SHOREA ROBUSTA GAERTN.F. (SAL) IN THE FORESTRY OF NEPAL

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ABSTRACT

The distribution, silvicultural characteristics, growth rate and economic importance of *S. robusta* Gaertn.f., an indigenous hardwood species in Nepal, were analysed. The natural *S. robusta* forests in the southern plains of Nepal (the Bhabar-Terai) have been seriously degraded during the past decades. Forest inventories and trials in Nepal have revealed a good regeneration potential for the existing *S. robusta* forests. After regeneration felling the new *S. robusta* crop reaches a standing stem volume of 100 $m^3 ha^{-1}$ in ten years. With an average site quality of I/II, the maximum mean annual increment of stemwood (15 $m^3 year^{-1}$) is reached after 25 years and the maximum sawlog size wood MAI (5.7 $m^3 year^{-1}$, 20 cm top, under bark) after 60-70 years. The productivity of the dense naturally regenerated young forests is on a par with the commonly planted species in Nepal.

Keywords: *Shorea robusta* Gaertn.f., sal, Nepal, silviculture, growth, forest management

INTRODUCTION

Shorea robusta (common name sal) is a deciduous tree and belongs to the *Dipterocarpaceae* family. *S. robusta* forests mainly occur in two regions which are separated by the Gangetic plains. The northern region is a belt along the foothills of the Himalayas in India, Nepal, Bhutan and Bangladesh. The total area of *S. robusta* forests is more than 10 million hectares (e.g. Tewari, 1995). In the southern plains of Nepal, the Bhabar-Terai, *S. robusta* forests are dominant except in areas of very high rainfall where they are replaced by mixed forests. *S. robusta* forests cover most of the lowest fragile foothills of the Himalayas, the Siwalik Hills, and the valleys between them (Figure 1). Its maximum altitude in Nepal is about 1200 m (Shrestha, 1989). The total area of mixed *S. robusta* forests in Nepal is roughly 1.4 million ha, of which 238,000 ha are in national parks and protected reserves (Forestry Sector Institutional Strengthening Programme, 1993).

S. robusta is the most important tree species in Nepal. The natural *S. robusta* forests in the Terai were mainly untouched and unused until the 1950s. After that the government started large resettlement schemes in the Terai by clearing the forests for agriculture and eradicating malaria.

The timber of *S. robusta* is elastic, strong and durable. It is the main constructional timber in Nepal. It is used for making doors, window frames, planking, carts, and carvings, and in the past railway sleepers which were exported to India. *S. robusta* produces excellent firewood and good charcoal (Joshi, 1980; Jackson, 1994). The leaves of *S. robusta* are used for fodder and for disposable plates which are essential in various cultural and religious celebrations. The fat and oil from *S. robusta* seeds are commonly used as a substitute for cocoa butter and for cooking (Razzaque *et al.*, 1983; Bringi, 1988).

During the past decades the natural *S. robusta* forests in the Terai region have come under very heavy pressure from a rapidly growing population

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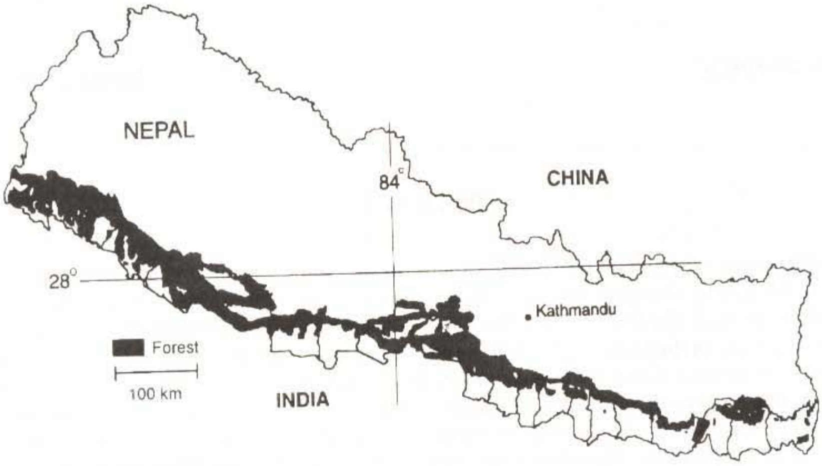


Figure 1. Location of the *S. robusta* forests in Nepal (Forestry Sector Institutional Strengthening Programme, 1993)

dependent on arable land and basic forest products. Uncontrolled and heavy grazing, intentional forest fires, and so called selection felling have led to deterioration of the forests. Despite good intentions, the fellings have led to "high-grading", i.e. they have been repeatedly carried out to a certain diameter limit (e.g. Pradhan, 1982) and the smaller and poor-quality trees which belong to less valuable species or are genetically inferior have been left in the forest. As a result of over-exploitation the natural *S. robusta* forests have become seriously degraded and the forest area is disappearing at a rate of 1.3 per cent per annum (Forestry Sector Institutional Strengthening Programme, 1993).

There are still 546,000 ha of natural forests outside the national parks in the Terai plains. The average volume of these forests is 144 m^3 ha^{-1}, of which 43 percent is *S. robusta* (Forestry Sector Institutional Strengthening Programme, 1993) (Figure 2). Handing over of forest areas to local communities through community forestry programme is the prevailing policy in the hill region. However, the large forests on the plains will be managed as national production forest blocks controlled by the Department of Forest. The aim of this study is to review the available information on the silviculture and growth of *S. robusta* and analyse the economic potential of these forests. Recent experience from the first silvicultural trials on *S. robusta* in Nepal are compared to past experience in India.

ECOLOGICAL REQUIREMENTS

The climate of the Bhabar-Terai of Nepal is tropical and sub-tropical with vegetation of the wet-monsoon type and a dry season lasting about 8 months. The mean annual precipitation is 1800 - 2200 mm, the mean temperatures of the warmest and coldest months are 31.4 °C in May and 15.1 °C in January. The absolute maximum and minimum temperatures are 44.9 °C and -2 °C respectively. Temperatures below 0 °C are very rare (Department of Irrigation Hydrology and Meterology, 1982).

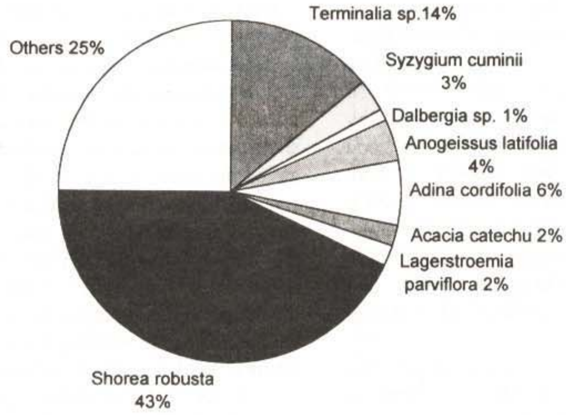


Figure 2. Proportional stem volume in the Bhabar-Terai of Nepal by species. (Forestry Sector Institutional Strengthening Programme, 1993).

S. robusta grows on a wide range of soil types. However, it avoids waterlogged, sandy and gravely soils which lie along rivers. *S. robusta* grows poorly on stiff clays, but it can tolerate nutrient deficiency (Griffith and Gupta, 1947), drought and mild frost (Joshi, 1980). It avoids limestone areas, but this appears to be because of the dry soil which is often found over limestone. As a whole, *S. robusta* is found in and on a wide variety of geographical and geological formations. It grows from the sub-Himalayan area, with a uniform geological structure consisting of older and more recent alluvial layers as in the Bhabar Terai of Nepal, to the south, where it reaches rocks and soils of different geological ages and physical and chemical composition and structure (Champion, 1933).

In the best sites *S. robusta* often forms pure stands. The tallest *S. robusta* trees in Nepal have reached a height of 45 metres with a diameter of 2.5 metres. The most common associates *of S. robusta* are *Terminalia bellerica, Terminalia tomentosa, Adina cordifolia, Lagerstroemia parviflora, Syzygium cumini* and in riverine forests *Acacia catechu* and *Dalbergia sissoo* (Figure 2). The braiding and meandering river systems flowing down from the foothills seem to play an important role in the early stage of succession of *S. robusta* forests. In some areas inside the large forest blocks of up to six river beds of different age and stage of forest succession can be detected (Salo, 1996).

NATURAL REGENERATION

Depending on the soil and climatic conditions, *S. robusta* starts fruiting at the age of 20-30 years. Good seed years usually occur every 3-4 years. Under natural conditions seeds will not remain viable for more than one week (Champion and Seth, 1968; Joshi 1980; Singh 1982). Germination and recruitment of seedlings is rapid (e.g. Suoheimo, 1995a). Seedlings that are exposed to unfavourable conditions such as fire, drought, frost and grazing frequently die back. The root system, however, remains alive and continues to send up new shoots. Many die completely, but normally a very strong rootstock develops which produces a shoot. Under suitable conditions the shoot continues to grow and eventually forms a tree. This process may take 3-30 years (e.g. Jackson, 1994; Matthews, 1989).

Dieback has been considered a major obstacle to *S. robusta* regeneration. For this reason *S. robusta* was placed on the list of endangered species in the Master Plan for Forestry Sector in Nepal, and plantations of faster growing species were recommended to replace the disappearing natural forests (HMGN/ ADB/FINNIDA, 1988). The annual dieback is by no means universal, however, and under good conditions the seedlings will produce a shoot which will continue to grow without dieback (Jackson, 1994; Rautiainen and Suoheimo, 1997). Because of the good coppicing potential of the *S. robusta* seedlings, regeneration is plentiful and establishment is fast if the seedlings are protected against fire and grazing.

The dieback seedlings are called seedling coppice (Joshi, 1980). The difference between stump or stool coppice and seedling coppice is that the former grows from the adventitious buds which arise on the stumps of the trees which have been felled, whereas seedling coppice is obtained from dormant buds below ground in the original hypocotyledonary region of *damaged S. robusta* seedlings. Thus seedling coppice is always of seed origin. There is a third type of regeneration from seedlings that have not died back. However, after regeneration felling more than 90 per cent of *S. robusta* seedlings have been reported to be of seedling coppice origin (e.g. Suoheimo, 1995a). *S. robusta* does not produce root suckers (e.g. Tewari, 1995). Even if the natural forests have been seriously degraded, the existing seedling coppice population, i.e. the rootstock in the soil, can serve as a seedling pool for a long period. This seedling pool can be an important reservoir of the original genetic variation in degraded forests.

SILVICULTURAL SYSTEMS

Indian irregular shelterwood and selection systems

Even though *S. robusta* is both economically and ecologically the most important tree species in Nepal, there is very little research data on its silvicultural systems in this country. However, has been studied and managed in India for over a century, and as a result there are plenty of *S. robusta* studies available in the Indian forest literature.

In India the irregular shelterwood system was recommended as the main method for *S. robusta* regeneration (Anon, 1960). A rotation period of 120-150 years was applied. Later on in India both the research and the management of natural *S. robusta* forests had to give way to plantation forestry. The Indian silvicultural systems affected Nepal as well because until the eighties most of the foresters from Nepal were trained in India. It seems that the Indian irregular shelterwood system as applied in Nepal was called the selection system. Both systems are for forests of uneven-aged structure and the practices are very similar. The main difference is that under the Indian irregular shelterwood system the regeneration fellings are confined to compartments or sub-compartments selected from the whole area of the working circle or felling series, whereas in the selection system the fellings are spread over the entire area annually (Parkash and Khanna, 1979). The exploitable diameter for *S. robusta* in Nepal was about 50 cm at breast height, and the felling was repeated after ten to twenty years in each felling series (e.g. Pradhan, 1982; APROSC, 1993). A further difference between the two systems is that under the Indian irregular shelterwood system regeneration is generally completed in about 60 years in the case of *S. robusta*, whereas in the selection system it is a continuing process throughout the life of the crop (Parkash and Khanna, 1979).

In Nepal, a true selection type of forest, in which all age and size classes and all species are mixed together over every part of the area, has proven very difficult to maintain in a sustainable way. As a result, the latest forest inventories in Nepal indicate that the uncontrolled selection system has destroyed the natural uniformity and degraded the ecological structure of the natural forests (Acharya and Seppänen, 1994; IUCN, 1995).

Uniform shelterwood system

At the beginning of this century the uniform shelterwood system was quite common in India but in the fifties it was concluded that the establishment of new seedlings could not be guaranteed (Anon, 1960).

The latest results in Nepal indicate that most of the existing mature *S. robusta* forests have abundant *S. robusta* undergrowth. For example, the forest inventory for Bara district (32,000 ha of forest) showed that 85 per cent of the forest area had recruited seedlings (Rautiainen, 1996). Trial plots established under the uniform shelterwood system have shown that this regeneration has the capacity to start growing fast if it is liberated from suppression and protected against fire and grazing (e.g. Rautiainen and Suoheimo, 1997). The trials in Nepal have also shown that if the number of recruited and established seedling coppice is sufficient, there is no need to leave any seed or sheltertrees in the regeneration areas, which is advantageous because *S. robusta* is a strong light demander.

Coppice systems and artificial regeneration

The first properly recorded experiments on artificial regeneration were started as early as 1896-1897 in India. *S. robusta* has mainly been regenerated artificially in taungya (agroforestry) plantations in combination with crops such as upland rice, maize, sesame and mustard. Good results have also been achieved with mixed plantations in which *S. robusta* is cultivated together with teak (Lamprecht, 1989). Planting or sowing of *S. robusta* has not been tested in Nepal on a large scale. Agroforestry trials started about 20 years ago were failures because the landless people temporarily resettled to cultivate the taungya area refused to move away, and the planted trees gradually disappeared.

Coppice systems have been practised in India for more than 100 years (Edie, 1913). Coppice systems are still the major systems of forest management in taungya plantations. Simple coppice and coppice-with-standards are the most common coppice systems (Lamprecht, 1989). In community forestry they have recently proved to be successful in the rehabilitation of degraded *S. robusta* forests in some Indian states. Because of the different objectives of the forest management, however, coppice systems with short rotations are not considered applicable to large scale national forestry strategies.

Trials on *S. robusta* coppice management which were started recently in Nepal show encouraging results on the natural regeneration potential of even the most degraded *S. robusta* forest areas (Tamrakar, 1994) (Figure 3 and 4). Such areas are normally near settlements and are suitable for fodder, fuelwood and other small size wood production. A uniform coppice system has been recommended for community forests because these are easier to manage and control than the selection system (Stewart, 1984).

GROWTH AND YIELD

S. robusta has been considered to be a slow growing species. According to old Indian growth and yield tables, the maximum mean annual increment (MAI) of stemwood of *S. robusta* is 3-11 m^3 ha^{-1} $year^{-1}$, depending on the site quality (Griffith and Sant Ram, 1943; Chaturvedi and Sharma, 1980). At the time when these tables were made, the rotation age was based on the requirement of the railways-every log had to yield two railway sleepers. Consequently, the rotation age was long, 90-150 years.

The MAI of stemwood of the existing, mainly uneven-aged, mixed *S. robusta* forests in Nepal has been estimated to be 3-6 m^3 ha^{-1} (Acharya and Seppänen, 1994). In many places, however, the actual net increment is much less due to rapidly expanding heart rot (Skarner and Sharma, 1995). The first measurements from the recently established permanent sample plots in Nepal to assess the growth and yield in uniform even-aged forests show much higher growth rates than the old Indian tables (Rautiainen, 1995).

A new *S. robusta* seedling in the year of germination may grow to a height of 20 - 40 cm. In the uniform shelterwood system the already recruited seedlings with a good rootstock start growing relatively fast after opening the canopy. According to the latest results in Nepal, the mean height of new generation in two years was 2.8 metres. The diameter growth in the open was as much as four times more than that of seedlings of the same size grown under canopy cover (Rautiainen and Suoheimo, 1997). It seems that if a well established seedling coppice crop can be protected from fire and livestock, the height growth can be about one metre per year.

The dependence of dominant height (H_{dom}, m) on stand age (T, years) for average site quality in these uniform stands has been described with a sigmoid equation (Rautiainen, 1995)(Figure 5).

$$H_{dom} = 38 / (1+81.941T^{-1.48})$$

Height growth is faster than that given in the tables for natural *S. robusta* I, site quality I/II in India (Griffith and Sant Ram, 1943), but somewhat slower than that for planted *S. robusta*

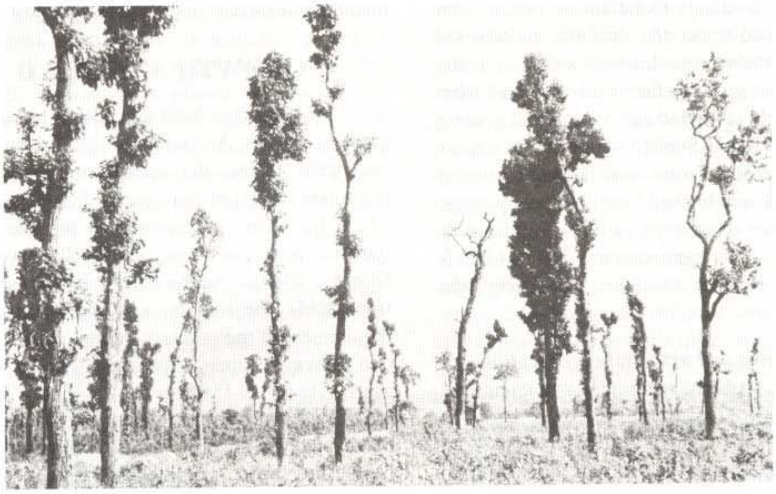


Figure 3. Degraded *S. robusta* forest with a good regeneration potential.

Figure 4. Same forest area as in Figure 3 after 6 years of protection. Stocking 7300 stems ha^{-1}, standing volume 84 m^3 ha^{-1}, mean annual increment of stemwood 18 m^3 ha^{-1}.

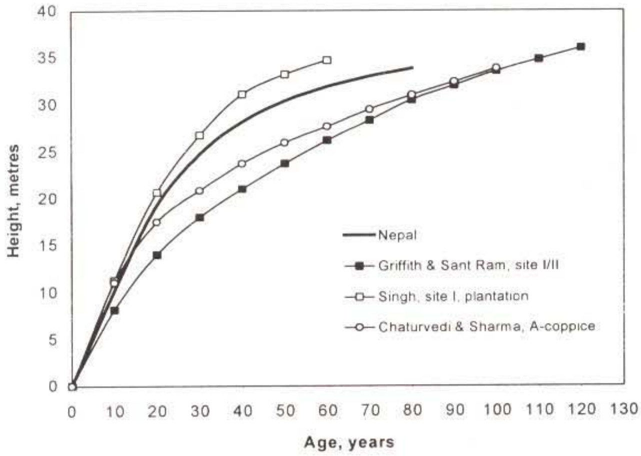


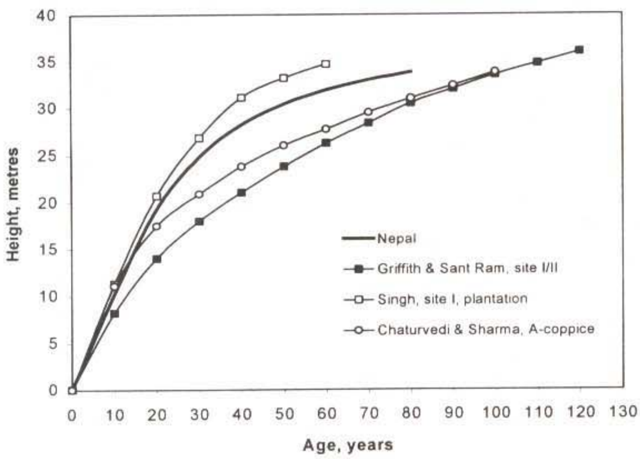
Figure 5. Development of dominant height of *S. robusta* in even-aged stands in Nepal compared to some Indian growth series.

on the best site quality in West Bengal (Singh, 1968).

Models have been made of the development of the number and mean diameter of stems, and used to compile yield tables for even-aged stands in the Bhabar-Terai (Rautiainen, 1995). Naturally regenerated young *S. robusta* stands are normally very dense, often having more than 10,000 stems ha^{-1} at the dominant height of 5 metres. The high initial density facilitates a much higher total woody and foliage biomass production than the normal plantation density of 1600 stems ha^{-1}. The standing stem volume reaches 100 m^3 ha^{-1} in ten years. The maximum mean annual increment of stemwood (15 m^3 ha^{-1}) in even-aged *S. robusta* forests is reached at the age of 25 years (Figure 6), and the maximum saw log size (top 20 cm, under bark) wood production at about 60 - 70 years (5.7 m^3 ha^{-1}). The old Indian yield tables for natural and coppice forests (Griffith and Sant Ram, 1943; Chaturvedi and Sharma, 1980) suggest much longer rotations and lower growth rates at a young age (Figure 7). The main factors explaining the difference between the Indian and Nepali data are probably that the even-aged forests grow free from suppression by big trees, and that the stocking in these forests is very high from the beginning because the plots were deliberately chosen in the fully stocked stands and special attention was given to small size wood production, i.e., to the needs of the local people. Moreover, in the Nepalese tables the age of the stand is defined as the years after starting protection, i.e. the dieback period is not counted, whereas the Indian data reflect the forest management practices normal at that time. The production of sawlog size wood in plantations (Singh, 1968) (Figure 7) conforms quite well to the Nepalese estimates. Nevertheless, uniform young *S. robusta* crops seem to produce much more biomass than acknowledged until now.

DISCUSSION

During the last 40 years, neither the Indian irregular shelterwood system nor the selection system in Nepal solved the establishment problems of *S. robusta* regeneration. However, the dieback of *S. robusta*, which has been considered to be a notorious and negative factor during the regeneration phase (e.g. Maithani *et al.* 1989; Tewari, 1995) is actually an exceptional ability representing a power to survive and regrow following damage as a result of exposure to harsh



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Young dense *S. robusta* forests growing free from suppression, forest fires and grazing can achieve growth rates in the Terai comparable to those of plantations of exotic or indigenous species. The maximum MAI estimated for planted *Dalbergia sissoo* on the best sites varies from 19.2 to 20.7 m^3 ha^{-1} in 11 - 13 years (HMGN/ ADB/ FINNIDA, 1988; Pukkala, 1990). The mean annual increment (MAI) estimates for *Eucalyptus camaldulensis* in the large plantations in Sagarnath, Nepal, were only 12.6 m^3 ha^{-1} in seven years (Pukkala, 1990). Although 33 months after the establishment of these plantations the recorded MAI in some areas was 14.6 m^3 ha^{-1} (White, 1986). Growth measurements for *Tectona grandis* in Nepal are very scanty, but a standing stem volume of 152.5m^3 was measured in one 10.5 year old stand. This is equivalent to an MAI of 14.5 m^3 ha^{-1}, excluding the light thinning at seven years (Joshi, 1982). All these growth rates were obtained with a normal planting density of 1200-1600 stems ha^{-1}. In naturally regenerated *S. robusta* forests high growth rates were observed only when the initial stocking was much higher than that.

In Nepal the demand for small size wood calls for finding a compromise between maximum total biomass production and high quality timber production. Traditionally, the national forests in both India and Nepal have served the goals of the national economy, which has meant the adoption of long rotations and large size final products. *S. robusta* coppice management experiences in India have shown that a rotation of 10-15 years could be suitable for pole production (Guhathakurta, 1992), and in Nepal coppice trial areas have produced 50.1 green tons biomass in four years (Tamrakar, 1994). As railway sleepers are no longer the main product of *S. robusta* timber, the rotation age in high forest systems could also be brought down to 60-70 years (Rautiainen, 1995) or even to 40 years (Bhatta, 1995). A combination of short coppice rotation forests and rotation for timber production would be a safe option to fulfil the multiple objectives. However, the data on market prices for different products is too sparse for calculating economically desirable rotations in Nepal.

The population residing within or near the Bhabar-Terai forest zone in Nepal is roughly 10 million (Central Bureau os Statisticts, 1995), and almost all of the people depend to some extent on the productivity of these forests. A conservative estimate of per capita fuelwood consumption from the national forests in the Terai is 500 kg $year^{-1}$ (Gautam and Thacker, 1994; Koirala, 1995) which gives a total consumption of 5 million tons $year^{-1}$. The estimated annual growth rate of woody biomass in the remaining 1.4 million hectares is about 4.5 million tons $year^{-1}$. The effect of tree fodder collection on the productivity is not included in these estimates. Thus, the supply demand balance is negative, and if the productivity of the forests cannot be improved the decline of the natural forests is bound to continue.

Nepal is one of the poorest countries in the world. Despite their rapid degradation, the remaining natural *S. robusta* forests could have a significant role in the development of Nepal's economy. The average market price of *S. robusta* timber in the domestic market is about 200 USD m^{-3} (Kanel, 1994), and international demand for high quality hardwood could make it possible to start exporting sawn material or other products. If all of the 300,000 ha suitable for production forests (Kotimäki, 1994) were put under active management, the expected annual government royalties and taxes would rise to NRs 2,000 million (36 million USD) in ten years (Pesonen and Rautiainen, 1995). This is twelve times more than collected now from all the forests in Nepal, and it would cover about one fourth of the foreign loans of Nepal. The total market price value would reach NRs 3,900 million (70 million USD) per year within the same period.

CONCLUSIONS

With a change in the forest management strategy it is possible to improve the production capacity of the natural forests in the Terai. It would be environmentally more sound to rely on the indigenous species and natural regeneration than to establish plantations of exotic species. The new, more sustainable strategy of forest management would satisfy the needs of rural people for forest products. If the existing degradation and destruction of the natural forests continues, however, millions of rural people dependent on forests will lose their sources of food, fuel, fodder, raw material for village industries and medicines.

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