Forestry in the Himalayas
How to Avert an Environmental Disaster

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High population levels and the mismanagement of land have led to serious environmental problems in the Himalayan region. Rooted in cultural and political history, forestry policy and local agricultural practices have resulted in the degradation of much of the forests used by villagers for fuelwood and for grazing livestock. Stripping the land of forests has led to increased erosion of the mountains and to siltation and flooding of waterways and prime agricultural land during the summer monsoons. Two models are here used to determine the area of forest required now and in the future for different projections of population levels. On the basis of current data for the Central Himalayas, it is shown that if appropriate population control and forest land and livestock management policies are adopted and implemented immediately, it may still be possible to repair the environment and avert a social and economic disaster.

The highest mountain system in the world, the Himalayas, stretches in a 2400-km arc of up to 300 km in width, separating northern India from the plateau of Tibet. At its base is the world's largest alluvial plain, one of the most fertile regions in the world and the breadbasket of India. The Himalayas rise in steps to the north and reach elevations well in excess of 7000 m. Almost every type of climate can be found in these mountains, and a wide variety of flora and fauna form a gradient from tropical vegetation to alpine meadows (Singh, 1971).

The Himalayan watershed is essential to the well-being of the 900 million people living on the Indian subcontinent (Gupta and Bandhu, 1979 and Moddie, 1981). Each year between the months of June and September, the monsoon brings with it rainfall varying from 75 mm in parts of Kashmir to 5000 mm in the northeastern states of India. It is well known that much of this rainfall is caught by the Himalayan forests, which supply the foothills and the plains with a continuous source of water throughout the following dry season. Also significant is the strong likelihood that a major part of this rainfall may be caused by the same forests, as recent research by Professor Salati and his associates in Brazil suggests (Weber, 1983).

Depletion of Forests

With the depletion of the forests in the Himalayas, many previously perennial hill streams are now dry for much of the year. Increased flooding during the rainy season and extended periods of drought are afflicting the northern plains. An examination of data on flood damage in India from 1953 to 1979 (Centre for Science and Environment, 1982, p. 62) reveals that the average annual area of cropland inundated and the value of damage in constant dollars has been increasing at the rate of 4 and 6% per annum, respectively,[1] from the 1950s to the 1970s.

Being a young mountain system, the Himalayas are subject to significant amounts of erosion. The once dense forest cover of the Himalayas helped maintain a shallow layer of topsoil by increasing its water retention capacity and reducing surface runoff and soil erosion. But now enormous quantities of sterile detritus are washed off the mountainsides, silting harbours, reservoirs, and riverbeds, and spreading over prime agricultural land in the rainy season. Annual rates of siltation in most of the reservoirs in India are 146 to 874% of the figures assumed at the time of construction. For the Ramganga reservoir in the Gangetic watershed the figure is 419%, shortening its expected lifespan by a factor of four (Centre for Science and the Environment, 1982).

The primary reason for the increasing floods and soil erosion is the large human and livestock populations now living in the Himalayas and the resultant depletion of the forest cover. Thousands of villages are scattered throughout the Himalayas, and, although there is a wide variety of land uses, the dominant pattern is that existing in the Himachal Pradesh (HP) and Uttar Pradesh (UP) states of India and in Nepal. Here, the majority of villagers farm small plots of terraced land (Figure 1) and depend on the forest for their very existence. Forests are required not only for meeting the fuelwood and timber needs of the farmers, but also for providing fodder and grazing for their livestock, which in turn produce dung for manuring the fields. Without the nutrients and the improvement in the texture and moisture-retaining properties of the soil provided by manure, the light and shallow soil of the Himalayas yields hardly any crops (Jackson, 1981). Every hectare of

Figure 1. Terraced fields in the Himalayas. (Photo: Courtesy Forest Research Institute, Dehra Dun.)

cultivated land thus needs many times more uncultivated (forest) land as 'support area' (Ashish, 1982). Human and cattle pressure on the support area has depleted tree cover, reduced the productivity of land and generally impaired the economic condition of the region.

No Self-Regulation

Observers have noted that there are no self-regulatory forces, as in natural ecosystems, that will prevent the destruction of forest and grazing lands in the Himalayas (Jackson, 1981). The situation has cataclysmic implications, for the inhabitants both of the Himalayas and of the plains below. The yearly losses of life, property and agricultural produce due to floods in the northern plains are steadily increasing. There is even a risk that exceptionally heavy rainfall could trigger massive erosion in the Himalayas such as occurred in Sikkim at the end of September 1983. However, there may still be a reasonable chance of restoring the ecological balance of the Himalayas by increasing forest cover and changing the lifestyle of the people if there is sufficient political will to do so. In this review we investigate the present and future requirements of forest area in the Central Region of the Himalayas, the eight hill districts of Uttar Pradesh which lie between Himachal Pradesh and Nepal (Figure 2), and suggest a strategy for the solution of the problems. In 1981 there were 15 003 villages in this region of 51 000 square kilometers with a population of 4.78 million (Planning Commission, 1982). About 64% of the villages had a population of less than 200, and only 90 (or just above 0.5%) had a population of more than 1500 inhabitants (Hill Development Department, 1982). The headwaters of the Ganga River, which provide water for most of the northern plains, flow from the region.

The problem of providing sufficient forest cover in the Himalayas is not merely technical in nature; it requires a plan of action that can win the support of the local population. Bearing this in mind, we examine two rather simple models that describe the minimum and maximum areas of forest needed to support the human and livestock population with assumed declining rates of population growth and given per capita fuelwood requirements. In view of the fixed land base and poor productivity of the region, these models emphasize the necessity of reducing population growth, prompt re-forestation of uncultivated lands, and management of existing forests primarily for fuel and fodder production. Though not based on the models, other suggested

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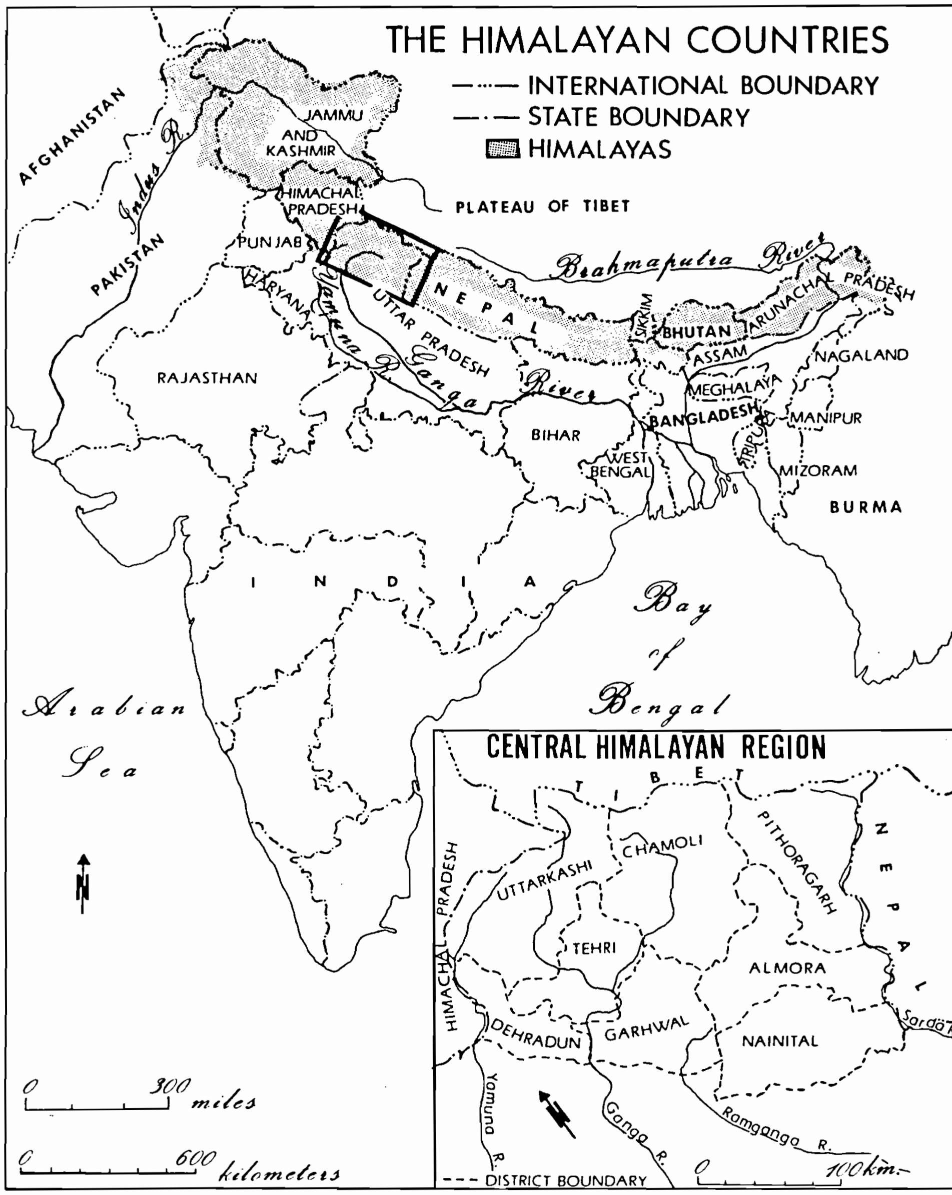

Figure 2. The Himalayan countries.

actions are the reduction in the number of grazing and browsing animals by substituting stall feeding, and reducing the area under grain production while increasing food supplements from more productive regions of India.

History of Forest Use

The mountain valleys of the Central Himalayas have been inhabited for over 1700 years, but when the first British explorers arrived at the turn of the 19th century, the region was sparsely populated and the forests seemed to be an endless source of timber wealth (Tucker, 1982). Under British rule, colonial administrators worked vigorously at transforming not only the lowlands into a prosperous agricultural economy, but also the interior, the hills. Extension of agriculture by clearing the forest was encouraged. There was virtually no control over tree cutting, and for many years there was no system of fire protection.

The resulting population increases were looked on with pride as achievements of the British Raj. By the 1850s, most of the best forests at lower elevations had been cut over. By the end of the century, the forest area is estimated to have been reduced by half (Jackson, 1981). The stable ecological balance established over centuries between man and his use of land, which consisted of forestry, agriculture and animal husbandry, was disturbed. Inadvertently, the population was being encouraged to grow beyond the limit the fragile environment could tolerate.

A growing scarcity of railway sleepers led to the Indian Forest Act of 1878. Under this law, forests to be managed on a sustained-yield basis by the Forest Department for timber production were designated 'Reserved Forests'. The villagers did not benefit directly from the main crop of these forests, where the objective was commercial timber production. Major parts of the coniferous forests in the Central Himalayas and substantial portions of the broad-leaved forests were reserved by the end of World War I.

Contradiction and Resentment

Relations between foresters and villagers became increasingly strained whenever a new area was placed under the Forest Department's jurisdiction. This was largely the result of contradictions in British policies. On the one hand, extension of agriculture and the consequent growth of population was being encouraged, and on the other, access to much of the remaining forest was being limited so as to ensure commercial timber production. No effort was made to change traditional agricultural practices, and this led to overuse of the forests that were available to villagers. These contradictions have essentially continued to the present.

Resentment against the colonial regime's seemingly arbitrary regulations and other injustices reached a climax in 1921 when thousands of acres of forest were suddenly ablaze in the hills of the present Uttar Pradesh state (Tucker, 1982). Despite some conciliatory action by the government, as the population continued to grow, people found that 'support areas' were not sufficient for their use. Distrust of the Forest Department therefore continued.

Beginning in the 1930s, some common forests near villages were placed under the management of special village councils, or *panchayats.* Due to lack of unity of purpose amongst villagers, *panchayat* forests were not always well managed, and in many places where they appeared to be so, it was only because the villagers exercised their rights of grazing and collection of deadwood and fodder in nearby Reserved Forests, thus preserving *panchayat* forest at the cost of government forest.

Increased Exploitation

After Independence in 1947, the resources were used with a new aggressiveness for economic development. Thus, those village forests (known as 'Civil and *Soyam* Forests') administered by the traditionally powerful Revenue Department were converted to agricultural land at a faster pace. In the 1960s and 1970s, commercial logging roads and strategic military roads for defence were extended to the higher altitudes below the tree line, opening up vast areas to exploitation (Tucker, 1983).

However, over the last fifty years, the forests which suffered most are those near the villages, mainly those outside the Reserved Forests (Tiwari, 1983). Valuable fodder-providing oak forests have been largely depleted, due to lopping for the increasing cattle population in the villages and the demand for charcoal in the growing district towns (Figure 3). By the 1970s, the shortage of fuel and fodder had become so severe that local women in certain areas refused to allow the felling of any trees, particularly those of broad-leaved species, for commercial purposes. This movement, known as *Chipko Andolan*, was partly responsible in the early 1980s for the state of Uttar Pradesh placing a moratorium on all timber cutting above the foothills.

At present, land use in the Central Himalayas varies from intensely cultivated agricultural land in a few valleys to well-stocked forest, with various shades of depleted vegetational cover in between (Figure 4). According to government records about two-thirds of the total land area is still classified as forest. But estimates from satellite images indicate that good forest cover may actually be less than 40% of the total area. We summarize in Table 1 two estimates of areas under different types of land use so that the reader may form his own opinion about the true state of affairs. These estimates help in arriving at some conclusions in the later parts of this paper.

Challenges to Foresters and Planners

The present dilemma faced by planners is to a large extent the result of their inadequate response when the first danger signals began to appear. The major factors contributing to this failure were the Forest Department's commercial, rather than local, orientation and, secondly, the lack of management of forests outside the Forest Department's jurisdiction with the aim of meeting the long-term needs of local inhabitants. Even after the authorities recognized[2] that the forests were quickly depleting and that erosion was increasing, there was no unified land management strategy that sought to reconcile agricultural and forestry use of land, and to address the problem posed by the Himalayas in its totality.

In the past, timber cutting in the Himalayas seemed desirable for progress, and ecology did not seem to be a problem. Today, however, attention must be directed towards averting ecological collapse, while meeting the requirements of a still-growing population. The first major challenge, therefore, lies in devising a solution that will meet both needs.

Today there is a wood shortage in the Himalayas that is so severe that in most areas one able-bodied member of a household is assigned to collect fuel and must typically travel several miles every day[3] over difficult terrain to do this (Figure 5) (Planning Commission, 1982). As a result government forests are becoming more difficult to maintain, because it is common for villagers to steal green trees for fuelwood, although their rights are restricted to deadwood. Thus, the only way to protect the forest cover of the Himalayas is to manage the government forests for villagers' needs. To meet the challenge outlined above, traditional approaches to forest management must be replaced by flexible responses; neither the boundaries of government forests nor the policy of

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Figure 3. Heavily lopped and grazed oak forest leading to soil erosion. (Photo: Courtesy Forest Research Institute, Dehra Dun.)

sustained yield and commercial forestry can be treated as unchangeable any longer.

Classical sustained-yield management has been almost a synonym for good forestry (Smith, 1969), but good forestry is management of forests so as to meet best the needs of the communities and of the nations that they serve. Under a superficial and short-run view, the needs of communities and the nation may seem to be opposed to each other. However, a comparison of the value of fuelwood and fodder with the value of railway sleepers, other timber and pulpwood is oversimplified and shortsighted. Unless local needs are adequately fulfilled, the overall timber supply position in the long run and the soil erosion and flood problem, even in the short run, will worsen and jeopardize the national interest. The long-run

Figure 4. Well-managed forest and terraced cultivation. (Photo Courtesy Forest Research Institute, Dehra Dun.)

needs of both the nation and the community are served only by maintaining a balance in the environment.

Fuel Wood and Population Growth

The objective of forest management in the Himalayas must therefore be reducing soil erosion with a very aggressive re-forestation program and meeting the increasing fuelwood, timber and fodder requirements of the local population. The Forest Department must sacrifice its goal of building an age-class distribution towards which it has been working for the past 50 years or more and ensure immediate and increasing future supplies of fuelwood to villagers. It must also relegate the objective of commercial timber production to a lower priority.

A second major challenge facing policy-makers is to reduce the rate of population growth. The overall

Figure 5. Carrying fuel from heavily grazed and lopped forest in Nepal. (Photo: Courtesy David Wells, Toronto.)

Table 1. Land use pattern of the Central Himalayan Region

Source	Area (km^2)
As classified[a]	
Village forest[b]	10 000 (19.5%)
Government forest[c]	
reserved	23 800 (46.4%)
municipal	230 (0.5%)
Total productive forest land	34 030 (66.6%)
Noncultivable land and land not available for cultivation	7 931 (15.3%)
Cultivated and Fallow land	9 251 (18.1%)
Total	51 112 (100%)
As estimated from satellite images	
Forest	
Poor cover[d]	8 281 (16.2%)
Good cover[e]	20 291 (39.7%)
Total productive forest land	28 572 (55.9%)
Rock, Snow, Alpine pastures[f]	13 289 (26%)
Cultivated agricultural land[g]	9 251 (18.1%)
Total	51 112 (100%)

[a] Based on Planning Commission (1982).

[b] This area is what remained with the villagers after reservation of forests under the Indian Forest Act. About 7600 km^2 of it is known either as Civil or *Soyam* according to usage. The remaining 2400 km^2 is managed by *panchayats* for providing fuelwoods, fodder and timber for local use. The Civil and *Soyam* forest is for the most part of poor density, misshapen trees and heavily grazed. *Panchayat* forests are sometimes better.

[c] This area is managed by the Forest Department on a sustained-yield basis to produce railway sleepers and other commercial products. Except for specified grazing, fodder, fuelwoods, and timber rights, local villagers do not derive any direct benefit from them. This area is generally well maintained, but figures include some permanent snow, alpine pastures, and many steep slopes that cannot be logged.

[d] Estimated as residual after deducting good forest cover, rock and snow etc., and cultivated land. Most of this area is village forest.

[e] The area considered forested by Gupta (1979) on the basis of satellite images. Most of this area is government forest.

[e] Gupta (1979) estimated this area to be 28% of the total area, and Ashish (1981) estimated it to be 26%. We have taken the lower figure.

[g] This figure has been taken to be identical to that given in government records because such records are quite accurate for agricultural area, while satellite images cannot easily distinguish between cultivated land and other bare land. An appreciable part of the cultivated land is in the valleys between the Outer Himalayas and the Siwalik foothills (Dehra Dun District) and even in the plains south of the Siwaliks (Naini Tal District) because the boundaries of these administrative districts, for which data are given, do not coincide with the topographic boundaries of the hill region.

population density in the UP hills is only 94 people per km^2 compared with 377 per km^2 for the entire state. But there are 17.6 people per cultivated hectare in the region as compared to 2.3–5.8 for the rest of the state which is more productive (G. B. Pant University, 1982). According to the Planning Commission (1982), virtually no Class 1 or Class 2 soils for agriculture remain in the Himalayas. The average family's grain production in the UP hills provides only about seven or eight months' food in the year, which means that many families obtain considerably less (Ashish, 1982).

Consequently, almost 60% of the male working-age group migrates to the plains and sends money home for the purchase of food grains brought from the plains (G. B. Pant University, 1982). This outflow has, ironically, resulted in a higher resident population in the hills than would otherwise have been possible. Thus, despite the emigration, the resident population of the Central Himalayas is increasing at the rate of 2.3% per annum (Planning Commission, 1982). As a result, the Himalayan region is not only among the poorest in India – about half of the population lives below the poverty line – but its rural environment is deteriorating fast.

Overpopulation has resulted in excessive fragmentation of landholdings. Land is usually divided among sons. In some cases the landholding of a single farmer may comprise 25 separate and widely dispersed plots of poor productivity. Meanwhile, most farmers try to maintain two bullocks, which may work for as few as 12 days each year and may be needed to plough as little as 0.4 ha (Ashish, 1980). In its attempts to increase food production, the resident population tries to maintain more livestock for dung and thus increases the pressure on forest areas.

Neither the local political leadership nor any government department (such as the Departments of Forest, Revenue, Agriculture or Education) has done much to explain the true nature of their predicament to the villagers. Because a certain amount of forest is essential for a given population, and because the total land area is limited, a vigorous population control policy is at the core of the problem. But in the light of the backlash against earlier overzealous attempts at population control, a sustained and imaginative policy is needed and must be implemented with justice and humanity, and supported by school and college education.

Livestock Causing Scrub

A third major challenge involves changing the land use practices of a society steeped in tradition. These practices revolve around livestock. Between 1972 and 1978, the number of livestock increased from 3.9 million to 4.1 million, an annual increase of 2.05%. However, almost all of the increase has been in the population of goats. The bovine population has perhaps reached its maximum in terms of what can be supported by existing fodder resources (Jackson, 1983), but the ubiquitous and all-devouring goats can still go on increasing in number. While other animals can be stalled and damage minimized, goats are notoriously difficult to manage by stall-feeding.

The freely grazing livestock on the common uncultivated land and forest near the villages eat and trample on tree seedlings, and thus check regeneration. This continuous pressure and the selective feeding habits of livestock cause a regression of forest to scrub (Figure 6) with sparse and inferior grasses (Smith, 1974, Jackson, 1981). In fact, Shah (1981) estimated that within 60 years the entire vegetative cover of the Central Himalayas could be destroyed.

Ever-widening circles of village forest pasture are reduced to a state of low productivity. According to Spurr and Barnes (1973), 'Around the world grazing by livestock has probably been more important than any other factor in reducing the productive capacity of uncultivated land.' In the Himalayas, areas in which grazing has been stopped can produce 3-4 times more grass and fodder for hand cutting (Ashish, 1981), and re-forestation with fodder species of trees can double yields of even the best grassland (TWP, 1980).

In a careful study, Jackson (1981) demonstrated that the Himalayan system of agriculture is operating far below its carrying capacity. He showed that the productivity of uncultivated land can be restored by reducing grazing and introducing stall feeding. Stall feeding also has the added advantage[4] of increasing the amount of dung that can be collected.

Halt Grazing

In a comparison of grazed and ungrazed woodlots, Steinbrenner (1951) found that the water permeability of soils was reduced by 90% due to compaction by grazing animals. When the surface organic layers and the soil aggregates are intact, infiltration rates usually exceed even heavy rainfall rates, thereby preventing surface runoff (Smith, 1974 and Armson, 1977). However, grazing and trampling increase runoff and erosion of the topsoil. Because it takes from 500 to 1000 years to replace one inch of topsoil in the Himalayas, every effort must be made to replace grazing with stall feeding, which will conserve the soil and reverse the rapid decline in vegetative cover.

Grazing is also responsible for grass fires often used by villagers to encourage sprouting of succulent green

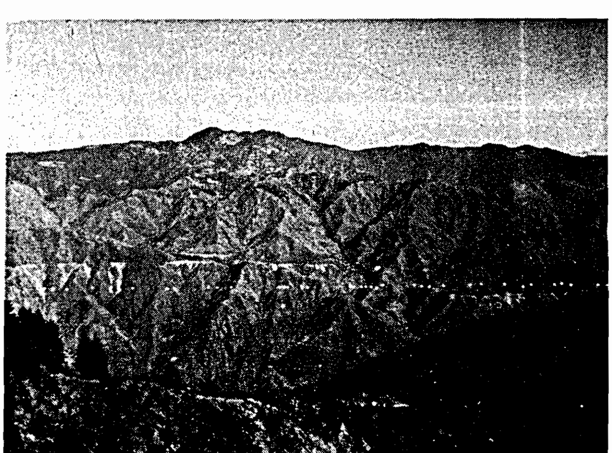

Figure 6. Grazing reduces forest areas to scrub. (Photo: Courtesy Bill Aitken, New Delhi.)

grasses. This practice weakens the grasses, hastens erosion (Kowal, 1966) and causes the spread of fires, damaging neighbouring forests.

Thus, there are many good reasons for discouraging grazing. In addition, with the exception of pastures above the tree line, forest, and not grassland, is the natural vegetative cover of the Himalayas. For an environmentally sound rural economy, Himalayan livestock must, therefore, depend on tree fodder, not grassland.

Yet, even if a villager were aware of the destructive effects of his livestock, as an individual he is unable to change the grazing practices because the village forest is common property, and mutual jealousies and distrust preclude joint action to bring about change. Education is the most effective means of overcoming peasant resistance to change which disturbs long-established customs. This third challenge to the improvement of land use practices in the Himalayas can be met only if the value of good land management is taught to schoolchildren. Greater involvement of the women of the hills in all decisions affecting land use will also go a very long way in changing poor practices, since it is the women who are primarily responsible for agriculture, fuel and fodder collection, and the maintenance of livestock.

Perhaps the most direct solution would be to reduce agricultural practices that require the use of the plough in the Himalayas, and return the pastureland to forest cover. This may be the only lasting solution, given the staggering population increase in the fragmented landholdings. Food imported from the plains could be used to subsidize this effort and could be treated as an investment to prevent flooding and heavy crop losses.

The final challenge is the development of an integrated approach to the whole question of the Himalayan environment. All of the efforts of the foresters will be futile if the population does not stabilize and farming methods do not change. Also, no change in land use patterns is possible unless the foresters modify their existing ideas and objectives and permit such change to take hold.

Forest Requirements: Two Models

While the central theme of land management in the Himalayas is soil and water conservation, its most important facet is the maintenance of forest cover. Table 1 summarises the land use pattern in the Central Himalayas. The total productive forest land is no more than 34 030 km^2 (66.6%) and may amount to only 28 572 km^2 (55.9%). Some of it is less than fully stocked, while some is protected forest. Therefore, we will use both the official area figures and the satellite estimates for our analysis.

In order to determine the forest base needed to provide for the fuelwood and fodder requirements of the Central Himalayas, we have examined two hypothetical situations that represent the extremes of actual possibilities. The first, called the *Old Forest Model*, assumes that the existing forest is in such state of stocking, regeneration and age-class distribution that enough area of 100-year-old Chir pine (*Pinus roxburghii*) trees will be available each year to meet the fuelwood needs of the increasing population, given that it will eventually stabilize at some predetermined level in a given number of years.

The second, called the *New Forest Model*, assumes that there is no forest available in the beginning and Chir pine has to be planted to meet the needs. In order to reduce the waiting time before such plantation could yield usable firewood, a certain proportion of the total area afforested is planted with a fast-growing exotic tree species, but eventually the entire area is to be put back under Chir pine cover.

Fuel Wood Needed

For both the models an average per capita fuelwood requirement is needed. No reliable information is available on this subject, but the national average is about 1.5 kg per person per day. Our models therefore calculate the area requirements for four possible per capita fuelwood consumption values. We consider 2.5 kg/day to be the most realistic[5] for the Central Himalayan region.

We have chosen Chir pine as the species for making our yield calculations. This has been done in spite of the fact that villagers would prefer to plant broad-leaved species, such as oak, which can be used for fodder. However, Chir is the only species that can be established on most degraded sites, and, if protected from grazing, grass cover and an understory of shrubs and broad-leaved species can grow under it. Such undergrowth is as important as tree cover for preventing soil erosion (Gaston, 1983). Chir also has a heat value of 5 million calories/kg, which is higher than oak, and its yield function is readily available. We also estimate the fodder forest area in addition to the Chir forest area required for fuelwood. Figure 7 illustrates the yield curve for Chir pine growing on Site Class 3 land. We believe that the average site class for the entire region is not very different from Site Class 3.

The mean annual increment, MAI, curve shown in Figure 7 represents the average volume produced each year, given the age at which a stand of trees is harvested. For convenience of graphical representation, the MAI curve shown is 100 times the scale given for the yield curve on the vertical axis and shows that Chir pine is most productive if harvested at the age of 100 years.

If forests are fully stocked, and harvested crops are 100 years old, Chir pine would have an average annual yield of 625 m^3/km^2. At a wood density of 0.6 g/cm^3, 2.5 kg/capita/day is equivalent to a demand of 1.52 m^3/capita/annum. Given the 1981 population of 4.78 million, this indicates that in that year an equivalent of 116 km^2 of 100-year-old Chir pine forest had to be harvested to meet the demand for fuelwood. The minimum area that can maintain this annual output continuously is 11 628 km^2 of productive forest, which is 34% of all area classified as forest. This is slightly greater than the area of degraded Village Forests (10 000 km^2) from which villagers must obtain their fuelwood. If population increases and fodder requirements are taken into account, the entire area of Village Forest, where productivity is considerably less than that of our yield assumptions, would soon be depleted.

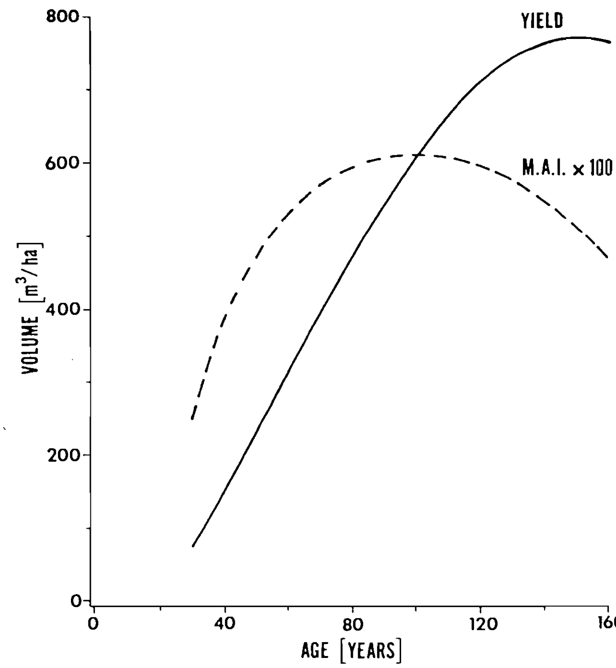

Figure 7. Yield and mean annual increment, MAI, curves for Chir pine, site class 3.

Reduce Population Growth

Figure 8 shows that if the rate of population growth were to continue at 2.3% per annum, the population of the Central Himalayas would grow from 4.78 million in 1981 to more than 40 million within 100 years, this being the time required for a Chir pine tree to reach its highest productivity. At this rate of population growth, the demand for fuelwood would outstrip the forests' maximum sustainable yield in 25 years, given the estimated existing good forest (20 291 km^2); in 32 years, given the land under government forest (24 030 km^2); in 48 years, given the entire area now classified as forest land (34 030 km^2); and in 66 years,[6] even if the entire region (51 112 km^2) were available for eventual re-forestation so as to form the 'normal' age-class distribution[7] of forestry literature.

It is evident that there must be an immediate effort to reduce the rate of population growth. In Figure 8, four alternative possibilities are presented, covering a range of annual reductions in the population growth rate (2.3% in 1981) from 0.015 percentage points to 0.04 percentage points. Under these strategies, the population ultimately stabilizes at a particular level

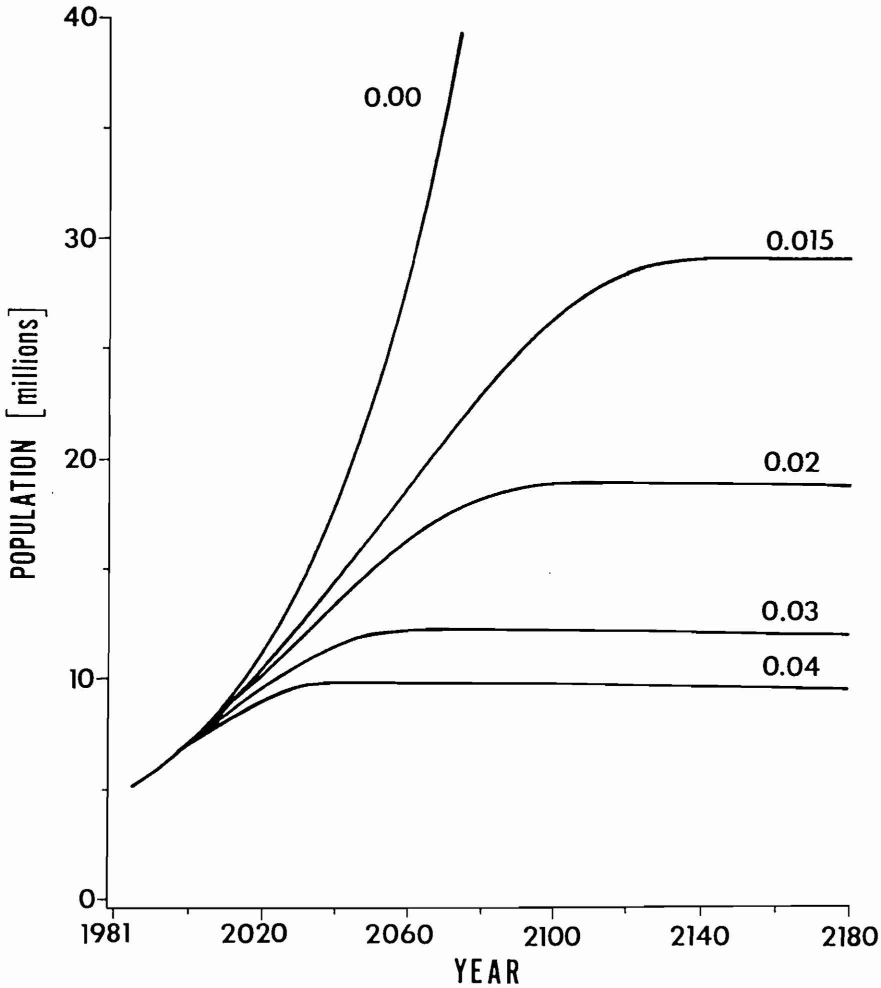

Figure 8. Population of the Central Himalayas projected at specified rates of reduction (percentage points per year) in the 1981 population growth rate.

since a negative growth rate has been precluded. The final population levels are reached in from 58-153 years.

Table 2 shows the final demand level for fuelwood for combinations of the daily fuelwood consumption per capita and the rate of reduction in population growth. These figures are then used to determine the minimum area of an 'old forest' that will be required to meet the maximum demand level for fuelwood based on the assumption that eventually 100-year-old crops will be harvested each year. Results are presented in Table 3.

Fodder Needed

In each model, the area required for fodder must be added to obtain the total forest area required for both fuel and fodder. On the assumption that all livestock can be stall-fed and that forests are managed efficiently, Jackson (1983) estimated a ratio of 3:1 for fuelwood and fodder forests in the Central Himalayan region. Taking this estimate to be reasonable, and assuming an annual fuelwood consumption of 1.52 m^3/capita/annum, the fodder forest requirement for the four population growth scenarios are

Table 2. Projected long term fuelwood requirements

Annual reduction in population growth rate (%)	Number of years to stabilized population	Final population level starting from 4.78 in 1981	Fuelwood Requirement (10^6 m^3) (Daily per capita fuelwood consumption kg) 1.5 (Annual per capita fuelwood consumption, m^3) 0.91	2.0 / 1.22	2.5 / 1.52	3.0 / 1.83
0.015	153	29.5	27.0	36.0	44.9	53.9
0.020	115	19.2	17.5	23.4	29.2	35.1
0.030	77	12.4	11.3	15.1	18.9	22.7
0.040	58	10.0	9.1	12.1	15.2	18.2

Table 3. Old Forest Model: Minimum forest area needed to meet long term fuelwood and fodder requirements for a 1981 population of 4.78 million

Annual reduction in population growth rate (%)	Number of years to stabilized population	Final population level starting from 4.78 in 1981 ($\times 10^6$)	Fuelwood consumption per person (Daily fuelwood consumption kg) 1.5 (Annual fuelwood consumption in m^3) 0.91			2.0 / 1.22			2.5 / 1.52			3.0 / 1.83		
			Forest area required (10^3 km^2)											
			Fuel	Fodder	Total	Fuel	Fodder	Total	Fuel	Fodder	Total	Fuel	Fodder	Total
0.015	153	29.5	43.1	24.0	67.1	57.5	24.0	81.5	71.9	24.0	95.9	86.3	24.0	110.3
0.020	115	19.2	28.1	15.6	43.7	37.4	15.6	53.0	46.8	15.6	62.4	56.1	15.6	71.7
0.030	77	12.4	18.1	10.1	28.2	24.2	10.1	34.3	30.2	10.1	40.3	36.2	10.1	46.3
0.040	58	10.0	14.6	8.1	22.7	19.4	8.1	27.5	24.3	8.1	32.4	29.1	8.1	37.2

24.0, 15.6, 10.1 and 8.1 thousand km^2. We assume that these figures would not be affected by differing rates of fuelwood consumption and therefore take them as constant. The total fuel and fodder forest requirements thus computed are also shown in Table 3.

For a daily per capita fuelwood consumption of 2.5kg and a rate of reduction in population growth rate of 0.04 percentage points (so as to reach a stable population of 10 million in 58 years from 1981), 32 400 km^2, or about 63% of the total area of the Central Himalayas, would have to be converted to productive forest area simply to meet the potential demand for firewood and fodder 5-6 decades from now. The estimated good forest area from satellite images is only 20 572 km^2, and after deducting 9251 km^2 of uncultivated land and 13 289 km^2 of rock, snow cover and alpine pastures, there is only 28 572 km^2 of potential forest land. Even the total area officially classified as forest is just 34 030 km^2. Therefore, unless the annual reduction in population growth rate is greater than 0.04 percentage points, the forests of the Himalayas will have reached the point of no return.

The New Forest Model

An alternative to the Old Forest Model is to assume that there is no forest to begin with. Unlike the area estimates presented in the last section, those generated by the New Forest Model are not restricted to long-run fuelwood requirements and provide an upper limit for area requirements. It is assumed that once land has been planted, fuelwood will be removed at the earliest practical time and will provide increasing yields for a growing population.

For the sake of simplicity, the New Forest Model assumes that the entire area is planted at the start of the first year. Under these circumstances, the initial harvest must be delayed until a reasonable volume accumulates. The results of a sensitivity analysis suggest that the earliest practical time to harvest Chir pine on Site Class 3 is at the age of 40 years. Reference to the MAI curve shown in Figure 7 indicates that harvesting a crop at this stage of development results in very low productivity and hence large area requirements.

To expect villagers, requiring fuelwood immediately, to support a new forestry program that requires them to wait 40 years to see the results is unrealistic (Agarwala *et al.* 1981). To overcome this problem we have combined trial plantations of fast-growing species with Chir pine. We assume that a fast-growing species could begin to supply fuelwood within a few years and continue to do so till the first harvest of 40-year-old Chir pine is ready.[8] Enthusiasm generated by *Ku babul* (*Leucaena leucocephala*), eucalyptus and poplar has given rise to the idea that the hill problem could be permanently solved by fast-growing species suited to the hill environment. This enthusiasm needs dampening because the long-term future of exotic fast-growing species in not certain in any locality. We have, therefore, assumed that land planted with the fast-growing species will have been converted to Chir pine in 40 years. In the long run, it is possible that only an indigenous species would succed in preserving the fragile ecological balance of the Himalayas. This system of forest management has the advantage of providing fuelwood from plantations shortly after their establishment while guaranteeing supply into the distant future.

Although our solution to the short-run supply problem might seem somewhat unrealistic, the New Forest Model shows how much area must be converted to productive forest if only the new growing stock of Chir pine that is established today were to be available after 40 years. Thus, the model has relevance because some localities are already nearing the end of their wood supply. It also shows that a fast-growing species, if successful, can help to provide fuelwood in the very short run, which is essential to the survival of long-term plantations. For illustration, the yield and MAI figures for Ningli willow (*Salix coerulea*) have been used in the model, though it is possible that we may be exaggerating the potential of fast-growing species by doing so (Figure 9).

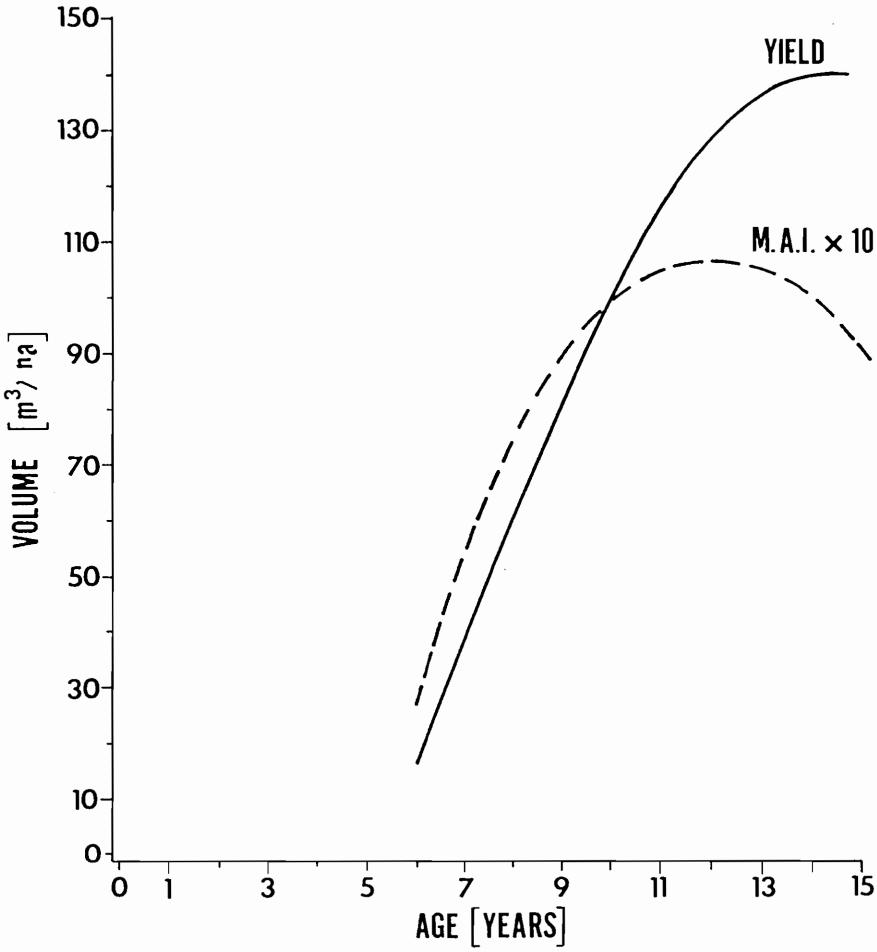

Figure 9. Yield and mean annual increment curves for Ningli willow, site class 2.

Fast-Growing Forests

The results of computer simulations[9] for various combinations of reductions in population growth rate and daily fuelwood requirements are given in Table 4. These results show: (a) the total area that must be planted for every 100 people of the initial population and, (b), how much of this area must be planted with a fast-growing species such as Ningli willow. A lower and upper boundary on the area that is initially allocated to the fast-growing species is defined by the minimum area needed to supply demand for the first

Table 4. New Forest Model: Minimum area of fuelwood forest per hundred people initial population

Annual reduction in growth rate (%)	Number of years to stabilized population	Final population level starting in 1981 (×10⁶)		Fuelwood consumption per person (Daily fuelwood consumption kg) 1.5 (Annual fuelwood consumption, m³) 0.91	2.0 / 1.22	2.5 / 1.52	3.0 / 1.83
				(a) Total area of forest (b) Area planted to Ningli willow (Hectares/100 people initial population)			
0.015	153	29.5	(a)	85.5	114.0	142.5	171.0
			(b)	17.7	23.6	29.5	35.4
0.020	115	19.2	(a)	62.8	83.8	104.7	125.7
			(b)	17.7	23.6	29.5	35.4
0.030	77	12.4	(a)	45.3	60.4	75.6	90.7
			(b)	17.6	23.5	29.4	35.3
0.040	58	10.0	(a)	38.2	50.9	63.7	76.4
			(b)	17.6	23.5	29.5	35.2

Table 5. New Forest Model: Minimum forest area needed to meet long-term fuelwood and fodder requirements for a 1981 population of 4.78 million

Annual reduction in population growth rate (%)	Number of years to stabilized population	Final population level starting from 4.78 in 1981 ($\times 10^6$)	Fuelwood consumption per person											
			(Daily fuelwood consumption, kg)											
			1.5			2.0			2.5			3.0		
			(Annual fuelwood consumption in m^3)											
			0.91			1.22			1.52			1.83		
			Forest area required (10^3 km^2)											
			Fuel	Fodder	Total	Fuel	Todder	Total	Fuel	Fodder	Total	Fuel	Fodder	Total
0.015	153	29.5	43.8	24.0	67.0	58.3	24.0	82.3	72.9	24.0	96.9	87.5	24.0	111.5
0.020	115	19.2	32.1	15.6	47.7	42.9	15.6	58.5	53.6	15.6	69.2	64.3	15.6	79.9
0.030	77	12.4	23.2	10.1	33.3	30.9	10.1	41.0	38.7	10.1	48.8	46.4	10.1	56.5
0.040	58	10.0	19.5	8.1	27.6	26.0	8.1	34.1	35.7	8.1	43.8	39.1	8.1	47.2

40 years, and the maximum area that can be cut over at least once to meet demand in this period. Sensitivity analysis indicates that, over this range, changes in the area planted with the fast-growing species have very little impact on the total area required.

In our example, plantations of Ningli willow were assumed to have been harvested six years after planting, and this entire plantation was assumed to be cut over within the first seven years of harvesting. Regeneration by planting or coppicing was assumed for as many cycles as necessary until Chir pine was available for harvesting at the age of 40 years.

In order to relate the results obtained from the New Forest Model (Table 4) to the results presented from the Old Forest Model (Table 3), the total areas given in Table 4 have been presented in terms of the estimated future population of the Central Himalayas in Table 5. These estimates indicate that the New Forest Model requires 21% and 35% more fuelwood and fodder area for the 0.03 and 0.04 percentage point rates of population growth reduction than the estimates of Table 3 if average per capita consumption is 2.5 kg/day. Although higher rates of reduction in population growth show the greatest increases in the area required relative to the Old Forest Model's long-run area requirements,[10] both Table 3 and Table 5 indicate that reducing the rate of population growth fast enough to stabilize population at 10 million is extremely important.

The New Forest Model shows that short-term needs can be met without exorbitant increases in forest area requirements. It also shows that future crops must be established and existing crops protected today in order to meet the much greater demand of the future. Because the model requires more area to be planted than the minimum required to satisfy the long-run needs, in later years growing stock will begin to accumulate and become available for alternative commercial uses.

Our estimates could perhaps be considered as less than conservative on the grounds that Chir pine is a slow-growing species and that we have not considered alternative fuels and fuel-efficient cooking stoves. However, development of a suitable hybrid of local species may take many years; introduction of natural gas, solar heating, kerosene, electricity and coal on a sufficiently large scale is not currently feasible; and it is too early to estimate the impact of the newer stoves on per capita fuel consumption.

In addition to uses considered by us, wood is used in villages for construction and agricultural implements. It is also used in towns, and in resin factories. The models, therefore, may not be so poor after all.

Conclusions

We have tried to show the serious nature of the ecological, social, political, and economic problems in the Central Himalayas of Uttar Pradesh today. These have arisen as a result of overpopulation and the absence of change in traditional land management practices.

Projections of population growth, when related to the area's deficit in food grain production, and to the gross and per capita decline in yields of fuelwood and fodder for the farming population, highlight the imperative need for a vigorous and rational family-planning policy.

Even if we ignore other uses of forest produce, there is currently a fuelwood and fodder shortage. In order to provide sufficient fuel and fodder for basic needs and to protect the Himalayas from further erosion, plantations must be established immediately.

However, this is not a simple proposal. The very land that has to be afforested in order to provide fuelwood is fully used to graze the cattle of the people who need the fuelwood. In order to free the land for afforestation, the practice of grazing livestock must be replaced by stall-feeding with hand-cut fodder. This will reduce the grazing pressure on the degraded village forests, and so permit re-forestation with fuel and fodder trees sufficient to meet the present and future needs of the resident hill population.

The total area of the Central Himalayan Region is 51 000 km^2. With 9000 km^2 under cultivation and an estimated 13 000 km^2 being snow cover, rocks and alpine pasture, the potential forest area is no more

Table 6. Area required to meet long-term fuel and fodder needs

Type of Forest	Old Forest Model: Area required (km^2)	% of total area	% of potential forest area	New Forest Model: Area required (km^2)	% of total area	% of potential forest area
Fuel Forest	24 300	47	84	35 700	70	123
Fodder Forest	8 100	16	28	8 100	16	28
Total	32 400	63	112	43 800	86	151

than 29 000 km^2. If it is assumed that per capita fuelwood consumption will be 2.5 kg/day and the 1981 population of 4.78 million, growing at the rate of 2.3% per annum, can be restrained so as to grow at rates progressively decreasing by 0.04 percentage points each year and thus stabilizing at 10 million after 58 years, our models reveal the findings shown in Table 6.

It is evident that even for the less area-demanding Old Forest Model there is not enough potential forest area to meet the fuel and fodder needs in the long-run. There is, thus, definite cause for concern and a clear need to begin re-establishment of forest cover on uncultivated land immediately, irrespective of whether it is classified as forest or not.

Our projections for the declining population growth rate were based on 1981 data. For every delay of 4 years in implementation of a population control plan, all estimated forest area requirements should be increased by approximately 10%. Furthermore, as the population has been increasing, rates of soil erosion have also been increasing, and productive land area is being lost.

If population growth rates are not reduced, fuel demands will exceed sustainable yields from the entire afforestable area, with consequences that will be disastrous, both for the people of the hills and for the people of the North Indian plains. By the same token, maintenance of forest cover in the hills will benefit the hill people directly, and will protect the people of the plains from floods and siltation.

As the forest area required to meet the hill people's rising fuel demands would include the area now classified as Reserved Forest, which now supplies the national economy with timber and pulpwood, a political decision will be needed to attend to the subsistence needs of the hill population, affecting the ecological balance of the Himalayas, rather than the relatively short-term economic interests of industry. Alternative sources of raw materials for the forest products industry would have to be found.

Education is one of the most important means of clearing a path to much-needed change. It can be imparted and changes best carried out with the support of the population affected. To illustrate this point, in this paper we assumed that a quick-growing species of fuel tree could be found, which would permit early harvesting, and so win the confidence and co-operation of the hill people in the re-forestation program.

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NOTES

1. The data pertain to all of India. However, the northern plains, fed by Himalayan rivers, account for the bulk of flood damage, so that the percentages given could easily be underestimates for the region.
2. This is evidenced by the stop put to the breaking of new land in the UP hills in the late 1960s.
3. Burning of dried cow dung to provide heat for cooking, so common in the plains devoid of forest, has recently been observed in some hill areas. Knowing the critical value of manure for their agriculture, hill folk usually burn dung only in desperate situations. This practice therefore signals serious shortages of fuelwood in some areas.
4. The milk yield of local animals can increase considerably with the use of tree fodder, stall feeding and improved feeding practices, like chopping of fodder and feeding it in mangers. As tree leaf fodder has higher protein content than grass and is green during the dry season, it is one of the best ways of improving the milk yields of Himalayan cattle (Jackson, 1983).
5. A survey by the Vivekananda Laboratory (1977) reports an average fuelwood consumption of 1.98 kg per day in Chausli village in Almora. However, a larger survey by the G. B. Pant University (1982) in Dwarahat Block, also in Almora, which included 32 familes from eight villages, reported an average family consumption of 12.7 kg//day, which, with an average family size of five, gives a mean of 2.54 kg/capita/day.
6. This overestimates the time actually required, since it is not possible to convert all land to productive forest.
7. A normal age-class structure permits equal volumes to be harvested. In our case a normal forest of Chir pine on Site Class 3 would have an equal area of forest in each age class from 1 to 100 years old which have reached their maximum productivity.
8. Thinnings are another intermediate source of fuel which, if properly conducted, could also increase average volume production.
9. The long-run productivity of the forest was ensured by requiring that a large enough area was planted to allow a

normal growing stock to accumulate after 200 years of harvesting.

10. Under the New Forest Model, initial harvests tend to have a relatively greater impact on the area cut in a given year than do later harvests, even though fuelwood demand is increasing. However, when the rate of reduction in population growth is low, the difference in the area required is small, because the final demand level is higher, and, as it increases, it begins to assume more significance than the initial demand levels.

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