Erosion control test plot in steep slopes at an amazonic rainforest highway

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ABSTRACT: This paper summarizes the efforts made to protect a very steep cut slope that was considered part of a critical sector in the Iquitos- Nauta highway, in the Peruvian Amazon Rainforest. The slope was mainly composed by clay with some sand content and the topsoil had already been washed away. Every rainy season, the slope was eroded away by surface runoff. The use of Indented Surface & Perforated Geocellular Confined System (IS&PGCS) proved successful. This technology allows earth and humidity retention, which favored the establishment of several vegetative species, even with a severe dry season. After the rainy season, not only the IS&PGCS system was in place, but also several vegetative species had already been established. Vegetation cover neared 100% in two separate slopes that were analyzed. In the cut slopes not covered by this system, severe erosion took place, destabilizing the slopes and compromising the highway structure.

1 BACKGROUND

An Erosion Control Test Plot Project at Iquitos – Nauta Highway cut slopes was started on June 05.

During the construction of the highway a lot of cut slopes were made in the natural terrain, leaving very steep slopes - 70 to 75 degrees with heights up to 16 meters. These slopes formed of clays with some sand content are easily eroded away by the effect of raindrops and superficial water runoff.

The soil erosion produces considerable soil slides, which obstruct the ditches, overfilling them, and impounding the waters, forcing the water to flow aside the ditch, moistening the slope toe, which increases the soil loss and causing new soil slides, also causing the flooding of the highway damaging its structure.

A team conformed by Columbia University – USA, and Universidad Nacional de Ingeniería – UNI, who offered a Grade thesis and cathedratic support respectively, and the technical support from Andex (Peru) and Presto (USA), private companies both of them; contacted the Loreto Regional Government (GOREL) to propose the execution of the slope protection test plot using revegetated Indented Surface & Perforated Geocellular Confined System (IS&PGCS). GOREL offered the logistics and local labor; they assigned the execution of this test to the Regional Department of Transportation, (DRTC) who selected a critical sector of the highway.

Photo 1 Sediments clogs side channels and culverts frequently.

2 PROJECT EXECUTION

The selected cut slopes are located at the station 82+060, where two slope sections had been cut, one at the Eastern side and the other one at the Western side, the slopes gradients were higher than 70 degrees in both slopes, and the heights were around 16 meters high.

A revegetation system was defined to protect these slopes against erosion, however as the surface of slopes were not organic soil, it was necessary to create an adequate organic media where the future renegotiation will be established; furthermore a mechanical system was also required to contain and retain the organic soil and humidity to allow seed germination and vegetation development.

IS&PGCS is a honeycomb type structure manufactured of high density polyethylene perforated strips, indented surface, and that required anchorage system in order to provide the adequate stabilization mechanism of the organic soil.

A 10 cm height layer of IS&PGCS was placed, anchored at the top of the slope, using tendons and a mix of wooden and steel stakes. The cells were filled with an organic soil and local soil mix containing seeds and seedlings from around the place, in order to promote a high competition between species to determine their behavior and to find the appropriate species for a specific erosion control program development.

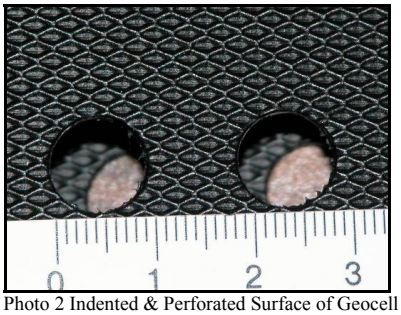

Photo 2 Indented & Perforated Surface of Geocell System.

3 PURPOSE OF THE TEST PLOT

- Determine the feasibility of I&PGCS application, and search the appropriate plant species for a specific erosion control plan in Iquitos-Nauta Highway slopes, Loreto, Peru.

4 RESULTS

In January 2006, when the test plot was exposed to the first rainy season, an inspection was conducted. The results are presented in this section:

4.1 *Comparative visual analysis between the test plot and the unprotected slopes of the highway*

Along the Iquitos-Nauta highway very steep slopes can be seen, greater than 45 degrees with heights between 5 and 20 meters, conformed by yellow and red clay soils with some sands content.

No vegetative cover or erosion control systems exists, the exposed soil is washed away by the effect of rainfalls, starting the movement of sand particles, causing later the slope failure because of the lack of support.

4.2 *Observation and analysis of slopes*

Soil bags and wooden stakes can be seen as failed solutions to alleviate the erosive effect. These "solutions", supposed to be cheap, behave like sediment traps more than erosion protections. When these traps area heaped up, these "Solutions" collapse; with the sub-sequent failure of the slopes. Exposure of soil to the effects of rainfall irremediably ends with the soil loss and subsequent slope failure.

A lot of failing slopes were seen, sediments ended up collapsing the drainage system (ditches); increasing the moisture at the toe of the slopes causing more failures and damages to the highway structure.

4.3 *Test plots*

Two slopes were observed, each one located aside the highway, and they are oriented in the north-south direction, therefore, one is facing to the east and the other one is facing to the west.

Watching areas close to the test plots, soil losses were observed along, with rills and gullies. However in the test plots area, the system prevent the shear effects of the runoff, no sediments were seen in the ditches next to the test plots, showing a good protection of the slope, and absence of sediment washout.

The test plots shows a lot of vegetative cover - superior to 80%, cushioning the rainfall effects of overflow and providing a good stability to the slopes, insuring this sector of the highway.

4.3.1 *Eastern slope*

The slope facing the east shows a great vegetative coverage near to 85%.

Grazing effects and footprints could be seen on the slope. Also deformations of the upper part of the I&PGCS could be seen due to fire effects, apparently people tried to burn it using some kind of fuel which residues have damaged the soil productivity impeding the vegetative development in that sector.

A great dominant of "pasto india" (Panicum maximum) that was above 90%.

At the base of the slope three species of grasses exist: Panicum maximum, Paspalum virgatum, Gynerium sagittatum, Cyperus luzulae and a thorny bush unidentified, a Hyptis recurvata; at the top of the slope a Solanum sp. plant was found with a lot of fruits.

The vegetation density increases in relation with the height of the slope, in the lower part of the slope the vegetation is represented by two species and three plants per square meter, the middle segment is represented by one specie and five plants per square

meter, the third segment is represented by one specie and sixteen plants per square meter, from this segment the vegetation cover is 100% with only one dominant specie, Panicum maximum.

4.3.2 *Western slope*

The western slope has a higher diversity of plants (15 species), although, the "gramalote" predominates in a 70%, the other species had gained enough height and strength to insure permanence. It is expected that competence and succession processes occur along the time to determine the status of the populations. Plant coverage can be qualified as a 100% and all cells presents plants with strong stems and intense green healthy leaves, with no evidence of diseases or pests.

4.4 *Plant species found*

Panicum maximum: Strong stems, thick with presence of root growing in the knots up to 2.70 meters. Dark green strong leaves with longitudes averaging 60 centimeters. Neither flowering nor seeds, the whole plant propagation is through stolons.

Hyptis recurvata: Strong stems, deep roots, inflorescence and seeds are present, leaves lightly affected by "siga-toca". Present in both slopes, with a major presence in the southern sector of the western slope.

Paspalum virgatum: abundant grass in the western slope with seeds, and incipient stolons, dominates the borders of the I&PGCS.

Cyperus luzulae: abundant in the western sector with in-florescences and seeds, this specie dominates the south-ern side of this slope. Strong plants with deep roots.

Solanum sp: one plant located at the top of the slope with inflorescence and ripe fruits.

Strong stem and leaves with a height of 1.25 meters.

Two unidentified species of fern were observed, also so-me algae and fungi at the deep zones of the I&PGCS over the native slope soil, lichens were also observed at the same place.

Two plants of "cocona" were found, with fruits; specie that was not initially planted in the system, which proves that its seeds where transferred by another agent, we guess birds; this points out that the biological cycle of the food chain of the surrounding ecosystem has started to establish inside the test plots.

4.5 *Relationship of plant species with I&PGCS.*

The proper characteristics of the I&PGCS system creates a Group of positive factors for the germination process of species:

- The cells supported on the natural slope behaves like a continuous of micro ditches, one behind another, reducing to the maximum the hydraulic energy of the run-off flows, in which absence the amount of water resource would be below the required for the process, the fines of the organic soil would be washed away, just as the nutrients and inoculated microorganisms in development;
- The texturing of the cell walls of the I&PGCS (indentations), retains moisture because of the surface tension of the water, important aspect during dry season (like August 2005);
- The texturing achieves the micro confinement of the soil fines; also fixing the salts, nutrients and microorganisms that exists inside the system.
- The perforations and mainly the percentage of the perforated area of the cell walls allows a good interrelation between roots, stolons and the system, stolons and roots pass through perforated walls creating a vegetative web that works retaining the soil and as a niche for species of annelid, insects and arachnidan.

The roots are strong with a good length covering all the spaces of the cell, and achieve penetration into the soil of the slope in depths superior to 10 centimeters (some measured species had roots length up to 40 centimeters, showing that at least 30 centimeters went through the natural slope for at least 30 centimeters), indicative of favorable conditions. The penetration of the roots into the natural slope would work as anchorage of the revegetated I&PGCS to the slope.

Photo 3 Roots penetration into the slope anchors the system.

The vegetative development process, both in roots and leaves, are favored by the soil support and interrelation and nutrients, particles, roots, micro and macro organisms, stolons, etc. flow through the perforations in the walls of the cells. Inter - relation between species and the respective competition and complement of the organisms, favoring the system stability from the point of view of ecological niches and ecosystems.

Photo 4 some species had roots length up to 40 centimeters.

The soil confinement and soil fines micro confinement, due indentation of cell walls, allows the stability of factors like temperature and humidity. Both stability parameters help good development of propagation factors and growing of the edaphic fauna. This favors the nutrients flow processes and better use by plants. Part of these nutrients modifies the chemical characteristics of the slope soil, which is used by the organisms that begins colonization processes of these soils.

4.6 *Relationship of the system with the slope and the agricultural capacity of the soil*

In the soil colonization process by organisms of the edaphic fauna, the plants roots find feeding and support favorable conditions, which provide biological and chemical additional elements, which help the development of micro niches that strengthen the new ecosystem.

The presence in the slope of organisms like algae, lichens and ferns are indexes that the formation of organic soils had started, which favors the succession of species by relationship of competence and complementation.

With these kinds of activities, the penetration of roots is not only by anchorage roots, feeding roots also develops in the slope soils overcoming the limits of the soil contained in the cells.

The described activity shows that the revegetated I&PGCS and the slope are interrelated by vegetation means. In this phase the system is anchored to the slope through vegetation, but at the same time the soil of the slope is constantly modified, increasing its agricultural capacity, which increases the root strength and therefore the plants development and strength, foliage is denser and the slope protection is greater, the cycle strengthen over time, stabilizing even more the slopes.

4.7 *Associated fauna.*

The soil analysis contained in the cells showed the presence of a high biomass from animal origin. The presence annelids, insecta and arachnidan is an index of the good state of the soils from the diversity point of view and in reference to the biomass a 0.3% of living biomass related to macro organisms was measured. Insects, reptiles, rodents, birds and even cattle form the associated fauna; this fauna is associated as the system provides nutrients, shelter and enough elements to sustain the characteristics of the ecosystem, with its flux of nutrients.

4.8 *Efficiency of the protection system placed on the slopes*

The superficial stability of the slopes is provided by the efficiency in the soil loss control at the slope. If slope soils are kept in place and hopefully anchored by the roots, it is guaranteed the immobilization of the same and the adequate water flow in the drainage systems, minimizing sediments, water impoundment, pore pressure due by moisture excess and the failure of soils.

5 CONCLUSIONS

In this test plot monitoring, we have detected that the system had reduced in more than 90% the sediments flow (elimination of the washout of particles from the slope).

Slope coverage and protection had been favored with local vegetative species and is successful.

Vegetative species succession had been allowed.

A niche had been created for a great number of species, and the biological cycle of the food chain of the ecosystem that surrounds the test plot had initiated.


Photo 5 Final version of the project

6 RECOMMENDATIONS

- Continue monitoring the test plot.
- Suggest to DRTC and GOREL, to begin a comparative evaluation between slides cleaning and highway maintenance and the possibility of using the I&PGCS at critical highway slopes. The analysis would establish convenience of its use as an standard erosion control program, overall at critical slopes.