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Reducing the Footprint of 3D Seismic in the Tropical Rainforest of Ecuador

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Abstract
Multiple seismic exploration programs have been conducted in the Ecuadorian Amazon since the 1970s without reusing previously cleared areas for heliports and camps, resulting in unnecessary cumulative deforestation impacts. Walsh Environmental Scientists and Engineers (WALSH) and EnCana have developed a remote sensing technique to eliminate these redundant impacts by accurately identifying historic heliports and camps in mature tropical rainforest for reuse in a 3D seismic exploration program.

Introduction
Modern seismic exploration programs in a mature tropical rainforest typically utilize a combination of road, river and helicopter access. Many remote exploration areas are restricted to river and helicopter access due to a lack of existing road infrastructure and legal requirements by government regulators not willing to open up new roads, which would accelerate secondary impacts associated with legal and illegal settlement (1). In a roadless seismic operation, heliport and camp clearing typically is the most significant deforestation impact. Seismic activities are often repeated in a particular exploration area due to new data requirements as the seismic acquisition technology has become more sophisticated or a new operator requires additional subsurface data.

Helicopter access to the program is required for the movement of laborers, equipment and material. The impact of these operations is dependent upon the usage and type of access. The smallest impacts tend to be ‘drop zones’ where equipment is lowered through the canopy on a long line. The helicopter pilot will search for a natural opening in the canopy as close as possible to his target and mark the location with GPS. In the majority of cases no vegetation clearing of a drop zone is needed.

A heliport is an area of sufficient area for a helicopter to safely approach and land to discharge laborers or equipment. Heliports vary in size depending on the topography, wind patterns, height of canopy and type of helicopter in use. In heliportable operations heliports are strategically located for operational efficiency and safety in the case of a medi-vac.

Camps in heliportable operations usually result in the greatest impact. They contain living areas, room for support material equipment storage, and a heliport, usually in close proximity to one another.

Historically cleared areas for heliports and camps have naturally regrown quickly with low diversity secondary forest. These areas are difficult to locate or have been ignored by subsequent seismic campaigns resulting in multiple deforestation impacts as new heliports and camps are cleared from the high diversity mature tropical rainforest unnecessarily. A remote sensing technique for determining the location of these historically cleared areas and effective reuse in the Ecuadorian Amazon is described, which has eliminated these redundant deforestation impacts.

Measuring Biodiversity
The area of the seismic program is located largely within Yasuni National Park, with very high animal and plant diversity **(Fig. 1)**. Biologists have measured 2,274 species of trees (2), 567 species of birds (3), 173 species of mammals (4), 105 species of amphibians (5), and 83 species of reptiles (6), 382 species of fish (7), and over 100,000 species of insects (8) in the relatively restricted area of 982,000 hectares.

Fig. 1 – Location of 3D seismic project in Ecuador.

Previously intervened areas with secondary regrowth in tropical rainforest typically have much lower diversity than mature rainforest, which may take centuries to reach maximum diversity and ecological equilibrium (9).

A typical 0.25 hectare botanical study plot in this mature rainforest yielded 159 trees, represented by 28 families and 73 species, consisting mostly of Iriartea deltoidea (Arecaceae), (12 individuals); Zygia dependens (Mimosaceae) (seven individuals); and Chrysochlamys membranacea (Clusiaceae) (six individuals). Most of the tree species were represented by only one individual.

A botanic plot at an historic heliport an camp consisted of only five main tree species including "guarumos" Cecropia scyadophylla, Pourouma bicolor (Cecropiaceae); Ochroma pyramidale (Bombacaceae; Inga sp. (Mimosaceae); Vismia baccifera (Clusiaceae). The shrub layer consists of: Psychotria sp. (Rubiaceae); Miconia sp. (Melastomataceae); Siparuna sp. (Monimiaceae) and species belonging to the families: Piperaceae, Arecaceae, Pteridaceae, Rubiaceae and Gesneriaceae. A similar lack of diversity of animal species can be observed in these secondary forests.

Due to the exceptionally high diversity of the mature tropical forests, reuse of previously intervened areas can result in a significant biodiversity dividend.

Remote Sensing Technique

In the effort to identify these low diversity islands within high-diversity mature rainforest, satellite imagery (Landsat 5 and 7) was acquired from multiple years (1986, 1991, 1999, 2002) for the proposed seismic area.

A supervised digital classification technique was used to map vegetation in each of these images with the goal of identifying areas of low diversity vegetation for potential heliports and camps. Vegetation classes were generated from the seven spectral bands using ArcView.

The Landsat satellites have a spectral resolution of seven bands, from visible light (0.52 microns) to thermal infrared (12.5 microns) as shown in **Fig. 2**

Fig. 2- Landsat Satelite Spectral Resolution

Band 1	0.45 - 0.515 µm
Band 2	0.525 - 0.605 µm
Band 3	0.63 - 0.69 µm
Band 4	0.75 - 0.90 µm
Band 5	1.55 - 1.75 µm
Band 7	2.09 - 2.35 µm
Band 8	2.09 - 2.35 µm
Thermal Band	10.4 - 12.5 µm

The first three bands are visible light. Generally the infrared bands are best for distinguishing vegetation types: secondary vegetation foliage has a low chlorophyll content in the foliage, mature rainforest foliage has a moderate chlorophyll content, and palm tree (morete) wetland foliage has a high chlorophyll content. For this analysis Band 5 (medium infrared), Band 4 (near infrared) and Band 3 (visible) were combined for the best definition between vegetation types.

GIS specialists worked closely with the field botanist to divide the image into seven classes including: bare soil, morete wetlands, mature forest, river vegetation, secondary vegetation, agricultural areas and water. Three classes were identified as targets for heliports and camps including: bare soil, agricultural areas and secondary vegetation.

Since the proposed seismic area was not permanently inhabited, only visited occasionally for hunting and fishing, there were no significant areas of bare soil and crops. There was incomplete information on previous seismic campaigns, but no precise data on the location of the old heliports hidden in a sea of undisturbed mature forest. The distinction between secondary vegetation and mature forest was very subtle in the raw and processed images due to relative size of the features (ranging from 30m by 30m to 140m by 140m) to the pixel size of the images (30m); and the similarity of spectral signal.

After careful inspection of the Landsat images, faint rectangular-shaped areas were manually identified. These features were enhanced using different band mixtures. They ranged in size from 0.1Ha to 1.8Ha and generally were aligned, indicating they may be associated with a historic seismic line. These rectangular features also appeared on multiple years of images confirming they were not problems in data quality of the Landsat images. The features were progressively more difficult to distinguish on images from later years, a trend that is attributed to progressive re-growth and diversification of the forest canopy **(Figs., 3, 4 and 5)**.

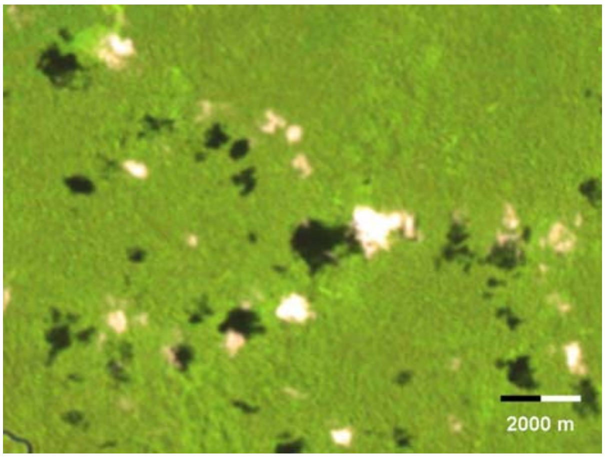

Fig. 3 - Landsat 5 (1986) image of mature rainforest in proposed seismic area, no patches of secondary forest present.

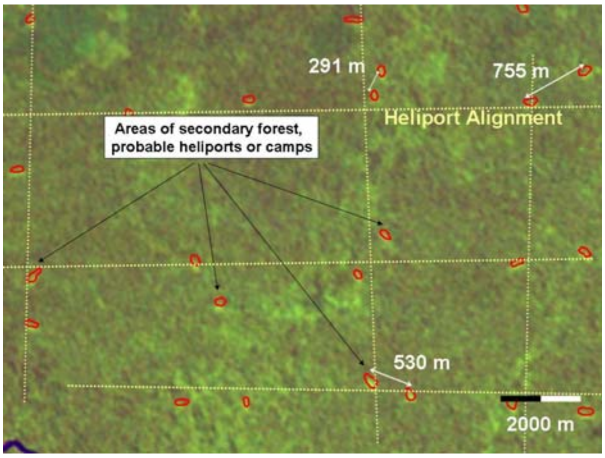

Fig. 4 - Landsat 5 (1991) image of same area with several sets of aligned secondary forest patches, suggesting they are associated with old seismic lines.

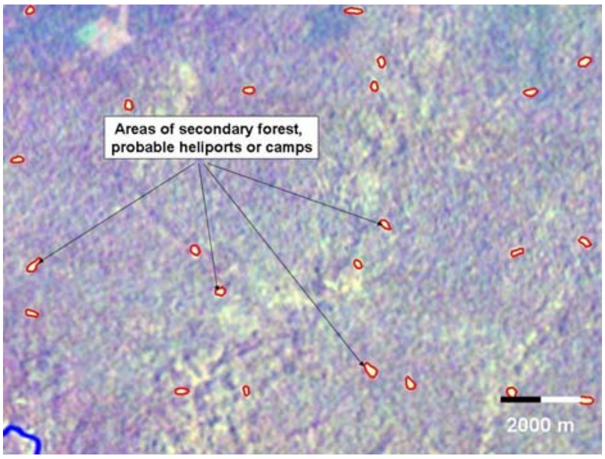

Fig. 5 - Landsat 7 (1999) image of same area with secondary forest patches at the same locations.

High resolution IKONOS imagery (one meter pixels) was also obtained from 2003 and 2004 and these features appeared in the same locations very clearly. This imagery was acquired in three bands, all visible light. Because no infrared bands were used, distinction of secondary forest could not be determined by the spectral signal. The high-resolution imagery had sufficient detail so that areas could be distinguished based on visual texture. Mature rainforest had a rough appearance due to different heights and shapes of trees, while the secondary canopy was very uniform. These canopy patterns in the candidate historic heliports were interpreted by the botanist and determined to be cecropia (Cecropia sp.) or balsa (Ochroma pyramidale) canopy, which are typical pioneer species in the Ecuadorian Amazon.

These potential historic heliports and camps were presented in the Environmental Management Plan and a commitment was made to reutilize these locations. A total of 324 locations were identified, approximately three times the necessary heliports needed for the program **(Fig. 6)**. In some cases the historic heliports and camps are within several hundred meters of one another, perhaps due to the lack of knowledge of previous seismic programs. The cutting of these heliports was an unnecessary impact on the rainforest ecosystem that could have been avoided by reusing disturbed areas for heliports.

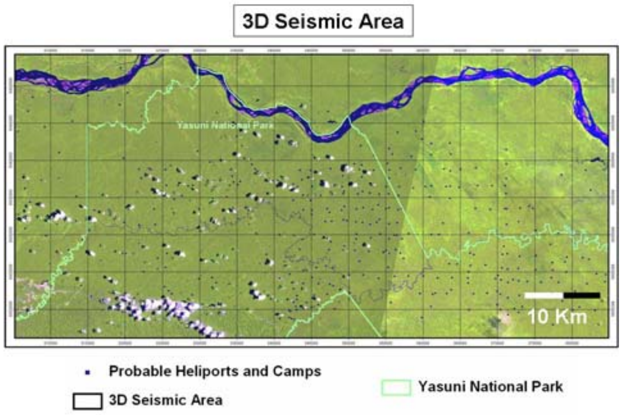

Fig. 6 - Locations of 324 secondary forest locations in proposed seismic area, probable historic heliports or camps.

Field Confirmation and Reuse of Historic Heliports and Camps

Helicopter over-flights prior to the seismic program confirmed that 95% of features identified in the satellite images were indeed groves of pioneer species and most likely historic heliports and camps. The remaining features were igapo wetland vegetation and landslides also regrown with pioneer species. These locations needed to be disqualified for the current seismic campaign, since they did not meet the logistical requirements of the program. The data from the over-flights indicated that the heliport locations generated in the GIS lab is very reliable without actually conducting ground-truthing, saving both time and resources in the planning process **(Fig. 7)**.

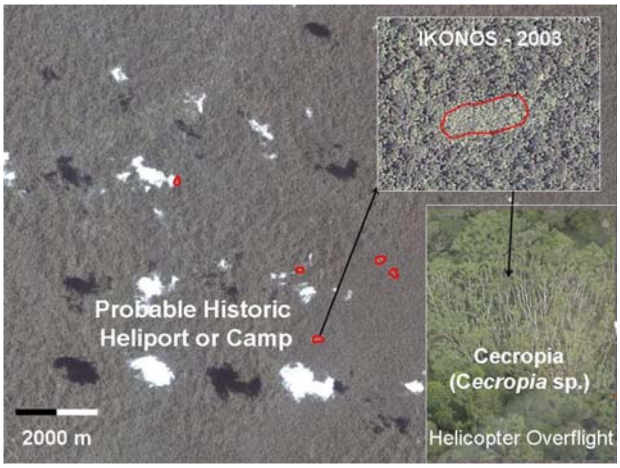

Fig. 7 - High resolution IKONOS imagery and helicopter photograph of a probable historic heliport or camp.

The seismic campaign was initiated in October, 2004. As the line cutting and surveying progressed the surveyors referred to the mapped locations of previously identified cleared areas. Suitability was first determined by proximity to the lines for access, size of the original clearing, and location with respect to other established camps or heliports. Prior to clearing a heliport and camp, a scouting team consisting of a surveyor, biologist, forestry technician and indigenous community member would fly over prioritized areas to aerially confirm. The survey team and biologists would then enter the proposed area for the clearing and confirm if the site met the operational requirements of the seismic program, the strict requirement of the Environmental Management Plan (minimum distances from sensitive areas such as rivers, mud licks, nesting areas, and leaf-cutter ant farms), and indeed was located in a grove a secondary vegetation. Usually clearing an old heliport saved time and money as scouting was quick, the trees were easily harvestable small diameter soft wood, the locations had been previously evaluated for helicopter operation – an important factor in hilly areas, and generally were close to a reliable water supply. The new heliport size in most cases was much smaller than the original heliports, located within a buffer of secondary regrowth **(Fig. 8 and 9)**.

Fig. 8 - Seismic camp located at a historic heliport and camp, within a grove of secondary vegetation of cecropia.

Fig. 9 - Seismic heliport located at a historic heliport and camp, next to river with restricted use and within a grove of secondary vegetation of cecropia.

Future Applications

The Ecuadorian Ministry of Environment and other stakeholders are encouraged that this technique prevented additional cumulative deforestation impacts during this seismic program. There is a general consensus among the regulators and environmental stakeholders that this should be adopted as an industry standard in Ecuador, since there are demonstrated environmental, logistical and cost benefits. Operators should consider applying this technique to seismic programs in other sensitive tropical environments in other parts of the world where historic intervention in the forest canopy has occurred but may not be obvious or has just been ignored.

References

1. Groth, Frederick H and Rivera, Patricio H. “Primary and Secondary Impacts Associated with Colonization and Oil Exploration in the Amazon Rain Forest”. Proceedings of the Twelfth International Conference Applied Geologic Remote Sensing, **(1997) I-59**. http://www.walshenv.com/papernet/cover.htm

2. Valencia, R., R.B. Foster, G. Villa, R. Condit, J.C. Svenning, C. Hernandez, K. Romoleroux, E. Losos, E. Magards, & H. Balslev: “Tree species distributions and local habitat variation in the Amazon: Large forest plot in eastern Ecuador,” Journal of Ecology **(2004) 92: 214.**

3. Fjeldas, J., Canaday, C.: “Aves del Parque Nacional Yasuní,” P 144 in J.P. Jorgenson and M. Coello Rodríguez (Eds.). *Conservación y desarrollo sostenible del Parque Nacional Yasuní y su área de influencia. Memorias del Seminario-Taller 2001,* Ministerio del Ambiente/UNESCO/Wildlife Conservation Society. Editorial SIMBIOE: Quito, Ecuador (2001).

4. Utreras, V., & Jorgenson J: “Un breve resumen de los mamiferos del Parque Nacional Yasuní-Amazonia ecuatoriana,” P 145–156 *in* J.P. Jorgenson and M. Coello Rodriguez (Eds.). *Conservación y desarrollo sostenible del Parque Nacional Yasuní y su área de influencia. Memorias del Seminario-Taller 2001,* Ministerio del Ambiente/UNESCO/Wildlife Conservation Society. Editorial SIMBIOE: Quito, Ecuador (2001).

5. Shawn McCracken: *Unpublished data.*

6. Almendáriz-Cabezas, A. “Diversidad de anfibios y reptiles del Parque Nacional Yasuní (resumen),” P 143 *in* J.P. Jorgenson and M. Coello Rodriguez (Eds.). *Conservación y desarrollo sostenible del Parque Nacional Yasuní y su área de influencia. Memorias del Seminario-Taller 2001,* Ministerio del Ambiente/UNESCO/Wildlife Conservation Society. Editorial SIMBIOE: Quito, Ecuador (2001).

7. Barriga, R.: “Peces del Parque Nacional Yasuní,” P 139–142 *in* J.P. Jorgenson and M. Coello Rodriguez (Eds.). *Conservación y desarrollo sostenible del Parque Nacional Yasuní y su área de influencia. Memorias del Seminario-Taller 2001,* Ministerio del Ambiente/UNESCO/Wildlife Conservation Society. Editorial SIMBIOE: Quito, Ecuador (2001).

8. Erwin T.L., M.C. Pimienta, O.E. Murillo, & V. Aschero: “Mapping patterns of diversity for beetles across the western Amazon Basin: A preliminary case for improving conservation strategies” in *Proceedings of the California Academy of Sciences* (2004).

9. Kricher, John C.: *A Neotropical Companion,* Princeton University Press, Priceton, NJ (1989) 436.