Predictive GIS Model Topographic accessibility to South America

Lucía Magnin[1]

Diego Gobbo[2]

Juan Carlos Gómez[3]

Antonio Ceraso[2]

Keywords: South America, topographic accessibility, first Americans

Introduction

We analyze the surface of South American territory to generate accessibility models required by another work presented at this symposium. They are presented at continental spatial scale, and seek to incorporate data useful as proxies of the environment at the Last Glacial Maximum (LGM *ca*. 20,000-18,000 years before present) (Miotti and Magnin 2010).

Assumptions and objectives

The methodology employed here is oriented to the delimitation of natural corridors of low resistance to pedestrian movement for the South American continent using Geographical Information Systems (GIS). It differs from the calculation of optimal pathways in that it does not delimit the shortest path to link one origin and one destination point. Instead the output is a surface which, due to its good accessibility condition, represents areas potentially usable as pathways (Llobera 2006, Cerrillo Cuenca 2008). The objective is to use today's topography to model ancient coastlines (Gilderson *et al.* 2000, Isla and Bujalesky 2008), to include the extension of glacial masses (as delimited by Clapperton, see Rabassa 2008; Stanford et al.

[1] CONICET – División Arqueología del Museo de la Plata. Arqueología de Paisajes Patagónicos (FCNyM – UNLP), Paseo del Bosque s/n, CP: 1900, L Plata, Buenos Aires, Argentina; TE: 5402214259638 internal phone:126; lmiotti@fcnym.unlp.edu.ar; lmagnin@fcnym.unlp.edu.ar

[2] FCNyM – UNLP

[3] FCNyM – UNLP; INREMI

2005) considering them as barriers to the passage, and use the relieve as a surface to calculate access costs.

The specific objective of this work is to generate two predictive maps required by another work presented in the Symposium (Miotti and Magnin 2010). The first map represents rivers as partially permeable barriers, while in the second, rivers and marine costs are movement stimulators. The grater or lesser adjustment of archaeological data to these two models will bring new information to the study of general tendencies in the study of the first Americans from a spatial point of view (see Miotti and Magnin 2010).

Data and methods

The general methodology used here is delineated by Fábrega Alvarez (2006): Optimal Displacement Model (MADO from the spanish “Modelo de Acumulación de Desplazameinto Optimo desde un origen”). Nonetheless, we highlight a difference from the application by this author. Here, the origin points are not archaeological sites, but random points within a grid of polygons which cover the study area. This analysis does not seek to establish optimal access between sites (for an application of this approach see Anderson and Gillan 2000), but to characterize the terrain in base of its natural accessibility, considering any point of origin to the movement. This procedure permits to generate a model for natural mobility. This methodology based on a random point’s grid was previously applied to other scale and study problem by Cerrillo Cuenca (2008).

Conclusion

In this work we use SIG (Arc Map 9.2 and Grass 6.4) to model the main accessibility characteristics that the South American territory could have presented at the LGM. The different processes applied can be viewed in the diagram at figure 1. Due to the flexibility of

GIS in the management, testing and revision of models, the data used here can be revised in the future.

1. As basic data we used a digital elevation model GEBCO_08 Grid. This is a three-dimensional model of the ocean bathymetry and topography emerged with a spatial resolution of 30 arc-seconds (each pixel measures 945.44 m on each side) (The GEBCO_08 Grid, version 20091120). These data and all products were projected to UTM strip 20, south.

2. This basic data was used to model the extent of land area in the last glacial maximum. Sea level was set at 105 m below the current level (following Gilderson *et al*. 2000; Isla and Bujalesky 2008). The resulting grid file has 6109 columns and 8993 rows. This modeling procedure is a simple device that allows modeling shoreline broadly; however is a simplification of a reconstruction process (see Waters 1992, Dincauze 2000).

3. The hydrographic network was modeled by the module ArcHydro 1.3. ESRI via the command for calculating accumulated flow. Consequently, the resulting hydrographic network is a raster file composed by continuous flow accumulation values. The values at each cell represent the number of cells upstream in each case. The lower values do not represent a significant barrier to the passage, and conversely, higher values constitute a potential barrier to be crossed by purely pedestrian means.

4. The South American glacier extent was incorporated into the model as barriers from the scanning, georeferencing and orthorectification of maps published in Rabassa (2008:163) and Stanford *et al.* (2005:338).

5. From the digital elevation model, hydrograph and glaciers map two friction maps were generated. The friction map "a" presents extremely low accessibility values for glaciers (set as barriers to the passage); and, for rivers, values that are gradually higher increasing their cumulative flow values from the headwaters to the mouths. The friction map "b" also features glaciers as barriers to access, but considers the network of rivers and a coastline of 50 km

around the perimeter of the continent as attractors to movement, since its accessibility values there are high.

6. A regular grid of polygons of 300 by 300 km was generated to cover the entire study area (South America) and one point was randomly situated within each polygon (N = 244).

7. Every one of these points was set as the origin to generate a cumulative cost surface using the GRASS module “r.walk". This is superior to others because it includes Naismith rules for calculation of cost estimates, it makes anisotropic estimates and resolves the tendency to polygonal artefact generation in the resulting surfaces using the "chess knight's move". The cost surfaces differ from the measurement of distances in a straight line, in that it uses a digital elevation model as the base data and incorporates a moderator of distance or "friction map" (Whitley and Burns 2007).

In figure 1, the cumulative cost surface maps resulting from the use of friction map 5a were named as “7a”, and the maps resulting from the use of friction map 5b were named “7b”.

8. Using each accumulated cost surface map, 243 flow accumulation surface maps were generated using the GRASS module “r.watershed", setting the remaining points of the grid as the origin, being the destination point established by the accumulated cost surface map used every time. This was achieved using a python script which automates the process of calculating the cost maps (r.walk) and flow accumulation map (r.watershed). As a result 59,049 flow accumulation maps were generated.

9. The final step is the sum of accumulated flow surface maps derived from the friction maps “5a” and “5b” (Model 1 represented as “9a”, and Model 2 represented as “9b” at figure 1). These are models of general accessibility of America, which do not assume points of origin or destination for pedestrian populations flow into the continent. The models generated are surfaces of continuous values with cells whose values represent areas of higher accessibility from the total origin points analyzed.

Acknowledgements:

We thank César Parcero Oubiña and Enrique Cerrillo Cuenca dispel doubts about the application of the methodology. This work was possible thanks to a Post doctorate CONICET grant.

References

Anderson, D. and J. C. Gillam 2000 Paleoindian Colonization of the Americas: Implications from an Examination of Physiography, Demography, and Artefact Distribution. *American Antiquity* Vol. 65(1): 43-66.

Cerrillo Cuenca, E. 2008 Recorriendo un territorio desaparecido: restitución fotogramétrica y análisis del paisaje de la necrópolis prehistórica del vado de Alconétar, Paper presented at V Simposio internacional de arqueología de Mérida. SIG y análisis arqueológico del territorio, Mérida.

Dincauze, D. F. 2000 *Environmental Archaeology. Principles and Practice*, Cambridge University Press, Cambridge.

Fábrega Alvarez, P. 2006 Moving without destination. A theoretical GIS-based determination of movement from a given origin, *Archaeological computing newsletter* 64:7-11

Waters, M. R. 1992 *Principles of Geoarchaeology*, The University of Arizona Presss, Tucson.

Isla, F. and G. Bujalesky 2008 Coastal Geology and Morphology of Patagonia and the Fuegian Archipielago, In *The Late Cenozoic of Patagonia and Tierra del Fuego*, edited by: J. Rabassa, pp. 227-240, ELSEVIER, Amsterdam.

Llobera, M. 2006 Arqueología del paisaje en el siglo XXI: reflexiones sobre el uso de los SIG y modelos matemáticos, In: *Territorios antiguos y nuevas tecnologías. La aplicación de los SIG en la arqueología del paisaje. Jornadas de arqueología,* edited by I. Grau Mira, pp. 109-124, Universidad de Alicante Press, Alicante.

Miotti, L. L. and L. A. Magnin 2010 América del Sur desde hace 18.000 años: accesibilidad topográfica y dispersión humana, In: *Book of abstracts V Simposio Internacional: El Hombre Temprano en América: a cien años del debate Ameghino-Hrdlicka (1910-2010)*, pp. 130-131. Cooperativa Gráfica El Río Suena.

Rabassa, J. 2008 Late Cenozoic Glaciations in Patagonia and Tierra del Fuego, In *The Late Cenozoic of Patagonia and Tierra del Fuego,* edited by: J. Rabassa, pp. 151-204, ELSEVIER, Amsterdam.

Stanford, D; R. Bonnichsen, B. Meggers, and G. Steele 2005 Paleoamerican Origins: Models, evidence, and future directions, In *Paleoindian Origins: Beyond Clovis,* edited by R. Bonnichsen, B. T. Lepper, D. Stanford and M. R. Waters, pp. 313-353, Centre for the Study of the First American, Texas A&M University Press: College Station.

The GEBCO_08 Grid, version 20091120, http://www.gebco.net

Whitley, T.G. and Burns, G. 2008 Conditional GIS surfaces and their potential for archaeological predictive modelling. In *Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA),* edited by A. Posluschny, K. Lambers and I. Herzog, pp.292-298, Berlin.

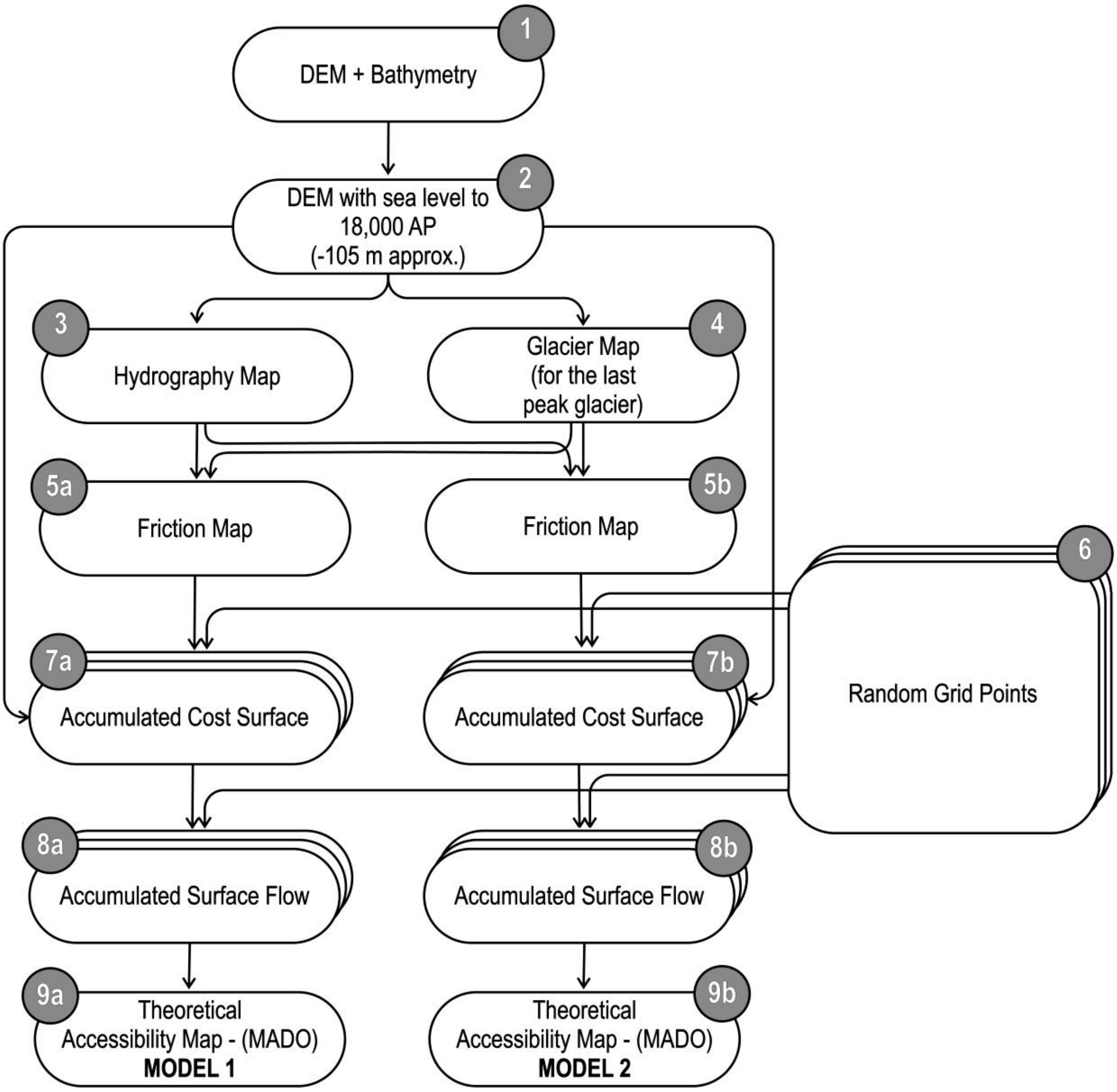

Figure 1. Diagram showing the input data, the geoprocesses applied, and the models obtained.