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SPATIAL ANALYSIS AS A TOOL FOR FIELD RESEARCH. CASE-STUDIES IN PROGRESS FOR URBAN AND LANDSCAPE CONTEXTS

1. Introduction

This paper focuses on interpretation of historical landscape both at urban and territorial scale. It comes from an ongoing research, so the discussed processes and outcomes should be considered preliminary. Analysed case studies concern the evolution of a specific settlement or the detection of potential location for archaeological sites, above all when historical and archaeological data are not available (Arnoldus-Huyzendveld, Citter, Pizziolo 2016; Verhagen 2018; Verhagen, Whitley 2020). All the discussed instances have a similar methodological setting. A GIS dataset has been created and used to carry out spatial analyses; collected information come from different sources (above all excavations, historical maps, toponymy, medieval documents) and were integrated with geomorphological data to analyse settlement patterns and their diachronic relationship with environmental factors.

2. Urban contexts: backwards from the late(st) morphology

This section concerns urban contexts and the examined cases are Monselice (Brogiolo, Chavarria 2017, also for bibliography about previous researches) and *Salapia*-Salpi (De Venuto, Goffredo, Totten 2021). The first was a fortified early medieval settlement in the Euganean Hills (Veneto) and still exists today. The latter, Salpi, developed as a city in the 11th century and was abandoned during the early modern period. It occupied an artificial hill, superimposed on the western part of *Salapia*, a Roman city refunded in the 1st century BCE, along a coastal lagoon in Northern Apulia.

The object of the study is the hypothetical reconstruction of the medieval city (Monselice: Cardone 2017; Salpi: Goffredo, Cardone 2021) starting from the late urban morphology (Cardone, Giacomello 2018, 129-130). The analysis concerns the parcels extracted from the oldest geometric cadastre for Monselice (1810) and from the magnetic survey for *Salapia*-Salpi.

2.1 *Density of parcels*

Kernel Density Estimation (KDE) has been carried out to evaluate concentration/fragmentation of parcels. Lines (corresponding to boundaries

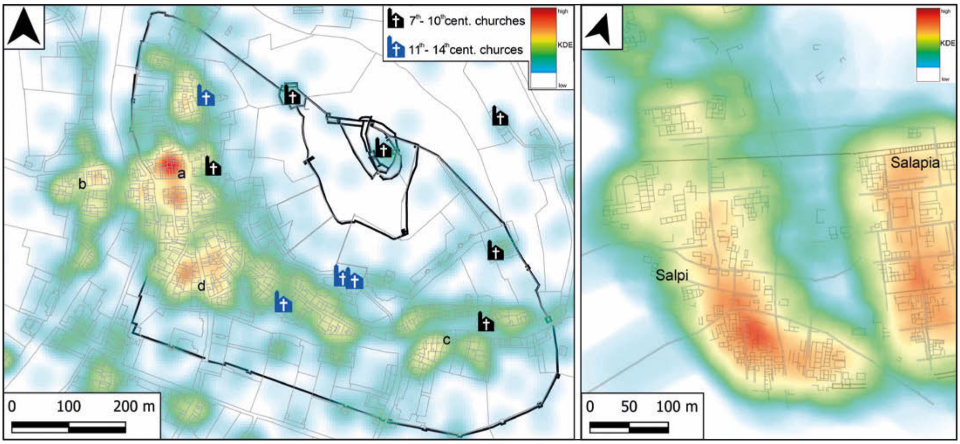

Fig. 1 – KDE in Monselice (left, based on centroids) and Salpi (right, based on lines).

of parcels) and points (centroids of parcels) density were estimated; no hierarchy of parcels has been assigned (so features do not have difference in weight) because very poor information about their functions are available. Density estimation highlights the difference between the northern and the southern districts of Salpi, according to the morphology shown by magnetic survey (Fig. 1). The southern district appears as a highly fragmented, residential area; excavations confirmed a gradual, intense occupation of empty spaces by dwellings during 13th and 14th centuries and their sizes suggest a planned subdivision (Goffredo, Cardone 2021, 306-309).

Instead, KDE returns a clustering structure in Monselice, represented by various concentrations, above all surrounding early medieval or 11-13th century churches. This result shows that older churches played a role as attractor of built-up lots and suggests a development of the city in the plane area by clusters, not still totally fused in 19th century. The concentration related to the main square (Fig. 1a) is expected for many reasons: that area was already occupied by a sector of early medieval Lombard settlement and the S. Paolo's church; it became the commercial (as the later Insula district; Fig. 1b) and administrative core of medieval and modern city. The eastern concentration (Fig. 1c) is likely a result of a long-term process: a local, isolated settlement near the S. Martino's church is hypothesized from 10th century documents, subsequently absorbed in the city. The southern concentration (Fig. 1d) is likely related to a node of viability rather than medieval churches; indeed, even if we cannot rule out a later development, converging roads could be a trace of a forced access (a bridge or a gate?) prior to Late medieval walls.

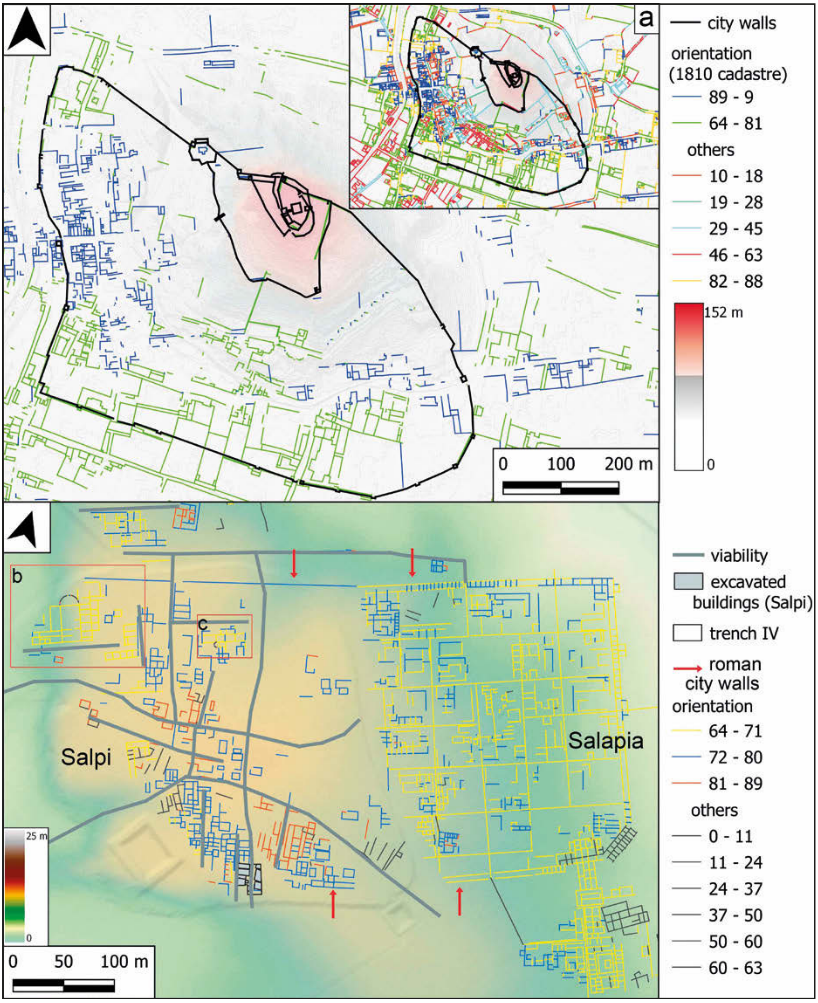

Fig. 2 – Main orientations of the urban fabric in Monselice (top) and Salpi (bottom).

2.2 *Orientation*

Orientation estimates have been carried out in order to find the relationship between the elements of the city (blocks of parcels, infrastructures, environmental features) and possibly their sequence. The analysis has been applied to lines (boundaries of parcels, buildings, rivers and canals, roads); just segments longer than 2 m were computed to obtain more reliable results. Tools used are EasyCalculate10 (ArcMap Esri 10.6); Azimuth in Field Calculator

(QGIS 3.16, 3.22); MorphAl, a plugin set for Alpage Project on Paris (https://alpage.huma-num.fr/gis-plugin/). Finally, orientation was reclassed to 0°-89° to group orthogonal lines as a single value; the range of values was obtained combining data from archaeological structures and Jenks natural breaks optimization. Used ranges group about 10°, but the high variability in urban contexts prevents the use of more narrow ones.

Two factors are affecting the orientation of parcels in Monselice. Firstly, orientation depends on geomorphology; values from NW to SE correspond to local slope direction, related to the Rocca (Fig. 2a). So, it prevents a general link between orientation and dating of parcels. Secondly, we cannot rule out chronological factors, because the main ranges are related to structured arrangements (Fig. 2). 89°-9° orientation interests an early medieval, settled area W to the Rocca, so this orientation could represent a previous arrangement which influenced the medieval phases (Brigand 2015 for a synthesis about the dynamics of transformation and transmission of the parcelling). 64°-81° orientation characterizes southern walls (13th-14th centuries) and nearby parcels, so we can easily suppose that it's a late medieval layout, when larger city walls were built. Dating of existing historical buildings is compatible with these hypotheses.

Different processes concern *Salapia* and Salpi. Obviously, the main orientation (64°-71°) corresponds to the arrangement of the Roman city (*Salapia*) and the total length of its lines is greater than the sum of other ones. Nevertheless, it is remarkable that some areas of the medieval city, Salpi, show the Roman orientation as well. Two districts (the western one corresponds likely to the cathedral) preserve the main orientation (Figs. 2b, 2c), while the central sector is oriented as the western sector of Roman walls (72°-80°); micro-orographic system caused this slight divergence of walls. We can suppose a strong preservation of (late)Roman layouts; this entails that the Roman city was not cancelled by the medieval artificial rise of the hill and excavations confirm a quite thin thickness of the 11th century fill (Goffredo 2021, fig. 12). Nevertheless, we cannot rule out a secondary, destruction hypothesis; the (late)Roman structures partially remerged after a levelling carried out during the last decades in some areas of the hill.

3. Dynamics in the historic landscape

Other notes are related to landscape scale; they concern the Northern Apulia and preliminary presented analyses will be further supplemented. They aim to analyse the landscape patterns in Daunian Mountains and Gargano, focusing on the post-classical period. The initial steps have been the detection of landform and high flood risk/marsh areas to determine the first parameters for favourable locations of ancient settlement (Citter, Patacchini 2017 and

Citter 2019 as a model for these applications to archaeological contexts). QGIS 3.22.0 tools (including Grass and Saga) have been tested to calculate landform (Topographical Index-TPI: Weiss 2001; Geomorphon: Jasiewicz, Stepinski 2013) and water accumulation (Wetness Index-TWI: Mattivi *et al.* 2019). Unfortunately, just 10/20 m DTMs are available for the whole examined area.

3.1 *Landform*

The first case study concerns the area between Daunians mountains and Lucera (Foggia). Slightly raised plateaux delimited by fluvial incisions mainly characterize this territory. Alluvial, terraced deposits covering sub-apennine clays constitute the upper part of plateaux and higher hills; they result intensely occupied. Basic settlement choices are quite evident, based on the known archaeological sites. In the Middle Age, cities occupy highest hills mainly as requirements for defense and control; quite the opposite, our knowledge of minor sites is still scanty. So, the first aim was the detection of possible locations for rural sites known from sources (usually indicated as "casale", an open and not independent settlement).

Used tools are TPI (10 ranges from two maps with different radium) and Geomorphon (Fig. 3a-b). A selection of highly positive values from TPI has been considered because, even if it is not formally corrected, it results useful to accurately detect low-raised plateau, otherwise reclassified as part of wide, flat areas. Slight difference in heights complicates the setting of starting parameters.

The selection of raised elements (Fig. 3c) mainly corresponds to elongated uplands; these are hills similar to those on which Montecorvino and Tertiveri stood (cities likely founded in the early 11th century: Favia, Giuliani 2022). This selection accurately includes known medieval sites (both cited cities and sites for which we know location from sources, e.g. Guardiola). Some small reliefs stand out as potential abandoned settlements (as they share features with other archeological sites, i.e. flat summit, terraced levels, isolated location) and will be verified by aerial and field survey. Moreover, a series of low but pronounced reliefs between Montecorvino and Lucera is comprised within this selection; some dependencies of Montecorvino (the casale of S. Lorenzo de Rivo Morto and two estates related to churches of S. Paolo and S. Nicola, cited in documents from 13th century; Martin, Noyé 1991) were likely located in that area (Fig. 3d), as suggested by historical cartography and toponymy.

We must point out that traditional sources do not provide enough data to exactly locate these settlements; described boundaries of the estates in these documents are very difficult to be georeferenced, while modern maps just report some toponyms without the location of the medieval settlements. TPI

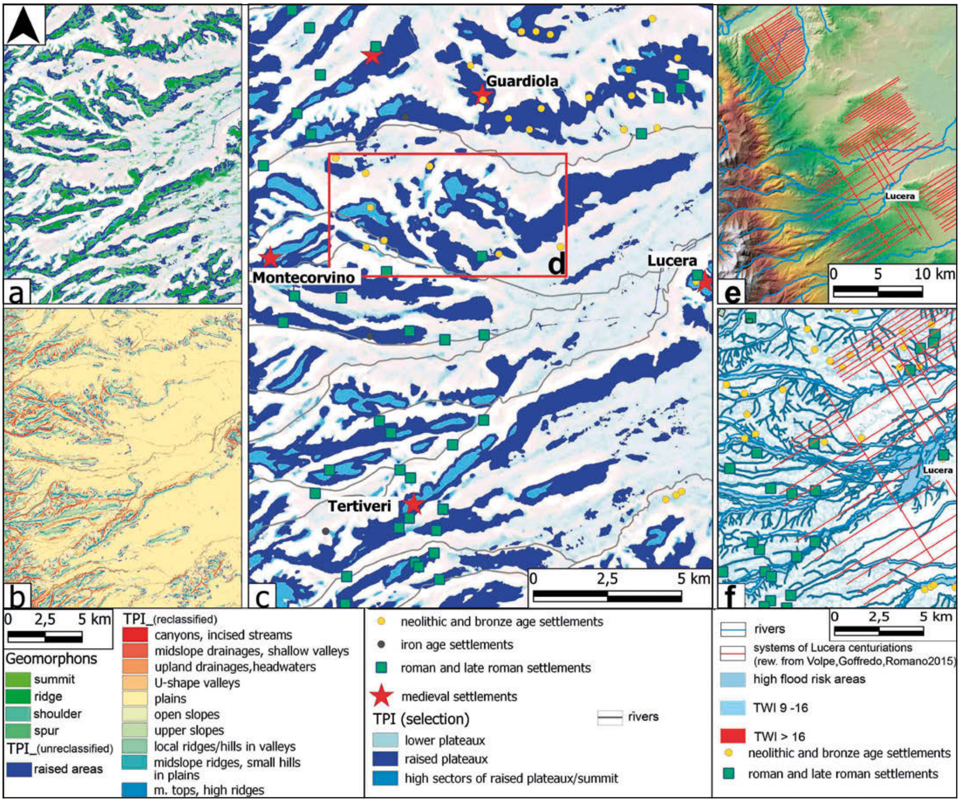

Fig. 3 – The area between Lucera and Daunian mountains: landform (a: raised zones from selection of geomorphons and unreclassified TPI; b: reclassified TPI); settlement pattern (c) and the area of the reliefs between Montecorvino and Lucera (d); centuriations (e) and hydrologic system (f).

instead helps us to overcome the lack of traditional sources and it is useful to narrow down searches in the wide space deduced from maps and toponyms. This process allows us to identify specific areas to be verified by field survey: TPI defined an area of about 148 ha within a space of about 2765 ha extracted from toponymy and cartography. Moreover, the ongoing publication of surveys carried out by Ager Lucerinus Project (Marchi, Muntoni 2018) will add new information for this area and for comparison between spatial analysis and archaeological data.

3.2 *Hydrographic network*

TWI index allows a further evaluation of potential areas for settlement. Discussed examples, however, take into account recent alterations of landform

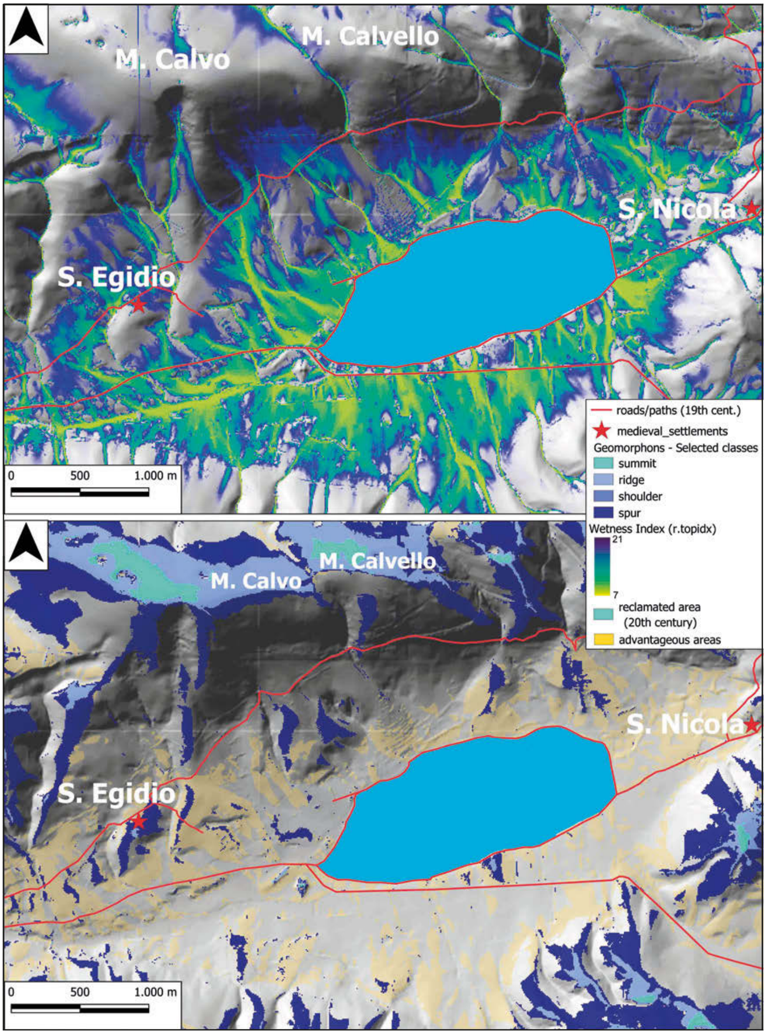

Fig. 4 – The area of S. Egidio: TWI (top) and favorable areas (bottom) for the medieval settlement (raised or low slope/wetness areas).

and reclamations, in order to provide an interpretation not exclusively applied on current DTM. Some examples concern the Gargano promontory. In the central area medieval settlements are mainly located along the EW fault that crosses the massif. They often occupy the upper slope of this valley system, where a dense network of torrential streams flows (locally called *lame*) and caused flood phenomena and local swamps still in 19th century. So, the

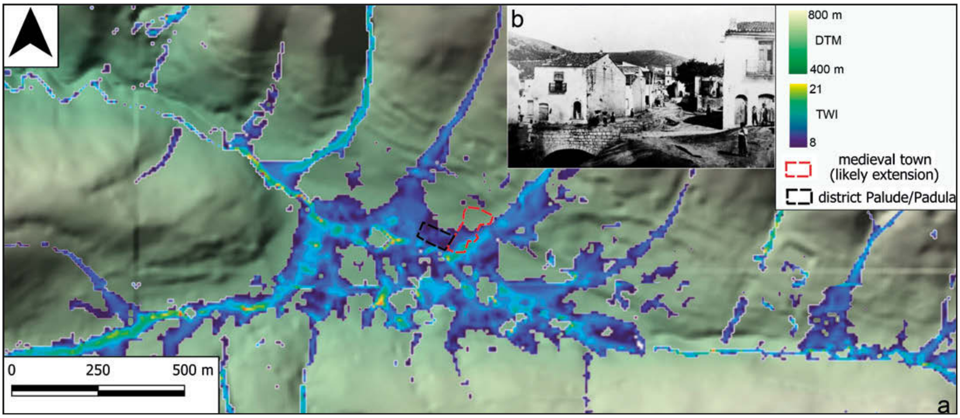

Fig. 5 – a) S. Marco in Lamis, TWI ; b) unpreserved bridges in *via Lungo Iana* (Tardio 2010, 6).

reconstruction of hydrological network is a very important factor to detect unsuitable portions of territory and to create cost surfaces.

At first we consider the area of S. Egidio (Fig. 4) near S. Giovanni Rotondo, where a lake (*pantanum S. Egidii*, more likely a mere or a large pond; Martin 1994) occupied a carsic depression, produced by a sinkhole and pull-apart movements; it was reclaimed at the beginning of last century. In the late 11th century the S. Egidio monastery was built on a spur facing the lake. A hamlet and agricultural fields developed there between the 12th and 13th centuries, but their exact location is unknown. The overlapping of TPI and TWI maps help us to detect potential areas for these elements, because high hydrological risk and geomorphological instability affected this region. Indeed, the runoff waters coming from northern reliefs gather there and documents probably imply a formation of the lake during 11-12th century, while its surface was probably frequented before the Iron Age (Monaco 2017, fig. 3). So, a considered favorable area (Fig. 4) consists of raised zones nearby the monastery, selected by TPI, and zones characterized by low dampness (to avoid hydrological risk) and low slope (otherwise unsuitable for farming use); slope <20% and TWI <7 have been considered in the final raster.

A short consideration concerns S. Marco in Lamis (Fig. 5). The city is reported since the early 11th century; it developed on the northern slope of a valley, while the bottom part was interested by a river (Iana) and a swamp produced by the torrential rivers (locally *lame*) that cut through the slope; they both were buried in the last two centuries. In that sector TWI correctly returns an elonged zone characterized by high values, corresponding to the river, and a wider sector characterized by the accumulation of waters. In these case historical pictures (they report at least two disappeared bridges in the early 20th century; Fig. 5b) and toponymy (the existence of a swamp at the foot of historical center is proved by the toponym "palude" or "padula" for the district facing the lowest sector) provide a validation of TWI results.

3.3 *Notes for the future work*

Other synthetic remarks come from combination of TPI and TWI analysis as a tool to underline different criteria for settlement choises and a delimitation of potential exploited territory in a diachronical, long-term analysis. They concern the ongoing development of previous notes and will be presented shortly. The examined area is between Daunian mountains and Lucera (Fig. 3e-f). Here the neolithic settlements (Hamilton, Whitehouse 2020) mainly occupy the raised plateaux, often their edge overlooking (paleo) fluvial incisions. Moreover, their location implies a significant stability of the geomorphologic landscape in this region. They avoid high-risk flood areas and their location frequently corresponds to very low-TWI (<2, Fig. 3e) spaces delimited by higher TWI values (>9, Fig. 3e). This is a useful criterion to be implemented into a multicriterial predictive research for neolithic sites in this region (already carried out projects are Danese *et al*. 2014; Dufton 2021), above all to balance the distribution of known sites.

They have been mainly detected by cropmarks (where the ditches of the villages cut the local *crusta*, a surface, carbonate layer), but systematic field surveys show a scattered, Neolithic presence even where the aerial photos are less effective. In a later phase, flood risk areas do not strongly affect the distribution of Roman sites, located in the low flat zones in addition to raised terraces; moreover, the cropmarks related to Lucera centuriation (Fig. 3e-f; a synthesis in Volpe, Goffredo, Romano 2015, 475-488) are visible in areas characterised by high TWI values. This wider exploitation of territory is a conceivable consequence of the hydraulic arrangement carried out by the centuriation (Dall'Aglio 2010 for this subject), in addition to a lower weight of the defensive factor.

Finally, TPI allows us a more detailed detection of the framework related to the medieval settlement and to the fortified frontier arranged by the Byzantines in the early 11th century (Favia, Giuliani 2022) in particular. TPI highlights an alignment of ridges as a watershed between Lombard and Byzantine settlements in the 10th-11th century according to written sources. Furthermore, it could suggest an organic planning: the Byzantine cities occupy the reliefs towards the plain; various sites in the highest area (reported starting from the late Middle Ages or the beginning of Modern Age) have a relevant location to this frontier and its crossings places. So, we cannot rule out that these sites have a coeval foundation to the frontier (outposts then developed as settlements?); therefore, the verification of their starting chronology becomes an important research objective.

4. Conclusions

A brief remark concerns an evaluation of patterns by GIS computation; it is not essential for some examined cases (i.e. districts with diverging macro-orientation or reliefs as potential sites, visible in DTM), but the automatic detection enables a work that is difficult to replicate in terms of quality (e.g., the small differences in orientation for Salpi), as well as producing an effective and fast outcome on large areas by comparison with a visual process carried out personally by the researcher.

Moreover, the analysis performed often combines retrogressive and predictive considerations; this depends both on the data available and on being an ongoing work. Available data are not sufficient and suitable to set an accurate, predictive process for most of discussed examples. A case in point concerns examined urban contexts compared to projects about medieval towns in Tuscany (Citter 2012; Gattiglia 2013), for instance. Published excavations in Monselice focused on the Rocca, but not the foothill area (except the zone near S. Paolo) where the medieval town center developed, while there is no previous research in Salpi.

In conclusion, the presented works aim for a dual purpose. Firstly, they intend to highlight key-points for the field research, to define areas «where to concentrate research efforts» (Verhagen 2018, 2) regardless of urban or landscape scale; it concerns above all contexts where traditional sources show a lack of data. Secondly, they aim to propose hypotheses on the diachronic evolution of contexts that cannot be investigated in a complete and exhaustive way, such as the abandoned cities for which a total excavation cannot be achieved.

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ABSTRACT

This paper concerns spatial analysis applied to urban and landscape scale; main aims are the reconstruction of the evolution in a specific settlement and the detecting of potential location for archaeological sites. Spatial analysis takes advantage of a GIS dataset containing different systems of sources (excavations, historical maps, toponymy, medieval documents, geomorphological data). Case studies at urban scale concern Monselice (Veneto) and Salpi (Northern Apulia). A retrogressive analysis aims to reconstruct the medieval urban fabric starting from the late morphology of these cities, using the modern cadastre or a magnetic survey. The Kernel Density Estimation and the evaluation of parcels orientation have been applied for a comprehension of the urban structure. At territorial scale, case studies regard two sectors of Northern Apulia. First step of these ongoing researches concerns the detection of landform (by TPI-Topographical Index, Geomorphons) and Wetness Index (TWI). This work helps us detect potential areas for settlements which are not preserved (dependencies of the city of Montecorvino and of the monastery of S. Egidio) and validate the outcomes of TWI (S. Marco in Lamis); moreover, it provides new hints about the relationship between settlement pattern, geomorphological elements, territorial/hydrological arrangement related to centuriation.