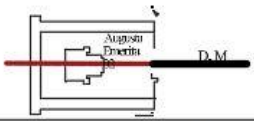
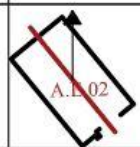
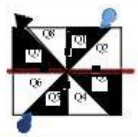
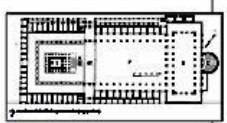
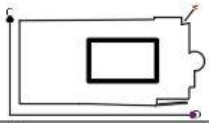
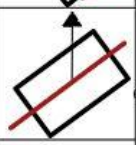
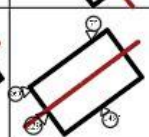
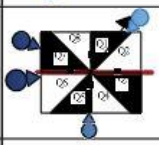
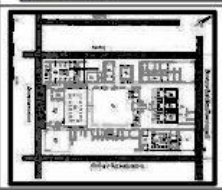
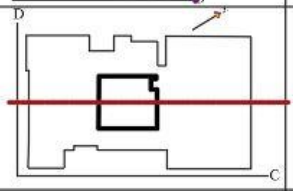
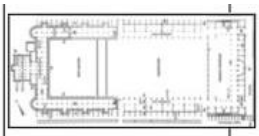
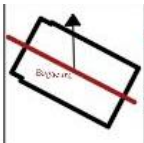
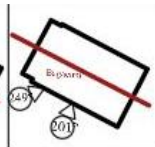
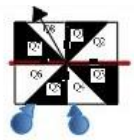
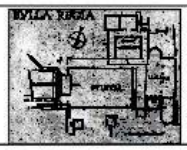
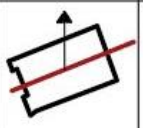
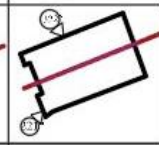
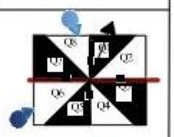
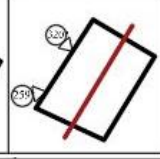
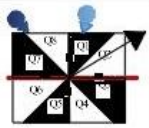
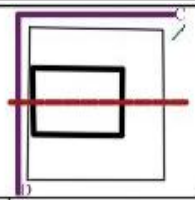
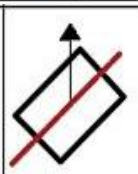
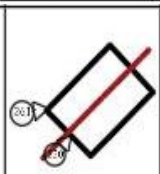
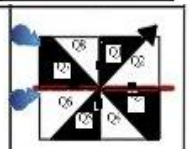
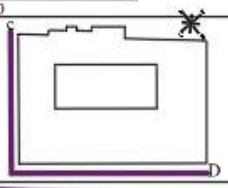
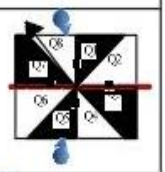
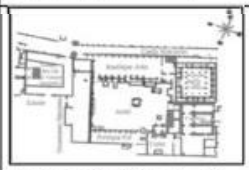
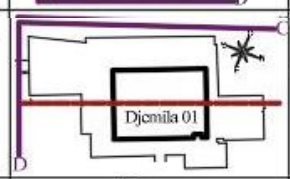
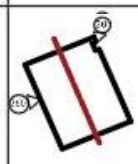
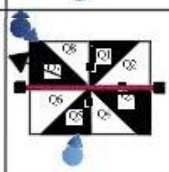
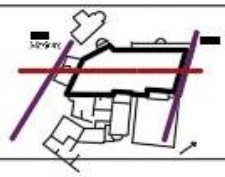
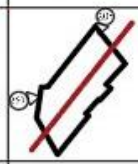
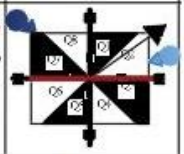
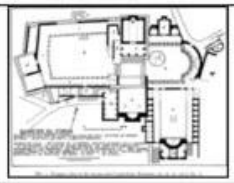
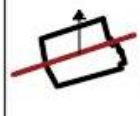
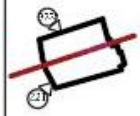
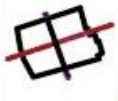
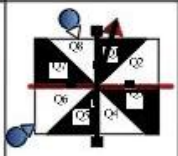
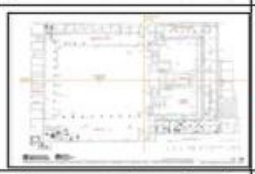
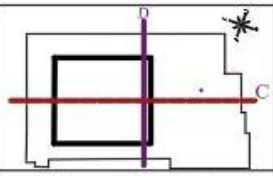
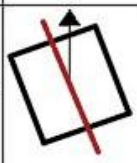
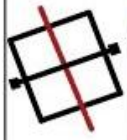
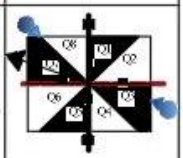
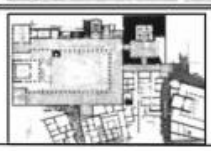
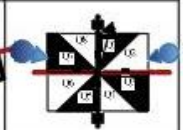
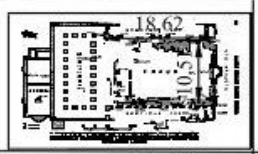
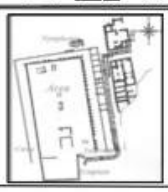
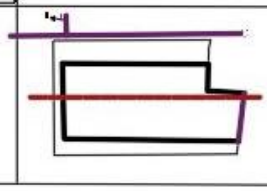
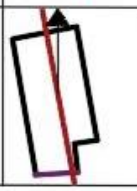
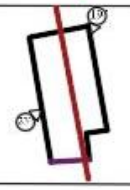
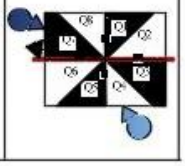
NOMENCLATURE

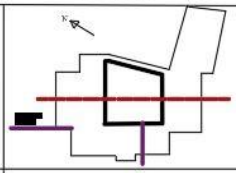
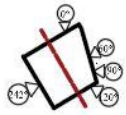
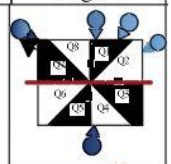
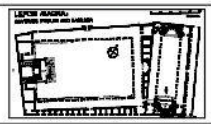
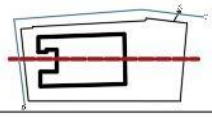
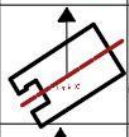
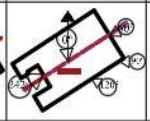
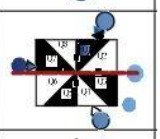
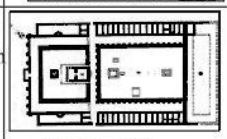
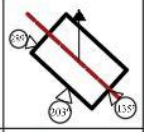
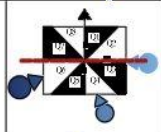
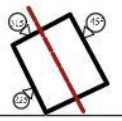
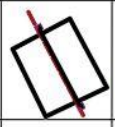
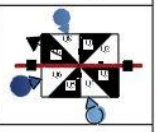
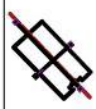
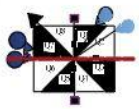
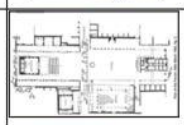
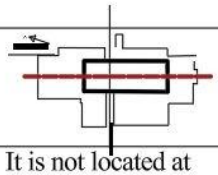
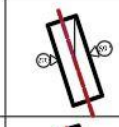
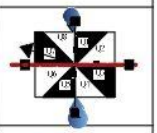
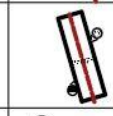
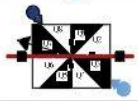
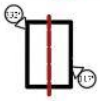
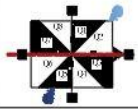
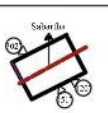
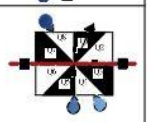
C.P	Construction period
A.I	Angle of incidence
W.D	Wind direction
TOP	Topography
W/L	Weigh /Length
A	Africa
E	Europe
Conv	Convex
Conc	Concave
Pl	Parallel
Pr	Perpendicular
Q	Quadrant
F	Forum
Vitr	Vitruvius
Ds	Direction of the slope
LA	Longitudinal axis
Cl	Contour lines

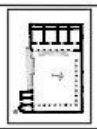
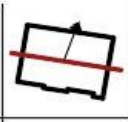
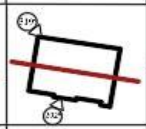
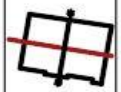
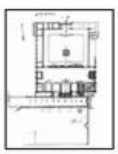
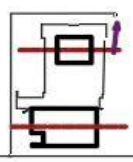
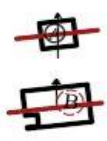
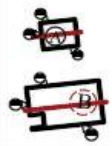
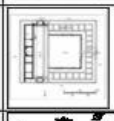
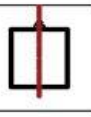
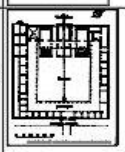
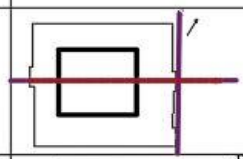
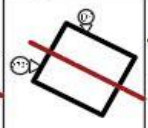
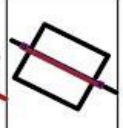
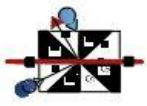
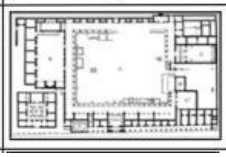
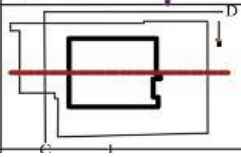
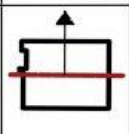
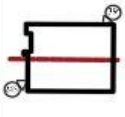
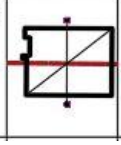
APPENDIX

Appendix A: The study corpus

	Forum	Illustration	Location	Orientation	Wind	Topography	Summary Diagram
01	Alba Fucens						
02	Augusta Emerita (Colony forum)					None	
03	Augusta Emerita(The provincial Forum)					None	
04	Augusta Raurica					None	
05	Baelo Claudia						

06	Bagacum nerviorum		Lack of information			None	
07	Bulla Regia		It is not located at the intersection of main street			Flat Terrain	
08	Colonia Iulia Valentia Banasa					Flat Terrain	
09	Colonia Ulpia Triana					None	
10	Cosa					Flat Terrain	
11	Djemila 01						
12	Djemila 02						
13	Dougga		It is not located at the intersection of main street				
14	Empúries						
15	Gightis		It is not located at the intersection of main street				
16	Glanum		It is not located at the intersection of main street				
17	Hippo Regius					Flat Terrain	

	Forum	Illustration	Location	Orientation	Wind	Topography	Summary Diagram
18	Leptis Magna 01					Flat Terrain	
19	Leptis Magna 02					Flat Terrain	
20	Lugdunum Convenarum		Lack of information			None	
21	Madauros		Lack of information				
22	Ordona		It is not located at the intersection of main street				
23	Ostia						
24	Pompei		It is not located at the intersection of main street				
25	Ruscino		It is not located at the intersection of main street				
26	Sabratha		It is not located at the intersection of main street				

	Forum	Illustration	Location	Orientation	Wind	Topography	Summary Diagram
27	Sala Colonia		Lack of information				
28	Sarmizeg--etuza						
29	Silchester		Lack of information			None	
30	Sufetula						
31	Timgad						

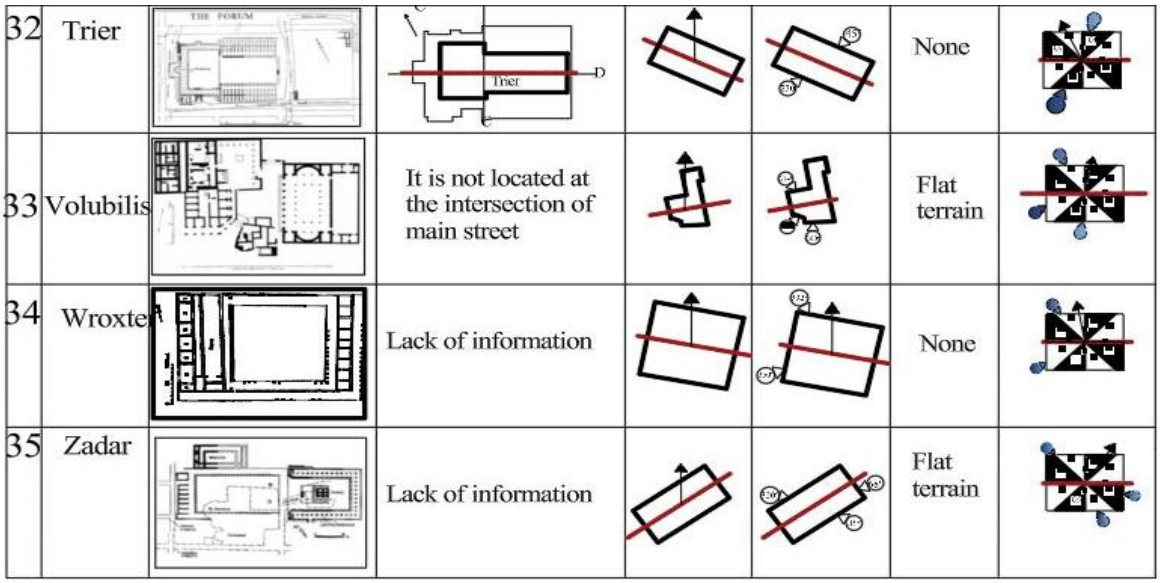


Figure A1. Forums corpus details

Appendix B: Coding and results of statistical analysis

Table B1. The coded results used to generate analyses with statistical software

Forum	Name	City	Continent	Era	Crossing	Solar O	Wind	Top
F1	Alba Fucens	Aquila	E	Per3	Yes	Q7	C2	Pl
F2	Augusta Emerita 01	Mérida	E	Per3	Yes	Q7	C2	None
F3	Augusta Emerita 02	Mérida	E	Per4	No	Q7	C2	None
F4	Augusta Raurica	Basel	E	Per3	Yes	Q1	C4	None
F5	Baelo Claudia	Bolonia	E	Per3	Yes	Q2	C2	Pl
F6	Bagacum Nerviorum	Bavay	E	Per3	None	Q8	C3	None
F7	Bulla Regia	Jendouba	A	Per3	No	Q1	C2	No Slope
F8	Colonia Ulia Valentia Banasa	Left Bank of Sebou River	A	Per5	Yes	Q2	C2	No Slope
F9	Colonia Ulpia Triana	Xanten	E	Per4	Yes	Q1	C1	None
F10	Cosa	Ansedonia	E	Per1	Yes	Q8	C3	No Slope
F11	Djemila 01	Sétif	A	Per3	Yes	Q7	C2	Pl
F12	Djemila 02	Sétif	A	Per6	No	Q2	C2	Conv/Conc
F13	Dougga	Téboursouk	A	Per4	No	Q1	C2	Pr
F14	Empuries	Girona	E	Per3	Yes	Q7	C2	Pr
F15	Gigthis	Médenine	A	Per5	No	Q1	C2	Pr
F16	Glanum	Saint Rémy	E	Per2	None	Q7	C2	Pl
F17	Hippo Regius	Annaba	A	Per4	Yes	Q7	C2	No Slope
F18	Leptis Magna 01	Khoms	A	Per3	No	Q7	C3	No Slope
F19	Leptis Magna 02	Khoms	A	Per6	No	Q1	C1	No Slope
F20	Lugdunum Convenarum	Saint Bertrand de Comminges	E	Per3	None	Q8	C1	None
F21	Madauros	Souk Ahras	A	Per4	None	Q7	C2	Pl
F22	Ordona	Foggia	E	Per3	No	Q7	C1	Conv/Conc
F23	Ostia	Ostia	E	Per1	Yes	Q7	C3	Conv/Conc
F24	Pompei	Naples	E	Per2	No	Q7	C2	Pl
F25	Ruscino	Perpignan	E	Per3	No	Pl	C2	Conv/Conc
F26	Sabratha	Tripoli	A	Per4	No	Q1	C2	No Slope
F27	Sala Colonia	Chellah	A	Per5	No	Q1	C2	Pr
F28	Sarmizegetusa	Hunedoara	E	Per5	Yes	Q1	C1	Pr
F29	Silchester	Hamsphire	E	Per3	Yes	Pl	C2	None
F30	Sufetula	Sbeitla	A	Per4	Yes	Q8	C2	Pl
F31	Timgad	Batna	A	Per4	Yes	Pr	C2	Pr
F32	Trier	Trier	E	Per3	Yes	Q8	C2	None
F33	Volubilis	Walili	A	Per5	No	Q1	C2	No Slope
F34	Wroxeter	Shrosphire	E	Per4	None	Q8	C2	None
F35	Zadar	Zadar	E	Per3	None	Q1	C1	No Slope

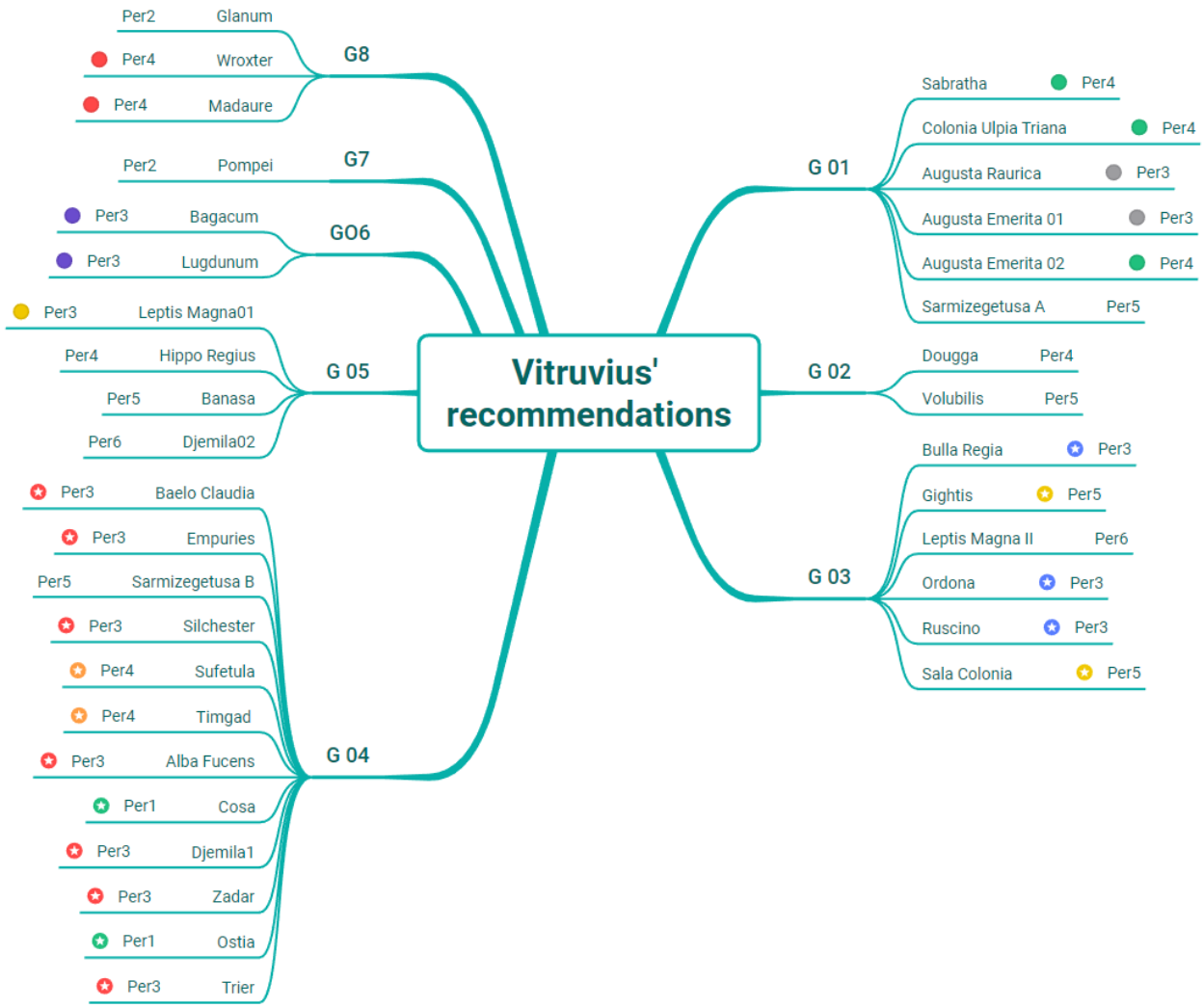


Figure B1. Categorization of forums according to the criteria of Vitruvius
Source: Authors

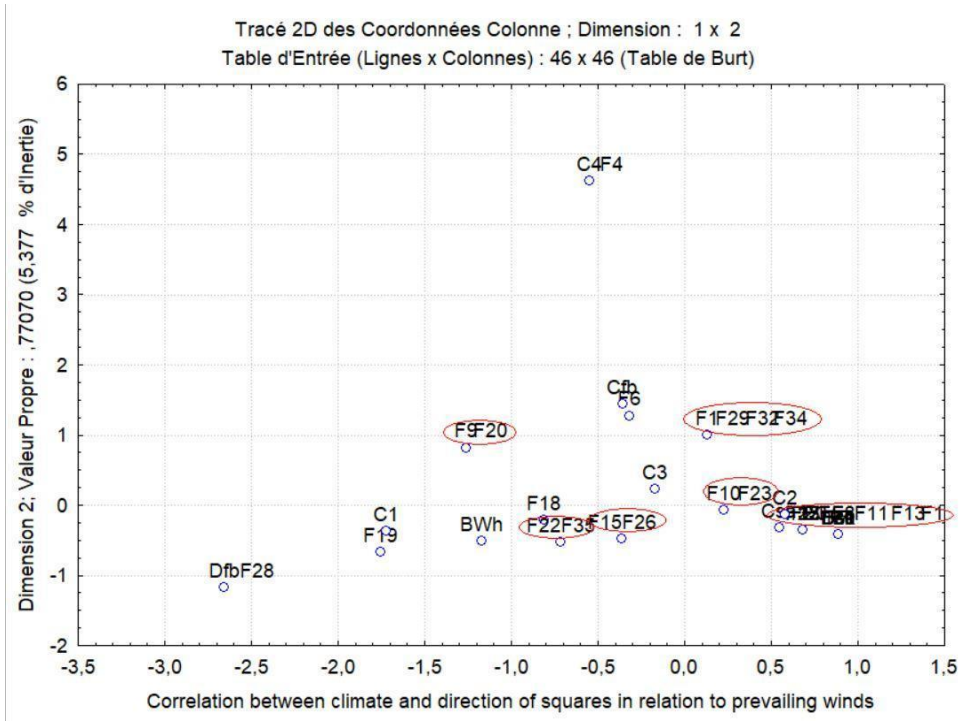


Figure B2. Correlation between climate and direction of squares in relation to prevailing winds
Source: Authors

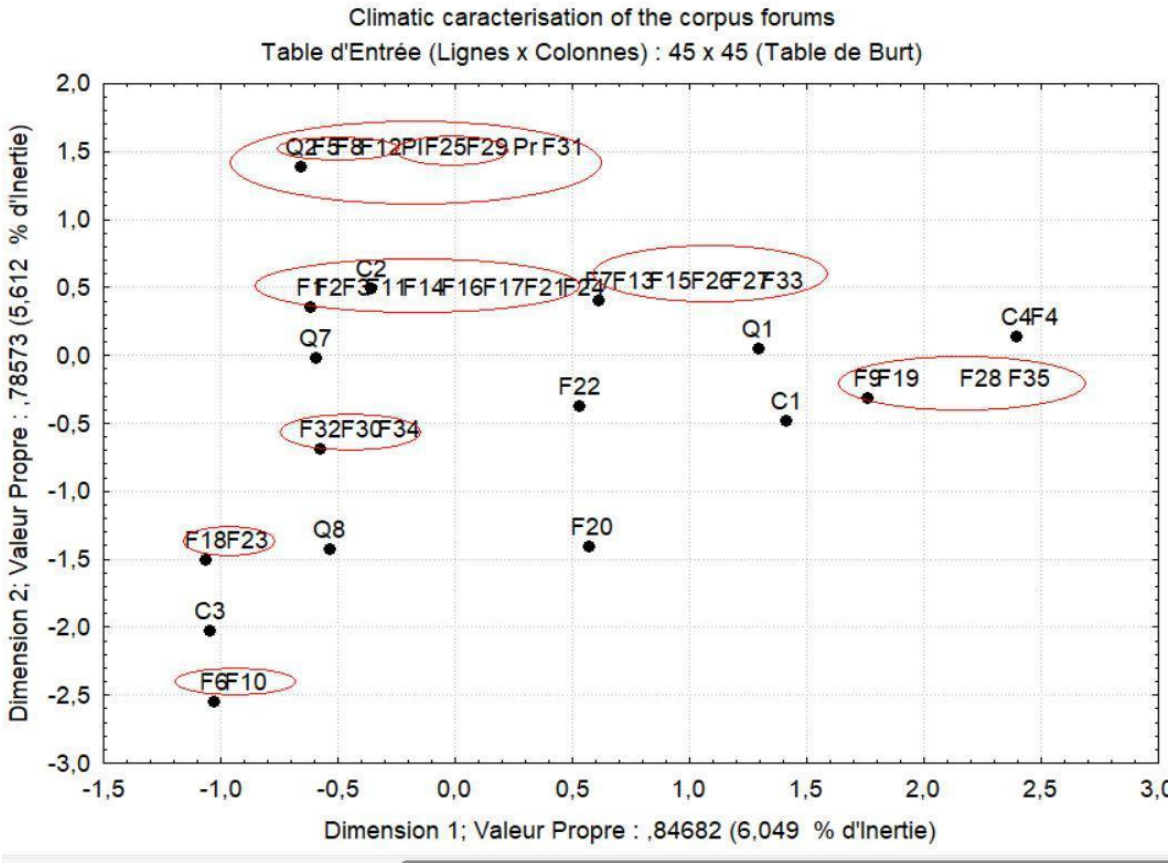


Figure B3. Climatic characterization of the corpus forums
Source: Authors

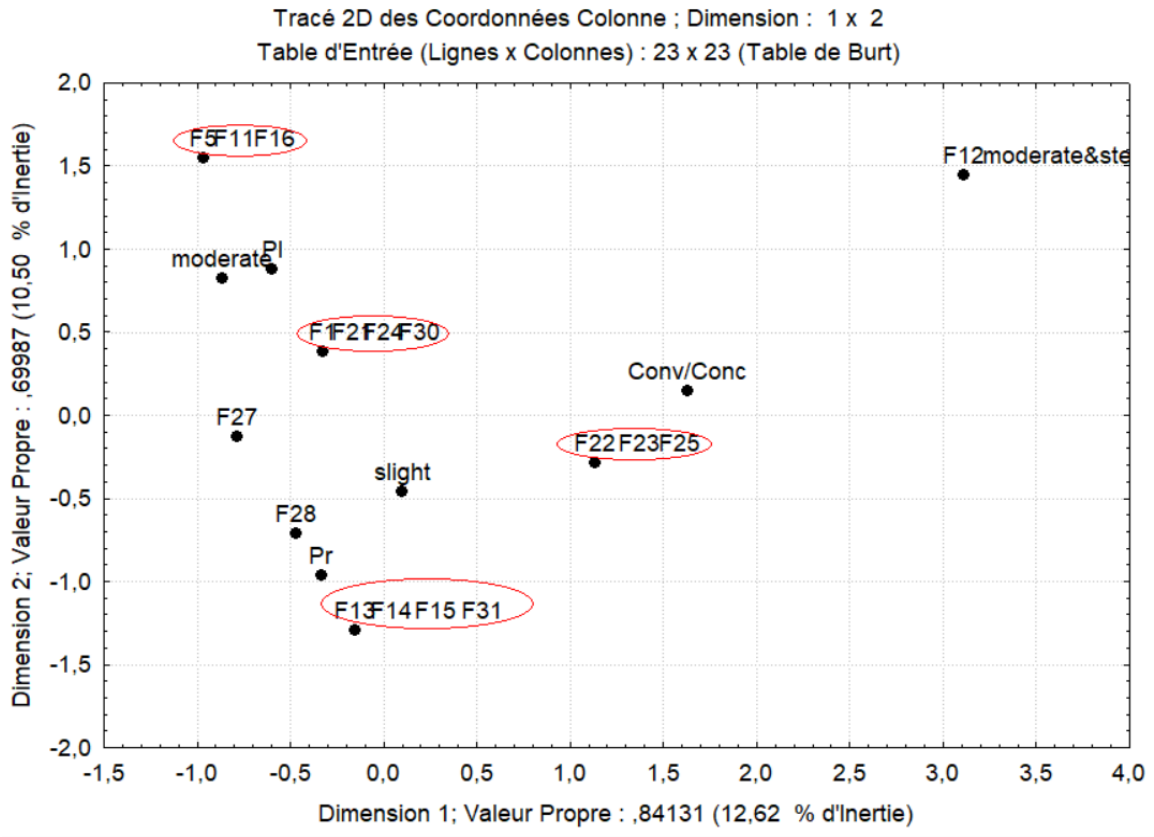


Figure B4. Topographic characterization of the corpus forums
Source: Authors

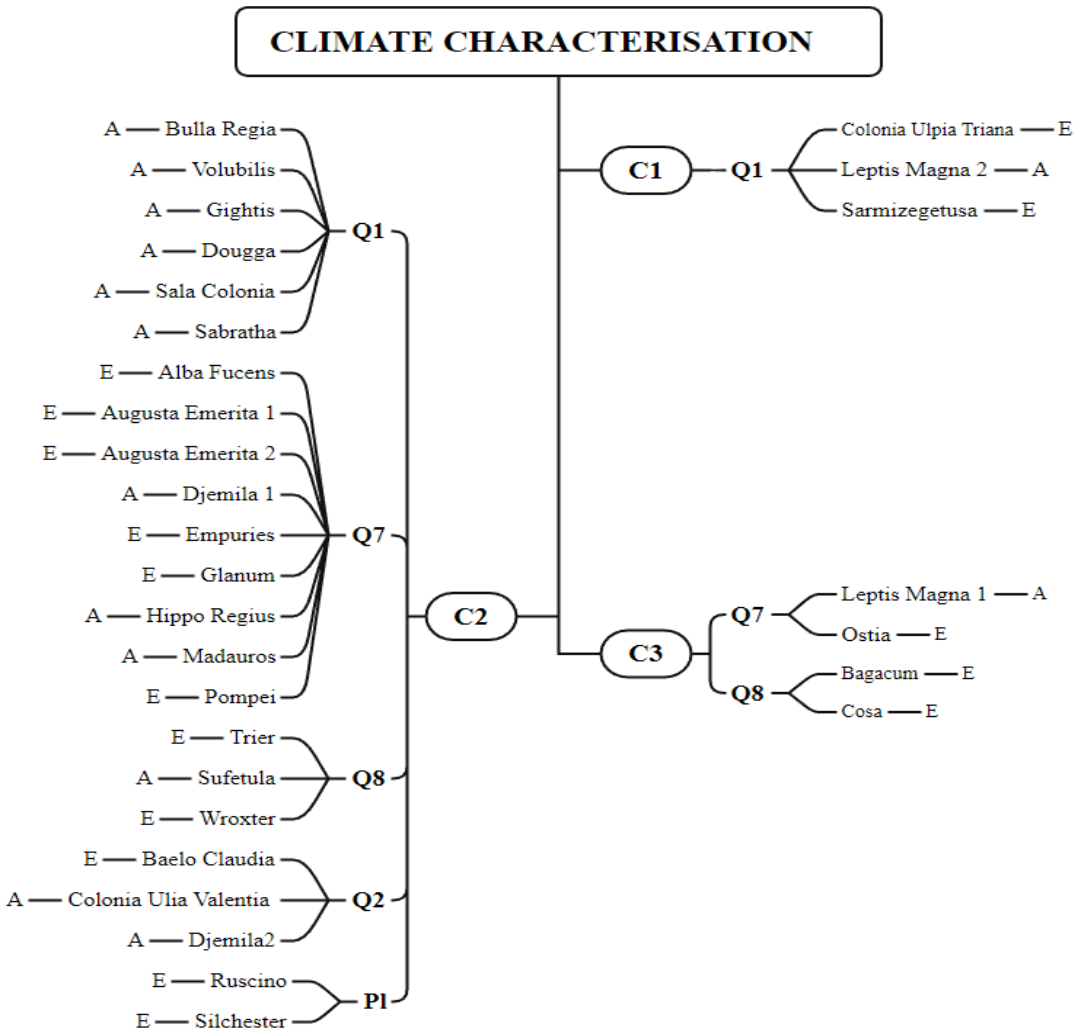


Figure B5. Diagram showing forum groups according to the wind and sun criteria
Source: Authors