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Trucks from an illegal logging operation transport timber along a partially paved highway that cuts deep into the Brazilian Amazon.

A global map for road building

Roads are proliferating across the planet. Located and designed wisely, they can help rather than harm the environment, argue **William F. Laurance** and **Andrew Balmford**.

Nearly 100,000 kilometres of road criss-cross the Amazon rainforest. That is enough to circle the Earth two-and-a-half times. Even in formerly remote corners of the world — the Congo region, Borneo, Siberia, Namibia — road networks are expanding apace. This global road rush is being driven by escalating demand for minerals, fossil fuels, timber and arable land, and by developing nations as they work to improve transport and energy infrastructures[1].

Roads can bring myriad environmental problems. In the Amazon, new roads in forested areas often promote illegal colonization of undisturbed areas, as well as mining, hunting and land speculation. More than 95% of deforestation, fires and atmospheric carbon emissions in the Brazilian Amazon occur within 50 kilometres of a road[2].

Yet the effects of a road vary depending on its location and design. A paved highway slicing through a large forest tract can precipitate an environmental disaster. Conversely, in places where farming is already widespread and intact habitat is scarce, and where there are sizeable gaps between current and potential farm yields, building high-quality roads can improve farms' efficiency, increase their profitability and limit their environmental impact.

We propose that environmental scientists, planners, road engineers and other stakeholders carry out a global 'road-zoning' project to map areas that should remain road-free and those in which transport urgently needs improving.

LAND-USE PRESSURES

The twenty-first century will bring profound changes in land use, many of them unavoidable and even desirable. Food demand is projected to double by 2050. Under current farming practices, this would require an additional 1 billion hectares of farming and grazing land[3] — an area the size of Canada.

Given escalating demand for food, fibre and biofuels, researchers and policy-makers have focused on improving agriculture through the use of modern crop varieties, fertilizers, pest control and better transport. The hope is that such technologies will allow farmers to increase yields without using too much extra land[4].

In practice, however, by making farming more profitable, yield improvements can encourage the conversion of land for more crop and livestock production[5]. For instance, as a result of high demand and innovations such as new cultivars, oil-palm plantations are rapidly expanding across the tropics — often at the expense of biodiversity-rich rainforests.

We are convinced that increasing agricultural yields will lessen the impact of farming on natural ecosystems only if coupled with effective land-use planning[6]. Roads, which profoundly influence the footprint of human activities, are a key element of such planning.

Numerous factors — economic, political, social and practical — influence road

planning. But a few key principles could help to guide the location and design of roads. For example, the most environmentally damaging roads are those that penetrate relatively pristine regions. This is because the probability that a patch of land will be cleared rises dramatically if an adjacent area has already been cleared[7]. For this reason, the first cut into a forest is also the most crucial.

Furthermore, paved highways typically have much larger environmental impacts than unpaved roads, especially in wet environments in which unpaved roads can become seasonally impassable. In Brazil, for instance, the Belém-Brasília Highway, completed in the early 1970s, now cuts a 400-kilometre-wide swathe of cleared forest and secondary roads through the Amazon[2].

In certain contexts, however, road building, or improvements such as paving, can be socially and environmentally beneficial. Often, agriculture follows roads created for other purposes, such as mining or logging. This can result in the expansion of farms into places with marginal soils or climates, or into locations that are too far from markets to be cost-effective. Conversely, well-planned roads can increase farmers' access to markets, reducing waste and improving profits. Anecdotal evidence indicates that ongoing road improvements in parts of sub-Saharan Africa are gradually raising rural farmers' access to fertilizers and increasing their capacity to transport crops to markets.

Several studies suggest that road improvements in areas suited to agricultural development can attract migrants away from vulnerable areas, such as the edges of pristine forests[8]. Concentrating people in carefully defined areas is beneficial, because the relationship between deforestation and population density is nonlinear. In general, migrants entering an already cleared area remove much less forest than those who arrived first[2]; latecomers may include merchants instead of farmers and loggers, for instance, or farmers who buy up previously established plots.

It is much easier for policy-makers to influence patterns of road development than to affect more socially complex problems such as population growth and overconsumption. Roads can be re-routed, cancelled or delayed. Large road projects are often funded by taxpayers, investors or international donors who can be surprisingly responsive to environmental concerns. For example, if corporations that build environmentally bad roads are publicly named, they can lose customers and shareholders. Concord Pacific, a Malaysian logging corporation, was publicly castigated in the early 2000s for bulldozing a 180-kilometre-long road into the highlands of Papua New Guinea — ostensibly to aid local communities. After the company grabbed more than US$60 million in illegal timber[9], it was fined $97 million by the national court of Papua New Guinea.

TRANSPORT PLANNING

We believe that a collaborative, global zoning exercise is needed to identify where road building or improvement should be a priority, where it should be restricted and where existing roads should be closed. A multidisciplinary team could integrate and standardize satellite data on intact habitats with information on transport infrastructure, agricultural yields and losses, biodiversity indicators, carbon storage and other relevant factors. Much of this information has been recorded or can be extrapolated from current data sources.

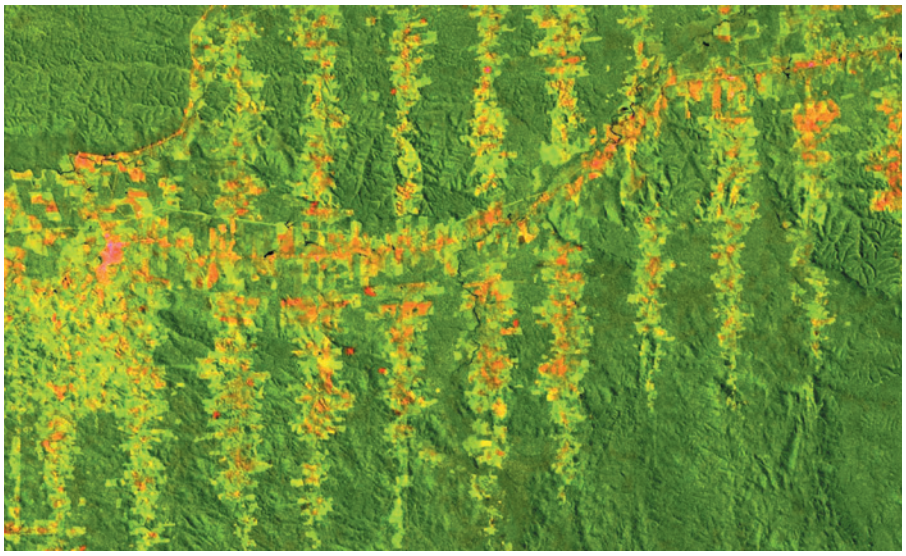
The next step would be to make the results of these analyses readily available as high-resolution, colour-coded maps to aid policy-makers, conservation organizations and others in planning roads. This mapping exercise could be repeated, and at finer scales, as circumstances on the ground change or data sources improve over time.

Beyond limiting habitat destruction, a global road-zoning scheme could safeguard rare environments and areas rich in endemic species. It could prove useful for a number of projects already planned or under way, such as the Tanzanian government's plan (which is being legally challenged) to bisect Serengeti National Park with a highway that could disrupt the area's world-famous migration of wildebeest and other wildlife, or the Ladia Galaska road network under construction in northern Sumatra, which will cut through hundreds of kilometres of rainforest and protected areas when complete.

For transport projects that have high environmental costs but seem unavoidable, such as Brazil's Manaus-Porto Velho highway — which is now under construction and has the potential to speed settlers and land speculators into the heart of the Amazon when complete — alternatives such as railways or river transport might be effective compromises. Trains and boats move people and products but limit the human footprint by stopping only at specific places[2].

"A global road-zoning scheme could safeguard areas rich in endemic species."

Keeping roads out of natural areas is one of the most tractable and cost-effective ways to protect crucial ecosystems. In a world struggling to conserve nature as land-use pressures intensify, managing transport networks is where the rubber meets the road. ■



LANDSAT

Satellite image of deforestation along the Trans-Amazonian highway in Brazil.

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