The geoglyphs of Titicaca

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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 \cite{1}; in spite of this degradation, these ancient structures remain clearly displayed by satellite imagery as a texture superimposed to the background landscape. There is 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 \cite{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 \cite{6}. 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 \cite{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 \cite{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. -15.649954, -70.132. In Fig.7, a complex scene composed by a snake and an animal assimilating 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 \cite{8} can be applied to the study of artificial landforms, such as geo-glyphs. After processing,
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


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