Topoclimatic Models and Viewshed in Archaeological Visibility Studies

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Abstract. This work shows a preliminary procedure that uses GIS for identifiying viewshed uncertainty caused by some particular topoclimatic phenomena. Since climate is extemely complicated for modelling at small-scales, I opt here for a first approach to such uncertainty through the study of terrain, e.g. identifiying areas of changeable visibility due to mist formation processes directly related to particular topographical features. The key is the use of terrain variables to compensate for unmanageable climate variables.
The procedure has been developed following field observations. It is a work in progress and it fits into the author's PhD Project, which deals with the importance of visibility (visibility understood as "cognitive/perceptual acts that served to not only inform, structure and organise the location and form of cultural features, but also to choreograph practice within and around them" (Wheatley and Gillings 2000:3) for a group of 2nd Iron Age hillforts in Southern Spain.
Keywords: Viewshed, Climatic uncertainty, GIS applications

1. Introduction

As many times reported (Fisher 1992, 1993, 1996; Wheatley 1995; Ruggles and Medyckyj-Scott 1996; Llobera 1999; Tschan et al. 2000; Gillings and Wheatley 2001; Wheatley and Gillings 2000, 2002:214–216; Van Leusen 2002; Zamora 2002; Lock 2003:177–182; Constantinidis 2004 among others), binary viewshed is a too simplistic way to represent visibility around a particular viewpoint.
Several defficiencies, very well sumarized in Wheatley and Gillings (2000), should be corrected in order to make computerized viewshed more realistic and geared to archaeological purposes. One of those aspects is the effect caused on visibility by atmospheric dynamics, since current viewshed calculation does not provide for climatic issues.
Field observations of daily and seasonal visibility's variations make clear aspects like how the radius of vision can change in more than 20 km at different times of a same day, or how the effects of haze, rain or sunlight's intensity deeply modify the quality of vision (Zamora 2002, 2003).
At a local scale, that one that principally interests to archaeological studies, climatic phenomena have a close relationship with terrain features.
The term "topoclimate" was coined by Thornthwaite (known by the author from Geiger 1966:455). It refers to the concept of "terrain climatology" (...) "the climate in a particular place, which depends not only on the configuration of the ground, but also on the type of soil and its vegetation cover" (Geiger 1966:453). While in these pioneering works the term "topo" seems to have a more extensive meaning than topography (see previous quotation), and although the word "topoclimate" itself, according to its greek origin, means "the climate of a particular place", in some of the current works the understanding of the concept "topoclimate" gives an special importance to topographical features:
"Topoclimatic models use topographic descriptors (elevation, slope, aspect, landscape position....) as primary input to build climatic surfaces that describe spatial and temporal patterns of such physical factors as temperature, incoming solar radiation (insolation), precipitation, soil moisture, and evapo-transpiration" (Rich and Fu 2000).
Probably this is due in one hand to the natural association of both terms (topos and topography) because of their semantic relationship, and in the other hand to the development of both DTMs and GIS software, which has paved the way for exploring topography more in-depth than any other geographical feature in the landscape (although, obviously, is not the only one).[1]
And in fact, in the work shown in this paper, topography has a high profile, and it is use, as previously quoted, "as primary input to build climatic surfaces".

2. Aims

The aim of this work in progress is to identify viewshed uncertainty from local climatic conditions through the use of GIS. The pursued result is the detection of uncertain viewable areas in the viewshed, in other words identifiying probable viewshed areas on weather related issues.
Another underlying goal is to stress the need for thinking on climatic processes when doing viewshed studies.

3. Proposal

Since climate at small-scale seems to be beyond modelling (or at least it is extremely complex) but terrain complies with it[2], the proposal showed here deals with the search for interaction points between both climate and topography that

can affect visibillity for archaeological purposes. I will use terrain variables to compensate for unmanageable climate variables.
Topographical features are an important factor in the modification of wind's direction, especially in the case of convex shapes of georelief (Pavlicko and Vysoudil 2002: 63). They have the power of generating microclimates, and can make different visibility conditions depending on its local particularities.
The procedure shown here will not give us a complete climatic incidences report on the viewable area, but a partial one, and many weighty aspects will remain unhighlighted. However, it will allow us to do a first approach to the problem through the use of GIS technics.

4. Case Study

One of the interactions between terrain and climate refers to the water vapour condensation phenomenon caused by the sudden ascent of wind when a convex topographical obstacle is found. Because of wind's direction is very sensitive to topographical features, as well as it is the driving force behind some climatic processes implied in fog formation, the particularities of topography can give some clues to detect climatic viewshed uncertainty.
When an air mass rises quickly, the pressure decreases and the particles of the air, like water vapour, expand and a cooling is produced. If the air has a high degree on humidity, condensation of the water vapour will occur.
Sometimes, this condensation is produced when humid wind blows against outstanding features on the landscape, since they do wind go up fast. If the particular area under study has some prominent topographical features, and required climatic conditions for condensation apply, those features during some periods could be affected by mist while the lower locations would remain still visible.
The implication of this process in viewshed refers to a decrease in the quality of vision, making the places under condensation effects partial or completely invisible to the observer (*Fig. 1*).

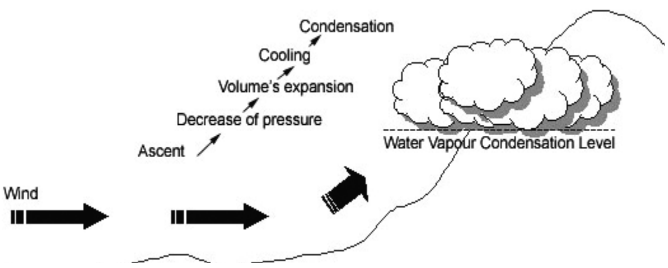

Fig. 1. Simplified scheme of the water vapour condensation process referred in the text.

4.1 The Study Area

This process has been identified in the viewable area of Alhonoz site. This is a 2nd Iron Age hillfort in the Genil river valley (Andalucía, Spain), in the stretch shared by the provinces of Cordoba and Seville. The landscape is a sedimentary basin, an open valley of mild topographical shapes. Hills and bottoms make up the land, and the river and its tributaries wind down the terrain. Some of these hills hold 2nd Iron Age hillforts on their tops.
For viewshed analyses from a certain viewpoint, I consider that the study area starts from the observer's location. Each viewpoint, each site in this case, has its own study area. The limit of the area, this is the radius, depends on many factors like what you want to see, the observer's location, and the particularities of the area. In the case of Alhonoz, the study area analized is a circle of radius 20 km round the site, and more exactely the viewable area inside that circle.[3] Almost all hills whithin this area are medium height, rising up to 200–300 m altitude, while the surrounding land extends from 100 to 200 m altitude approx. An exception is made by Sierra de Estepa, an isolated and important hill that in a short space rises up to 840 m.

4.2 Procedure's Steps

The procedure needs basically a DTM, software GIS[4] and the knowledge of wind, humidity and temperature figures all year round.

1 Possibilities for water vapour condensation
This step requires the analysis of observatory figures. Not all places in the Earth hold conditions for regular mist formation. So, it is necessary to check that temperature and humidity levels, at least in certain periods of the year, are suitable for the generation of mist (low temperatures and high humidity), and to verify that the water vapour condensation can occur occasionally on areas of archaeological interest.

2 Identification of unusual high altitudes
The computerised approach to this topoclimatic phenomenon starts with the identification of unusual high altitudes with steep slope within the area. For this task it is necessary to get two parameters: the metres over which altitude can be considered as unsual high, and the degrees above which slope would be steep enough to make wind rising in a brief time. The edge effects in the identification of unusual high altitudes could be overcome by the use of an extended DTM surface, like in any other spatial analysis.
These features will make wind go up quickly, which is required for the sudden descent of wind's temperature.

3 Wind's direction
The main wind's direction during the cold periods give us the slopes facing against wind. The data can be obtained from observatory figures. This can be shown using an aspect calculation of the DTM, and subsequently the slopes facing in the opposite direction to the wind will be selected.
4 Integration with archaeological features
The intersection of all layers involved in the process, i.e. high altitudes, steep slopes, slopes facing against cold winds (aspect layer) and viewshed, will give the area, if any, that can be at certain moments of the year visually blocked by this particular mist.

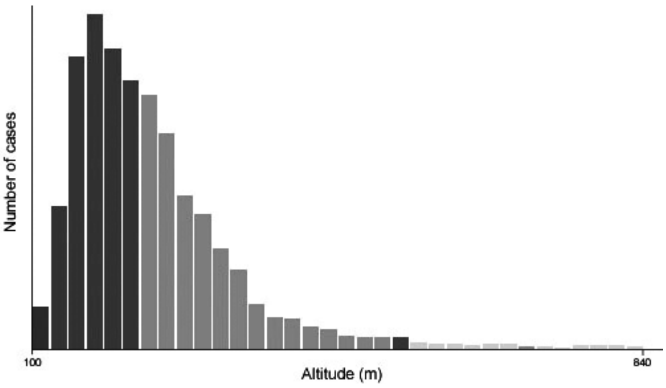

Fig. 2. Histogram of altitudes. The excepcionality of the height of a small part of the surface appears clearly in the right half of the graphic. This is an exemplary case that fits perfectly into the proccess for identifying unusual high altitudes. However, histograms can be deceptive and are not reliable enough to analyse topographical surfaces because identical histograms can refer to completely different terrains.

If on those areas there are archaeological sites or any other element of visual interest, their visibility will be temporarily blocked, while other areas not affected for the same condensation process will be visible even if they are located at a larger distance from the observer.

In the case study area (*Fig. 3*), the Sierra de Estepa is the place affected by the process. It contains one of the most importants hillforts from a visual point of view (its high position over the plain, at 606 m, allows it a large visual scope, 35 km maximum radius[5]). However, it is not always well seen from Alhonoz site (the viewpoint, located in the centre of the circle).

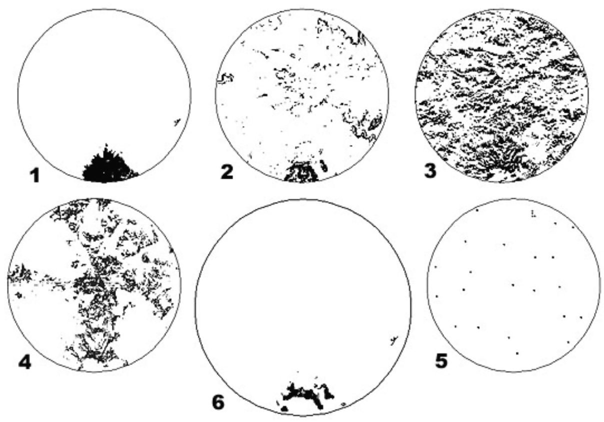

Fig. 3. Implied layers in the procedure: 1. Unusual high altitudes. 2. Slopes over 15%. 3. Aspect layer showing slopes facing against cold winds (North, Northeast and Norwest). 4. Viewshed. 5. Archaeological features (2nd Iron Age hillforts). 6. Intersection of all layers.

5. Conclusions

Although this procedure has come from field observations on just one particular area, the idea of approaching climate from terrain is methodologically correct for extrapolation to other areas since topography interacts with climate everywhere.

Other topoclimatic phenomena can be approached through the development of similar procedures. That is the case of the mist formation over large water surfaces[6] or in deep and narrow valleys (e.g. in the case of rock art sites located along and inside steep valleys, a quite extended application in visibility studies). Each area have different topoclimatic interactions, and, before talking about Models, a lot of fieldwork needs to be done in order to consider as many topoclimatic phenomena of viewshed importance for archaeological purposes as possible.[7]

The main problem refers to the choice of values for the parameters involved. Which water surface is potentially large, which altitude is unsual high or which valley is deep enough to be considered as a warning feature in viewshed analysis calls in a high percentage to the archaeologist's sense depending on each study area. Any approach to the topic needs a close supervision by the researcher, in order to manage every distinctive feature that the area under study can show and the archaeological purposes can require.

One thing is clear, that the viewshed analysis needs a previous visibility database. As well as in any other spatial study, where the cartographic features have a linked database (that is in fact the definition of GIS), the viewshed itself should have specific linked data, which have to come from not computerized sources (i.e. mostly fieldwork[8]). And another thing is even clearer, that viewshed analysis should not end where the GIS current scope ends. Viewshed is a study topic by itself, not a product of technology (although technology highly promoted and promotes it).

Notes

1. I would like to stress here the dictatorship of topography in computerized spatial analysis, since its facility to be modelized, with the difficulty of modelling other elements, frequently throws landscape studies out of balance.
2. The author is aware of Digital Terrain Models' deficiencies (Kvamme 1990; Marozas and Zack 1990; Fisher 1991, 1992, 1993; Hageman and Bennet 2000; Wheatley and Gillings 2002:114–118) as well as their implications on viewshed results (Fisher 1991, 1992, 1993; Ruggles et al. 1993; Wheatley 1995; Madry and Rakos 1996:120; Cheng and Shih 1998; Wheatley and Gillings 2000, 2002:209, Zamora 2003), and she refers here just to the terrain's capability to be digitally reproduced.
3. This radius is a theoretical reference, the maximum visual range from Alhonoz under optimal visibility conditions and for large distance targets (see Poster abstracts in this proceedings: Zamora, M., "Choosing the Radius in Viewshed"), not being applicable in the real world to all directions at the same time and for all targets. For the viewshed calculation it has been considered not just a viewpoint but several, all over the hillfort's surface.
4. That one used here is ArcGis 8, but any similar software would be appropriate. No program will get a perfect result.
5. Poster presentd at CAA2004: Zamora, M., "Choosing the Radius in Viewshed".

6 Water surfaces are not topographical features. However, their location and size can be reproduced in a GIS as well as terrain can be.

7 I have to emphasize here on the preliminary nature of the procedure.

8 The differences between present-day and past climatic conditions, in the cases where they apply, constitute another source of uncertainty to be taken into account

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