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### 1.1

#### What Are the Issues?

In the public mind, few things signify change in tropical forests more than the construction of a road; machines versus nature, artificial versus a natural construct. Muted, in much of the dialogue, are the social importance of forest roads and the technical knowledge required to properly design, construct, and operate them. Road infrastructures in tropical forests are complex engineering structures which provide access to forests. These road infrastructures involve engineering design, field layout, construction, and maintenance. They include bridges and other stream-crossing structures. Road infrastructures are commonly associated with the extraction of industrial wood, but they also provide access to forests for management, development, conservation, and protection purposes. Moreover, the importance of forests for biological diversity, non-wood products, cultural, and spiritual values, as well as environmental services, is widely recognized by the world community. In the context of sustainable development, as stated by Agenda 21 of the United Nations Conference on Environment and Development (UNCED) in 1992, the use of natural, renewable resources is a key demand of environmentally sound development. Resource use depends on accessibility of the relevant areas which can only be provided by the construction of forest road networks.

As a result, road infrastructure development has become a more demanding and complex discipline: planning and executing road infrastructure has become a difficult task, as these infrastructures must be designed and implemented in ways that accommodate, and if possible, enhance the various functions of the forests. In some cases forest roads form part of the planned network of public roads connecting diverse parts of a country or region and are essential components of developed infrastructure. This is especially true in rural areas where these roads provide mobility for people living in and around the vicinity of forested areas and benefit local communities in their daily socioeconomic activities. An improved transportation system allows not only

the existing forestry organization to increase its profit margins as transportation costs are reduced, but the surrounding area also benefits. Benefits for communities from an improved transportation system can come from several sources. Neighboring farms can have increased profitability as transportation costs are reduced. Labor will be better able to reach these areas, thus potentially lowering the labor costs or increasing its availability. Improved roads will allow for better access to health care and schools as vehicles will be more likely to reach isolated areas. Overall, the improved road network developed primarily for the forest enterprise may be a key element in the economic development of the area.

Forest roads may not be benign. Some argue that roads are the most significant cause of deforestation. Recent developments in road ecology consider the interactions of roads and the environment. These interactions can impact hydrology, vegetation, and animals. Roads can alter the hydrology of an area by often diverting subsurface flows to surface flows and increasing the amount and frequency of runoff to streams. They can cause significant increases in sedimentation from the cut and fill areas as well as the surface of the road, contributing to excessive river sedimentation, which could potentially have serious effects on water quality, aquatic life, and wildlife populations. Roads often provide a site for the establishment of noxious weeds that find recently disturbed cut and fill slopes ideal spots to occupy. Roads can impact wildlife habitat in multiple ways. Main roads with higher traffic volumes and travel speeds can increase mortality of animals owing to collisions with vehicles. Roads can alter habitat quality, as some species may avoid crossing well-traveled roads and suffer from increased predation on roads. Roads may enhance disruption of breeding areas or migratory routes of animal species. Roads, especially in primary forests, can lead to expansion of the agriculture sectors or allow for increased hunting.

Others, including the authors of this book, believe that road infrastructures that are properly designed, constructed according to environmentally sound engineering practices, and correctly maintained provide convenient, low-cost access to forest products and serve the needs for forest management conservation and protection. The revenue generated from the harvested forest products, notably industrial wood, provides the much needed resources to enhance sustainable forest management in the long term. It has been argued that the reason for improperly designed, constructed, and maintained roads is not so much a shortage of funds, lack of modern and suitable road building equipment, or the working methods, but far too little awareness of the negative impacts of poorly designed, planned, and constructed road systems on the entire forest ecosystem. Best management practices, if followed, will markedly reduce and control the negative environmental impacts of road construction and maintenance.

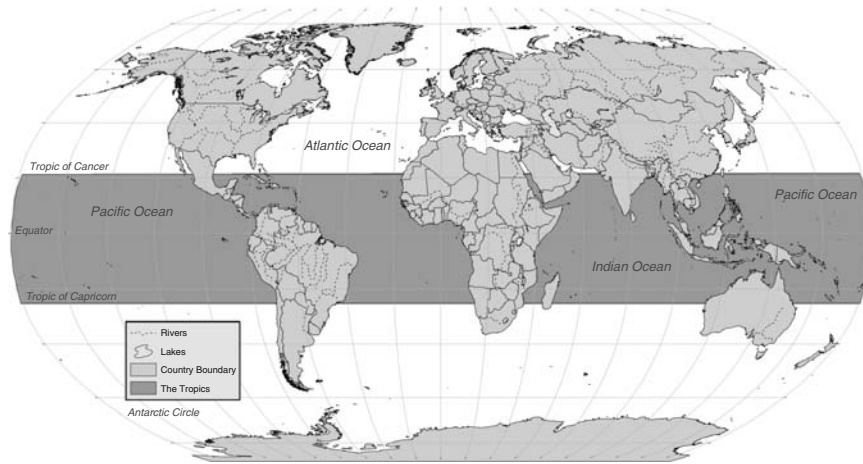
Roads do create a highly visible impact on the landscape, but they probably are not a direct cause of forest loss; rather they are the agent of change. The major causes of forest degradation and deforestation, among others, include overharvesting of high-valued species, excessive damage to the residual stands, overharvesting for fuel wood, illegal logging, overhunting, overgrazing and land conversion to agriculture and other rural development. Forest roads may be misused, attracting wood, game, and fish poachers and collectors of non-wood forest products from outside the forests, thus causing considerable negative impacts on the forest and the environment as well as on the local people. Although these activities are illegal, in many cases they cannot be controlled or stopped because of lack of capacity of the agencies responsible. All of these are made possible through road access, and thus roads become the *lightning rod* in a larger discussion of economic development and resource conservation.

This book is not intended to suggest appropriate forest development policies for a country or region. Its purpose is to present appropriate ways to plan, locate, design, and maintain tropical forest roads to maximize the benefits they create while controlling direct environmental impacts associated with construction, maintenance, and use. It is intended as a reference book for forest engineers and others interested in the design and management of forest roads. Although some methods and techniques discussed in this book may be appropriate for areas outside of the tropical forests and some may have originated in other regions, the focus is on techniques suitable for the special conditions found in tropical forests.

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## 1.2 Overview of the Tropics

The tropics are bounded roughly to the north of the equator by the Tropic of Cancer and to the south of the equator by the Tropic of Capricorn. Although the tropics are often portrayed as an area that has remained unchanged for a long time, i.e., not subject to glacial activity and large climate swings, that does not mean that they are homogeneous. Differences can be described by elevation, topography, temperature, mean annual rainfall, seasonal rainfall, and soils. The tropics can be divided into the warm tropics and the cold tropics, wet tropics and dry tropics. There are three major tropical regions, America, Asia, and Africa (Fig. 1.1). Some generalizations can be made between regions and within regions. Southeast Asia is much more mountainous than Africa or South America and has many young, eroding landscapes. It also has substantial areas of volcanic rock and soils. In Africa and South America, recent volcanic rock and soils are much less common.



**Fig. 1.1.** Tropics of the world

Considering within-region variation, slightly more than 50% of tropical America, for example, has a mean annual precipitation of 1,600–3,200 mm/year and less than 5% receives more than 3,200 mm/year and less than 5% receives under 400 mm/year. Similarly, the majority of tropical America has pronounced seasonal rainfall, with most of the seasonal rainfall coming in summer, but some eastern coastal areas have the pronounced seasonal rainfall coming in winter. Other areas have rainfall well distributed throughout the year. One can generalize that tropical America is flat. Eighty-two percent is less than 8% slope, and 4% is greater than 30% slope. And one could generalize that tropical America is well drained, but about 25% of the flat terrain would be classified as poorly drained.

Much international interest focuses on that part of the tropics that supports tropical rainforests (Fig. 1.2). Tropical America has about 50% of that total, with the remainder concentrated in Southeast Asia and Africa (Table 1.1). Tropical rainforests are found in places that have no dry months or only a few dry months. Tropical evergreen rainforest occurs in places with no dry season, and tropical semievergreen rainforest forms where there is a dry season. Tropical evergreen rainforests differ from semievergreen rainforests in that semievergreen rainforests have some species that are deciduous. In general, the western Amazon rainforests are evergreen, and the eastern Amazon rainforests are semievergreen. Southeast Asian rainforest is almost entirely evergreen and African rainforest is almost entirely semievergreen.

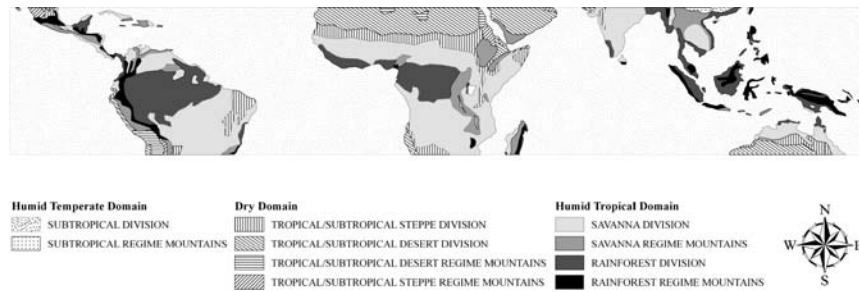


Fig. 1.2. Bailey's ecosystem classification of the tropics

Table 1.1. Distribution of tropical rainforest

Region	Rainforest area (million hectares)	Percentage of total	Primary location
South America	400	48	Amazon, Orinoco basins
Southeast Asia	250	30	Malesia, Asian subcontinent to India
Africa	180	22	Zaire Basin to Gulf of Guinea

### 1.3

#### Road Building Challenges in the Tropics

Tropical forest conditions pose special problems for forest transportation owing to several factors. These factors include (1) prolonged wet periods with high-intensity rainfall in many tropical forests, (2) scarcity and expense of good-quality rock in tropical areas, (3) swamps, and (4) harvest removals under the selective management systems designed to sustain natural tropical forests are usually low and may limit investments in roads. On the other hand, the tropics do have a number of very strong timber species which provide superior bridge-building materials for crossing the many streams and rivers in tropical forests.

### 1.4

#### Traffic Characteristics

Roads within the forest differ from general roads in that they serve a special purpose; efficient access for heavy vehicles associated with timber production. Their specialized function has three characteristics: low traffic volume, long,



<http://www.springer.com/978-3-540-46392-4>

Forest Road Operations in the Tropics

Sessions, J. (Ed.)

2007, XIII, 170 p., Hardcover

ISBN: 978-3-540-46392-4