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Evaluating Disturbance of E&P Access Roads

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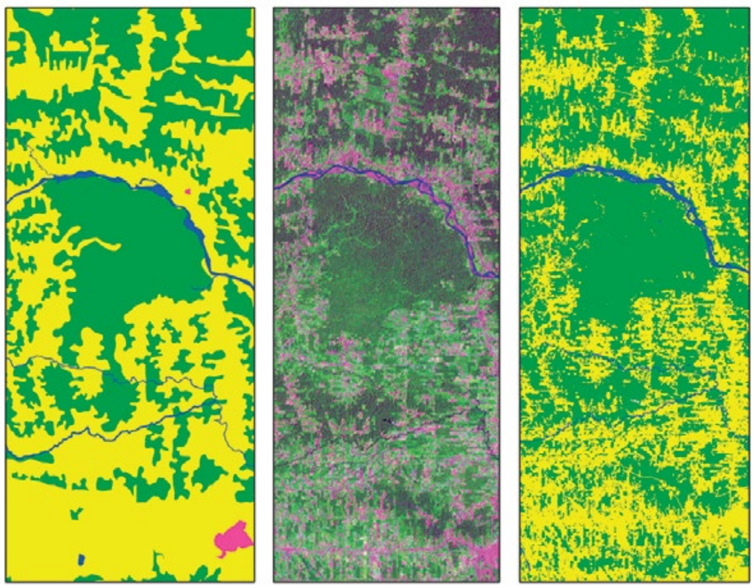
E&P development in remote regions is often considered a catalyst for landscape change through the direct alterations created by infrastructure features, as well as the accessibility provided by roads. The construction, expansion, and improvement of transportation routes in isolated areas can attract newcomers and resource users who engage in illegal logging, poaching, commercial agriculture, and colonization. These actions can lead to larger-scale surface disturbances that may also affect indigenous territories and natural preserves. However, do these peripheral activities and outcomes always accompany E&P development, or can controlled access minimize landscape change? Secondly, when peripheral activities do occur alongside E&P development, how do they contribute to landscape alterations inside oil concessions?

To answer these questions, remote-sensing and GIS techniques were used to calculate landscape infrastructure footprint (LIF) metrics, which link visible infrastructure features to surface disturbance. This "accounting-from-above" approach helped determine the spatial relationship between infrastructure pattern and land use/land cover (LULC), soils, protected areas, and colonization zones for the year 2000. The study area included four neighboring oil blocks in eastern Ecuador's tropical forest, displaying three types of E&P development: public access, controlled access, and roadless.



← Figure 1. This is a comparison of land-use/land-cover methodologies in Block O. The Ecuadorian remote-sensing agency CLIRSEN is on the left; the authors' LULC is on the right; and a Landsat ETM+2000 image with a 7,4,3 band combination (as RGB) is in the center.

Processed and enhanced Landsat imagery was used to create subset images of the concession blocks with different band combinations and to produce an LULC map, which was compared to a map by the Ecuadorian remote-sensing agency CLIRSEN. Roads were selected to represent infrastructure features and were updated using ArcGIS and expert knowledge. Google Earth (high-resolution) imagery was used to clarify questionable roads. GIS tools (such as clip, merge, buffer, dissolve, union, and intersect) proved invaluable in calculating various metrics associated with landscape disturbance including length of roads, types of access (public access, controlled, and none), road density, direct effects, and edge effects (core areas and number of rivers crossed). (See figure 1.)

Access Type and Oil Block

- Public access: Block O had the longest network of E&P roads (all designated as public access by the government), fertile soils, and some developed areas (located inside a government-designated colonization zone). Development unrelated to E&P activities occurred over several decades, and the road network became 3.5 times more dense.
- Controlled access: Blocks 14 and 16 were developed in the 1990s with one central E&P road, where access was controlled at the entrance to Block 14. Indigenous groups and energy company workers were the only people allowed to enter the area. Since other roads were few in Block 14 and not present in Block 16, the E&P network was the dominant one. The amount of agricultural conversion

in these two blocks was quite small, less than 2 percent.

- Roadless: Block 10 was developed with the use of helicopters. No roads were detected with Landsat imagery. This block retained 98 percent of its forests. Interestingly, agricultural land was found in all concessions, but some of this was linked to areas adjacent to rivers whose banks have historically provided fertile soils for farming.

Disturbance Metrics

- Road density: A factor in landscape fragmentation, which was rated on a scale, ranges from 0.1 in remote regions to 40.0 in urban locations. In Block O, the E&P road density rating was 0.17, and the density rating of other roads was 0.63, totaling 0.80, which is the upper density limit on the ability for some areas to support large mammals. In Block 14, the E&P road density was 0.02, and for other roads 0.01, totaling 0.03. Block 16's E&P road density rating was 0.04. Block 10, with no roads detected, had no road density measures. (See figure 2.)
- Direct effects: The amount of land directly disturbed by the presence of road and related infrastructure features. All roads were assigned a width of 15 meters for direct disturbance. E&P roads that included additional alterations associated with rights-of-way and pipelines, well pads, and central production facilities were assigned a width of 50 meters for disturbance, three times the area assigned to other roads.
- Edge effects: Transition zones of open land to forest where potential ecological disturbance may extend outward from infrastructure features. E&P roads were assigned a 100-meter edge effect width, and other roads were assigned a 65-meter edge width. Once determined, these edge effects were masked. Doing so revealed the remaining patches of land. These core areas were measured. (See figure 3.)
- Rivers crossed: Roads that cross over rivers indicate potential disturbance to aquatic ecosystems. Block O, with its dense road network, was most affected; however, the E&P road network river-crossing points in this block were less extensive than those of other roads. In Block 14 and Block 16, river crossings were linked to one E&P road, and Block 10 had no detectable river crossings.

Findings

Block O, the oldest concession, showed the greatest land surface disturbances. These were primarily linked to the additional and denser infrastructure network resulting from activities peripheral to E&P such as agricultural conversion and colonization. The remaining blocks, with controlled access and roadless E&P development, did not exhibit these surface disturbances. These findings highlight the importance of controlling road access if land conservation is a priority. (See figure 4.)

The accounting-from-above approach used in this study advances E&P environmental performance standards through the adoption of geospatial technologies with metrics and standardization. It also underscores that understanding, planning, modeling, monitoring, and mapping the E&P physical footprint, as well as peripheral economic activities, are very important tasks for E&P companies to pursue in remote regions and developed landscapes.

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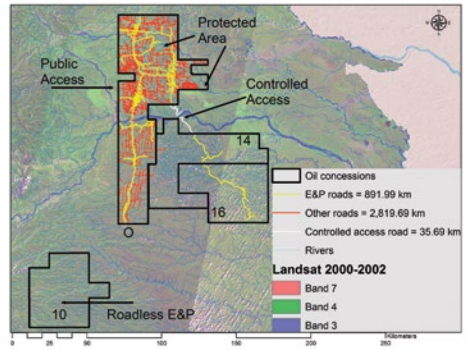
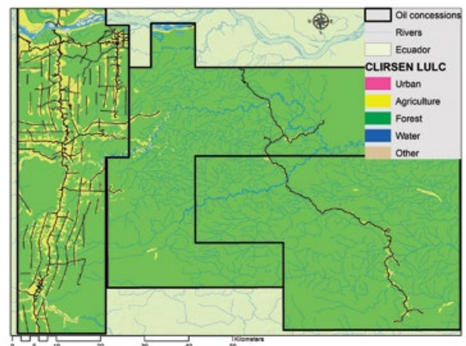
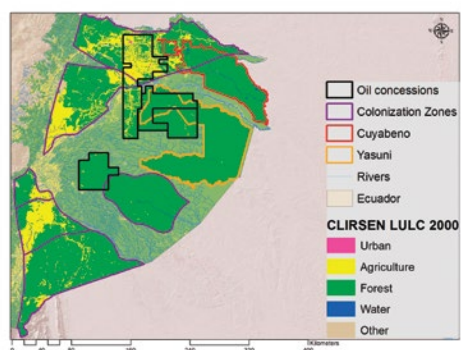


↑ Figure 2. This map shows the pattern of E&P and other roads in the four study area concessions. All roads in Block O were designated public access, a single E&P controlled-access road ran through Blocks 14 and 16, and some development occurred in Block 10 without using roads. Also, protected areas in Block O remained largely without roads.



↑ Figure 3. This map shows the core areas, or patches, that remained after all infrastructure features were discounted from the concessions. Parts of Blocks O, 14, and 16 are shown here. The dark lines represent edge effects for both E&P and other roads, measured at 100-meter width and 65-meter width, respectively.



↑ Figure 4. The CLIRSEN LULC map shows that agricultural expansion occurred primarily in the designated colonization zones (purple polygons) in Blocks O, 14, and 16. More than 95 percent of land cover remained forested within controlled access areas. Block 10 also maintained the majority of its natural state in areas of controlled access or not accessible by roads.

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