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"The geoglyphs of Titicaca" by Amelia Carolina Sparavigna, Politecnico di Torino, Italy

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Any landform composed of fine-grained materials evolves in wide and flat relieves, due to the down-slope transport of its materials over time. Earthworks, which are artificial landforms, are subjected to the same destiny, to be widened and flattened as a consequence of the natural degradation processes ^[1]: in spite of this degradation, these ancient structures remain clearly displayed by satellite imagery as a texture superimposed to the background landform. There is a wonderful example of a huge network of earthworks, covering a total of 120,000 hectares of the land near the Titicaca Lake. It is the result of an almost unimaginable agricultural effort of ancient Andean people that created an extensive agricultural system. People built a system of terraced hills and raised fields, which were large elevated planting platforms, with the corresponding drainage canals, to improved soil conditions and temperature and moisture conditions for crops. These remains of the prehistoric agricultural system are providing evidence of the impressive engineering abilities of the peoples who lived there in pre-Columbian times.

The local farmers call the artificial landforms "waru waru" or "camellones" (pre-Hispanic raised fields are present in other regions too ^[4]). They appreciated these evidences of the remarkable skills of their ancestors in 1981, when Clark Erickson, University of Illinois, recognized the significance of waru waru. He and other researchers started an experimental reintroduction of raised fields, in the Huatta, a land near the lake, in Peru, persuading some local farmers to rebuild a few of the raised fields, plant them in indigenous crops, and farm in traditional manner ^[4]. Let us remember that Lake Titicaca sits 3,811 m above sea level, in a basin high in the Andes on the border of Peru and Bolivia. The western part of the lake lies within the Puno Region of Peru, and the eastern side is located in the Bolivian La Paz Department. Both regions have the slopes of the hills criss-crossed with terrace walls. Satellite imagery shows some parts of the plain surfaces still covered with raised fields.

Let us observe the region of Titicaca Lake with Google Maps. We see raised fields having different forms and size, generally being 4-10 m wide, 10 to 100 m long ^[4]. In spite of erosion, the raised fields are clearly visible from the space. For instance, **Figure 1** shows a piece of this land (Huatta). Observing the figure, we can argue that the creation of these earthworks was previously planned, following the natural slope of the terrain. Another example, the head of a bird (**Fig.2**), where the beak is touching an old dry channel.

Many other interesting drawings are displayed by the satellite imagery. Let us see some of them, where their symbolic is quite evident. They are geoglyphs of huge dimensions.

In **Figure 3** we see a bird, where a circular pond is the eye. In **Figure 4**, it looks like a condor being represented on the surface. For the images, a processing method ^[8] was used that enhances the edges of earthworks. Two birds can be seen in **Figure 5**, the big one is protecting a canal with its beak and claw. In **Figure 6**, there is an animal that could be a hedgehog. Another artificial landform that could be a geo-glyph (a fish or a tortoise) is located at coordinates approx. -15.6464,-70.132. In Fig.7, a complex scene composed by a snake and an animal assailing it, covering a huge surface. Landforms in **Figures 1-7** are in Peru districts. A rule of thumb: to find the figures, look for circular ponds, because sometimes they can be the eye of an animal.

In Bolivia we see a large area (approx. coordinates -16.4275,-68.5822) where the raised fields have a different style. Here too, we see beautiful landforms, showing snakes, birds and other objects, not so easy to figure out. **Figure 8** shows a snake and a bird in the Bolivian country. In conclusion, the paper showed that the previously proposed image processing of natural landforms ^[8] can be applied to the study of artificial landforms, such as geo-glyphs. After processing,

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Figure 1: This is a part of the land near Lake Titicaca (Huatta, Peru). In the upper panel, the image from Google, in the lower one, the image enhanced with a previously proposed method ^[8]. Coordinates are shown in the figure.



Figure 2: The head of a bird, where the beak is touching an old dry channel. Coordinates are shown in the figure.



Figure 3: Many interesting drawings are displayed in the satellite imagery of this land. Among them, there are some which look as geoglyphs. Here we see a bird, where a circular pond is the eye. In the upper panel, the original image from Google, in the lower part the image enhanced with a previously proposed method ^[8].

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having the possibility to observe all the minute details of structures, a comparison of considered symbolic landforms with those of other regions is more easy [9]. A future work is devoted to a complete survey of all the Titicaca Lake region.

NOTE

[1] [1] *Being erosion acting on earthworks, as on all landforms, the study of those structures with known age and initial morphology is particularly interesting for geophysical researches. Comparing the original with the current shape provides the data for developing and testing models for long-term landform erosion. Such investigation was applied, for instance, to the Inca agricultural terraces abandoned at 1532 A.D. in the dry lands of southern Peru, see [2]. [2] Pattern and rate of erosion inferred from Inca agricultural terraces in arid southern Peru, Ana C. Londoño, Geomorphology, Volume 99, Issues 1-4, 1 July 2008, Pages 13-25 [3] Modeling the natural degradation of earthworks, M.A. O'Neal, M.E. O'Mansky, J.A. MacGregor, Geoarchaeology, Volume 20, Issue 7, October 2005, Pages 739-748*

[4] [4] *Pre-Columbian earthworks in coastal Amazonia, S. Rostain, Diversity, Volume 2, 2010, Pages 331-352 [5] Pre-Hispanic Raised Field Agriculture, C. Erickson, web page, <http://www.sas.upenn.edu/~cerickso/> [6] Agricultural Earthworks on the French Guiana Coast, S. Rostain, The Handbook of South-American archaeology, Volume 3, 2008, Pages 217-233 [7] Raised field agriculture in the Lake Titicaca basin, C.L. Erickson, Expedition, Volume 30(1), 1988, Pages 8-16*

[8] [8] *Enhancing the Google imagery using a wavelet filter, A.C. Sparavigna, 8 Sept 2010. Geophysics (physics.geo-ph); Earth and Planetary Astrophysics (astro-ph.EP), arXiv:1009.1590v1*

[9] [9] *A huge literature is available on the subject of geo-glyphs. Let the author note an article with several images, with a surprising title: Discovery of vast prehistoric works built by Giants? The Geoglyphs of Teohuanaco, David E. Flynn, a post of February 24, 2008 [10] <http://www.atlantisbolivia.org/geoforms.htm>*

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Figure 4. This landform appears as a geo-glyph representing a condor. In the upper panel, the original image from Google, in the lower part the image, the head enhanced with a previously proposed method [8].



Figure 5: Two geoglyphs in this area. They seem two birds. One is near the canal with beak and (white) claw at the bends of it. A green pond is the eye. Another figure is in the lower right part of figure.



Figure 6: This artificial landform could represent a hedgehog. Coordinates of hedgehog are -15.65154,-70.1334 (upside-down).



Figure 7: This is a huge geoglyphs. On the left, a snake with a bifid tongue, on the right an animal assailing it. The body and skin of the snake are created by the terraced hill, the head (darker area) is on the plain surface of the ground, a pond as its eye. The figure is reproducing a region 2500 m x 3000 m. Coordinates are -15.6281,-70.21858.

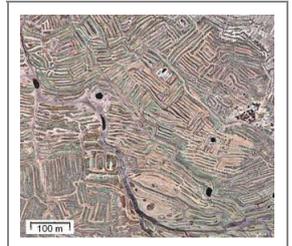


Figure 8: A snake and a bird in a plain region of Bolivia, near the lake. The style of this geoglyphs is different.

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