ENERGY-USE PATTERNS AND ENVIRONMENTAL CONSERVATION: THE CENTRAL HIMALAYAN CASE

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INTRODUCTION

A large part of the world today, the so-called Third World, depends primarily on biomass (food and wood), or "low-energy" sources, as opposed to "high-energy" sources, or fossil fuel, relied upon in the developed world (Odum 1983). This conspicuous difference in energy sources corresponds to the difference in per capita income between low-energy and high-energy parts of the world. The entire Himalaya, including the central part, comes under the low-energy category. Contrary to expectations held at the first International Conference for Peaceful Uses of Atomic Energy, Geneva, in 1955,[1] that the atomic age would close the gap between rich and poor leading to a state of equal and abundant energy for all, the dream cannot materialize because of the enormous "disorder potential" derived from using atomic energy (Wilson 1979).

Thus, at this juncture when fossil fuels are being depleted and the use of atomic energy continues to be a dream, the human mind is faced with the problem of developing alternative energy sources. In the Himalaya, people are still at the subsistence economy level and are faced with problems of dwindling biomass energy sources.

The heterogeneity (of climate, vegetation, culture, etc.) in the Himalaya calls for developing various models. The mountain ranges of the Central Himalaya have been particularly prone to landslides due to seismicity and tectonic stress (Valdiya 1985). Compared to the eastern region, it is drier, but more humid than the western region. The contribution of winter rains to the annual rainfall in the central region is remarkably less than in the west. The differences in climatic factors and those in geological history have caused differences in progress of vegetation and, concomitantly, in progress of human civilization of these three principal regions of the Himalaya. Through a number of perennial and annual rivers, the Central Himalayan mountains have profoundly shaped the development of the adjacent plains, also called the shadow zone of the mountain chains. The densely populated shadow zone, subject to extensive and intensive agricultural activities and varying stages of industrialization, have in turn influenced these central mountains.

In this paper, energy-use patterns and natural resource conservation are analyzed through an ecosystem approach that includes an attempt to link ecosystems of the mountain region with those of the shadow plains and vice-versa. The basic tenet is that in the large ecosystem of both the mountains and plains, the role of the former is mainly protective. Consequently, our search for energy sources focuses on low-energy sources (biomass plus nonconventional sources of energy) required to rejuvenate the subsistence economy in the mountains.

ENVIRONMENTAL BACKGROUND

Located between 28° 30' and 31°30' latitude and 77° and 81° longitude, the Indian Central Himalaya (Uttar Pradesh Himalaya) covers an area of about 51,000 km^2. In the north, it borders Tibet while toward the east, the river Kali marks its border with Nepal (Fig. 1). Toward the west lies Himachal Pradesh, and in the southwest and south, the region touches the boundary of plains districts, the westernmost being Saharanpur and the easternmost being Pilibhit.

Along the southern edge, the mountains rise abruptly from the alluvial plains. The Siwaliks, the first and southernmost mountains (10 to 50 km wide) stand 500 to 1200 meters high. They are separated from the Lesser Himalaya (also called outer or middle Himalaya) to the north by a major fault, the Main Boundary Thrust (MBT). The lesser Himalaya, where northwest-to-southwest ranges rise sharply to 2500 meters and above, is characterized by the presence of numerous transverse valleys. The river gorges provide only occasional, difficult access routes to the inner mountains. Beyond the outer ranges lie the Greater Himalayan ranges which are separated from the former on the south by the Main Central Thrust (MCT). In the ranges of the Greater Himalaya lie another series of valleys, then finally their headwaters in the glaciers and permanent snows. Most land is above 5000 meters, and many of the world's highest peaks rising above 7000 meters are in this region.

Between the deep alluvial plains and the Siwaliks, thin belts of *bhabar* toward the mountains and of *terai* toward the plains are identifiable. The *bhabar* is a 15 to 25 km wide belt of talus gravel slopes deposited by the Himalayan rivers. For much of the year, the mountain streams subside beneath the *bhabar*, emerging again slowly to carry finer alluvial silts into the *terai*, he level belt of super abundant surfacewater (10 to 25 km wide). Contiguous to the *bhabar* but structurally between the Siwaliks and the Lesser Himalaya, another landform called *duns* can be recognized. Dehradun, a major city of the region, is the most well-known example of a *dun*.

As in the rest of the subcontinent, the rainfall pattern is largely governed by the monsoon. Its influence increases with elevation up to about 2200 meters, and then declines with further rise (Table 1). In general, the monsoon (mid-June to mid-September) accounts for 60 to 80 percent of the annual rainfall. The contribution of winter rainfall (8 to 29 pecent) occurring due to western disturbances (Dhar et al 1984) tends to increase from east to west. The monsoon rainfall is of the order of 1000 mm in the foothills, 2000 mm in the middle elevations, and 500 mm in higher elevations and interior regions (Dhar et al 1984).

The monsoon period, which is also warm, is the most favorable for plant growth, and most ecosystem activities appear to be directly or indirectly

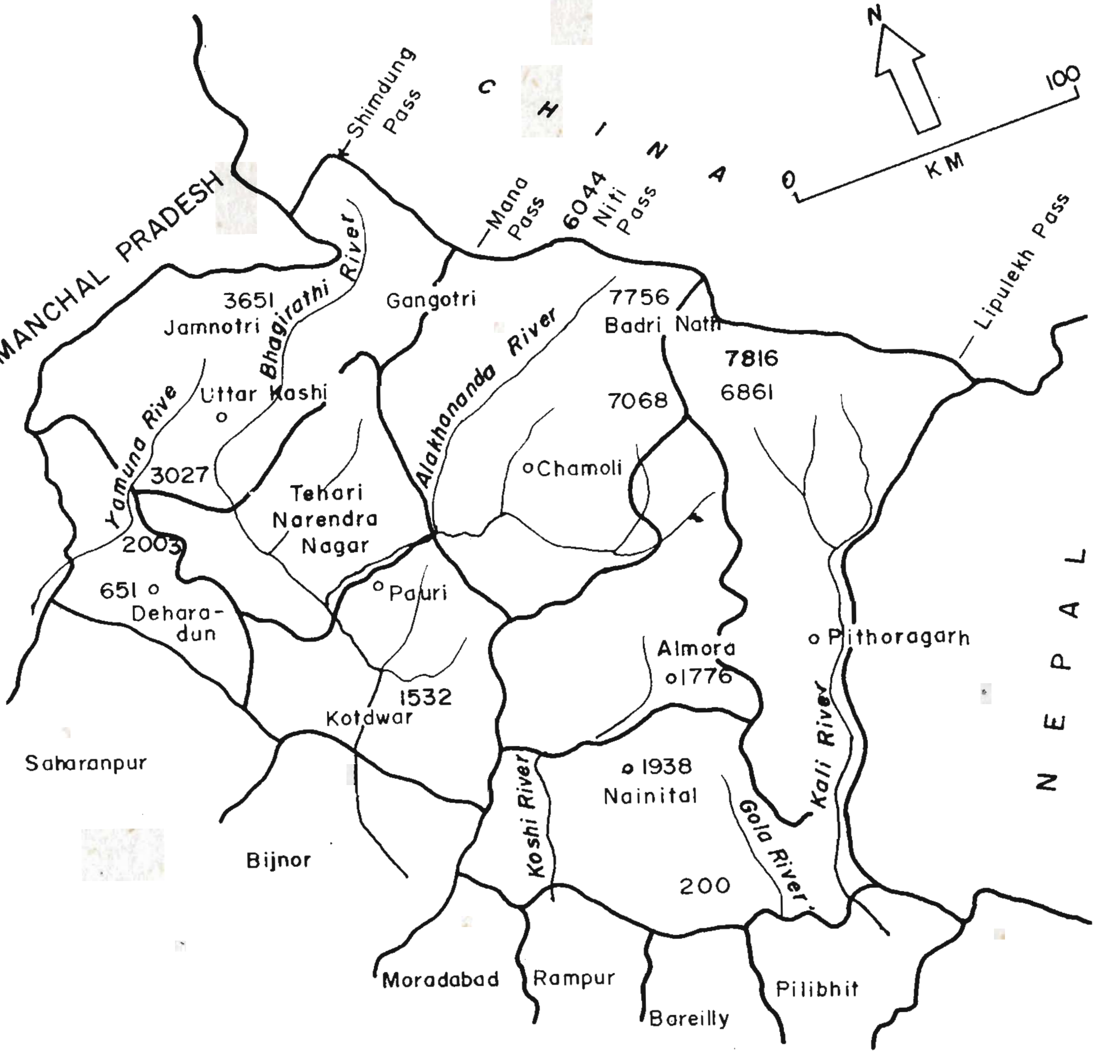


FIGURE I. INDIAN CENTRAL HIMALAYA AND ADJACENT PLAINS.

Table 1: Rainfall (mm) Conditions in Different Landforms of the Central Himalaya (Values are average of 6 years)

Locations	No. of Stations	Seasons: Winter (Nov - Feb)	Summer (March - June)	Rainy (July - Oct.)	Total
Terai	4	124.0	220.3	1096.3	1440.6
Bhabar	4	121.1	360.3	1403.4	1884.8
Frontal ranges of Siwalik and adjoining Lesser Himalaya	4	125.4	435.0	1855.6	2416.0
Interior Locations in Lesser Himalaya	13	119.5	349.5	894.4	1367.4
Rainshadow area	1	-	201.0	519.0	720.0

related to this period (Singh and Singh 1985a).

A rise of 1000 meters corresponds to a fall of 3.7°C in mean annual temperature. In the elevational belt of 1500 to 2000 meters, the mean monthly temperature ranges between 5.5°C and 8°C in the coldest month of January and between 19°C and 27°C in the hottest month of June. The above values in the *bhabar* zone range from 13 to 21°C in the coldest month and between 30 and 40°C in the hottest month. Snowfall during the winter season is frequent above 2000 meters.

Singh and Singh (1985a,b) have reviewed the structural and functional aspects of forest vegetation mostly on the basis of quantitative studies made earlier (e.g. Chaturvedi and Singh 1982; Pandey et al 1983; Negi et al 1983; Pandey and Singh 1981a, 1981b, 1982b, 1982, 1984a, 1984b, 1984c; Ralhan et al 1985a, 1985b; Pathak et al 1984; Saxena and Singh 1982a, 1982b; Saxena et al 1983; Singh et al 1984; Tewari and Singh 1981; Tewari and Singh 1983; Tewari et al 1984; Upreti et al 1985). In general, from lower to higher elevations the following forests prevail: *Sal* (*Shorea robusta*) forest below 1000 meters; *chir* pine (*Pinus roxburghii*) forest between 100 and 1700 meters; *banj eak* (*Quercus leucotrichophora*) forest between 1500 and 2200 meters; and *kharsu oak* (*O.semecarpifelia*), conifer forest (*Pinus Wallichiana*), and *Abies pindrow* (*Cedrus deodara*) above 2200 meters.

The Himalayan catchments are subsurface flow systems, and therefore are particularly prone to landslides, which become a serious problem in areas without tree cover. However, since the climate is benign in the middle elevation belt, the recovery of forests such as oak forests is rapid, provided biotic stress does not persist. In forests subject to low biotic stress, biomass value as high as above 700 dry matter per hectare is recorded, particularly in oak and *sal* forests. This value approaches the higher side of the forest biomass range reported for the world. The net primary productivity ranges between 11.0 to 27.4 tons per hectare per year. The higher values are comparable with those of highly productive forests of the world (Lieth 1973; Whittaker 1975). Compared to the world's temperate forests, larger amounts of nutrients accumulate in the biomass pool of these forests. Therefore, removal of forests means greater depletion of nutrients from temperate forest ecosystems.

According to the 1981 census, the population of eight districts of the Indian Central Himalaya was about 5.10 million, of which 3.47 million was in the mountains. Of the mountain population, nearly 82 percent was rural, with a density of about 77 per km^2 for the entire area, 72 for the rural sector, and 776 for the urban sector. The rate of population growth was 2.3 percent per year. Subsistence agriculture involving forest resources has been the occupation of most of the population for the last several centuries. According to Khanka (1985) the net migration (emigration minus immigration), for example, in Almora District was 13.5 percent and 9.4 percent of the population respectively in 1961 and 1971. Interestingly, emigration is directly related to literacy level, which is higher than in Uttar Pradesh (38 percent in Kumaun region as opposed to 27.4 percent in Uttar Pradesh in 1981) and size of land holdings. Although emigration increases the percentage of children, old people, and women, it is economically beneficial, as the earnings are higher at destination than at origin (Khanka 1985). However, the level of the mountain economy remains at the subsistence level.

THE PROBLEMS

Thompson and Warburton (1985) point out that the Himalaya have a plurality of contradictory and contending problems--each one focused by the shared credibility it enjoys in the eyes of those who subscribe to it. Such confusion is likely to arise when data is generalized across the entire Himalaya region and when the investigators do not belong to the region. The authors feel that the Indian Central Himalaya is relatively homogenous in landscape, population structure, and cultural attributes. The single major problem is how to revive the forest cover which, according to one estimate (Shah 1982), is on the verge of extinction.

This point is elaborated in the following statements:

1. Historically, subsistence agriculture and unregulated and illegal commercial exploitation of forests (Misra and Tripathi 1978) have led to the present state of inadequate forest cover.

2. Forest biomass provides an ecosystem structure which moderates oscillation in climate, checks total discharge of water, storm flows, and flood peaks in catchment (Hibbert 1967; Gilmour 1977) and reduces the frequency of landslides (Haigh 1984).

3. Deforestation led to the extinction of springs, the precious water source for domestic use (K.S. Valdiya).[2]

4. Deforestation not only impairs the life-support system of the soil, it also exposes the land to the destabilizing physical forces of rain, wind, and solar energy.

5. Such an impairment in hydrological cycle has caused recurrent flooding of plains.

6. These processes have combined to impair not only the infrastructure, which sustains the subsistence economy in the mountains, but has also has caused environmental degradation in the plains.

Any development plan which seeks to improve the energy-use pattern in the region needs to keep the above facts in view. The impaired energy-use pattern ought to be revived before attempts to provide new energy subsidies to the people are made.

COMPARTMENTALIZATION OF LANDSCAPE IN VIEW OF PRINCIPLES OF ECOSYSTEM DEVELOPMENT

According to the principles of ecosystem development in relation to the landscape as a whole, Odum (1983) recognized three types of life-supporting systems and an urban-industrial, heterotrophic system as the fourth type. The life supporting-systems include:

1. The human productive system or growth system(e.g. croplands, tree plantations, and intensively managed forests that provide food, wood, manure, and fibre)

2. Manure systems--the protective life support system which is more protective than productive, stabilizes and buffers the air and water cycle, and moderates temperature and other physical factors, while at the same time providing materials for human use (e.g. old-growth forests and climax grasslands)

3. Waste assimilative system, which is natural or semi-natural and that bears the brunt of assimilating the wastes produced by the urban-industrial and agricultural system (i.e. waterways, wetlands, and other environments receiving strong impacts)

Looking at the compartmentalization of the Indian Central Himalaya (including the plains of Nainital and Dehradun Districts) today, about 15 percent of the total area is in agro-ecosystem (cropland, current fallow, rural house, etc.) and less than 2 percent is in urban-industrial system (including rural roads), leaving about 83 percent as so-called natural systems, variously affected by firewood and timber harvesting, lopping, grazing, recreation, and pollution (Tables 2 and 3). However, a sizeable portion (about one-fourth of the total area) of the natural area is either devoid of vegetal cover or has negligible vegetal cover (rocks and severely eroded land, Table 2) and cannot be assigned to any category given by Odum. This is natural,

Table 2: Land-Use and Forest Cover in the Indian Central Himalaya

Land-Use	Area (km^2)	Percent of total area
Non-Forest[a]		
Snow [a1]	11003	21.59
High-Altitude Meadows[a1]	2522	4.95
Agriculture[b]	6975	13.69
Urban[b]	.575	1.13
Urban construction[b] (including roads, canals, etc)	1050	2.05
Rocks and Severely Eroded Land (almost devoid of vegetation[b])	2461	4.83
Low-and Mid-altitude Grasslands[b1]	354	0.69
Degraded Vegetation [c]	11374	22.32
Total Non-Forest	36314	71.27
Forest[a]		
Poor Forest	4709	9.24
Medium Forest	7666	15.05
Good Forest	2263	4.44
Total Forest	14638	28.73
Total Reported Area	50952	100.00

a After Singh et al (1984 a), interpreted from satellite imageries

a1 The aread mostly covered by snow and high-altitude meadows for which imageries are not available was partitioned into snow and high-altitude meadows by using the proportions of snow and high-altitude meadows in other high-altitude areas for which imageries were availabel (Singh et al 1984a, b). The respective values were added to the known values to calculate total area under snow and high-altitude meadows.

b Derived from Anonymous (1982); urban areas do not include those of plains of Nainital and Dehradun.

b1 Estimated by deducting the area reported for high-altitude meadows by Singh et al (1984a) from the sum of area reported for high-altitude pastures and other pastures in Anonymous (1982).

c Estimated by deducting the sum of areas reported for other non-forest landuses in the table (after Anonymous 1982) from the total area reported for non-forest by Singh et al (1984 a). This degraded vegetation category includes all the degraded forms converted, presumably from the original forests, e.g., scrubs, grasslands, weeds (such as lantana camara) - dominated vegetation, with a few scattered denuded trees.

Table 3: **Compartmentalization of the Central Himalayan Landscape According to the Ecosystem Development Theory (percentage area assigned to various categories are approximations derived from Table 2)**

System Category	Examples	Percentage of total area
Protective system	Forests	28.7
Productive system	Croplands, including current and old fallows and village settlements	15.7
Degraded systems	Mostly the land originally under forests, but now "blanks" subject to various destabilizing forests, plus water bodies	22.3
Non-biological systems	Permanent snow and rocks, almost completely devoid of vegetation	26.4
Urban-industrial	Mostly urban settlements, also includes roads	1.9
Unidentified		5.0

but almost a non-biological system. Like the urban-industrial system, solar radiation impinges upon these systems without being utilized in biological terms. But unlike the urban-industrial system, it is mostly devoid of human activity. Another large category (accounting for about 22 percent of the total area) is of severely impacted natural systems, termed "degraded systems". Both biomass and productivity of the various ecosystems of this category (grasslands, scrubs, weed-dominated ecosystem, etc.) represent a small fraction of the potential values. The vegetal cover is seasonal and often less than 25 percent of ground surface (Singh and Saxena 1980). Far from assuming the protective role, these ecosystems themselves are subject to destabilizing forces, thus losing huge amounts of soil, nutrients, and organic matter. Although, in view of the fact that such systems represent arrested successional stages, they can be recognized as the dissipation category of Odum. Their structural parameters are so reduced that they can hardly assimilate wastes derived from other systems. Unfortunately, the poor forest category given in Table 2, with the crown density of 10 to 30 percent, is on the verge of being converted to degraded ecosystem.

Compared to a highly industrialized

country like the U.S.A. (Odum 1983) where about 70 percent is healthy natural environment consisting mostly of forests and climax grasslands which support 24 percent in domesticated environments (agro-ecosystems) and 6 percent in urban-industrial areas (fabricated environments), the situation is gloomy in the Central Himalaya.

This area, characterized by negligible use of fossil fuel, low population density, and continued conversion of protective systems into destabilized ones, is surrounded by the vast, densely populated plains, which interact with the mountains variously where domesticated and fabricated systems are predominant. Thus, the impending situation is that of a mountainous region with a sizeable proportion of non-biological systems and a large proportion of degraded natural systems interacting with a plains region with large area in agro-industrial complexes. The destabilizing potential of such interaction could be profound.

ENERGY IN VARIOUS ECOSYSTEMS

Forests, grasslands, and croplands are the main ecosystems in the Central Himalaya. Of these, forests are by far the most important potential ecosystems in the mid-montane belt or agricultural zone. In this zone, grasslands in patches have developed owing to deforestation, heavy grazing, and fires (Singh and Saxena 1980). About 14 percent of the total land is under crops. The net primary productivity in terms of energy for various ecosystems is given in Tables 4, 5, 6, 7 and 8. It is apparent that, in general, forests are far more productive than the grasslands and croplands. In fact, most of the production values for forest ecosystems are in the range of the lower values reported for highly productive communities of the world (Singh and Singh 1984). Singh and Singh (1985a) pointed out that climatic conditions are favorable for forest growth. By and large, net primary productivity of our converted grasslands is markedly lower than those in the north temperate zone, where grasslands usually represent the climax stage (Ryszkowski 1985). It appears that the converted grasslands of the Central Himalaya are subject to destabilizing forces, such as excessive grazing and frequent burning, which lead to soil and nutrient loss under the influence of rainfall and wind. The destabilizing effect of the rainfall is likely to be particularly severe in this region, where most of the rainfall is confined to a short monsoon period, soil depths are shallow, and rocks are immature. With the conversion of natural ecosystem (in this case, forests) to grassland, or agricultural ecosystem, initially the availability of nutrients is increased above availability in the natural ecosystem prior to disturbance, but subsequently the impairment of biotic control leads to lower nutrient pool size than in natural ecosystems (Melillo 1985). Apart from the adverse effect of these destabilizing forces, lower productivity in grasslands and agricultural ecosystems is because of shorter growth periods.

Lack of irrigation water, fertilizer, and other productive inputs also limits agricultural productivity. Several indirect observations indicate the severity of degradation over large areas (Chand and Thakur 1985). Cox (1985) pointed out that although the use of

Table 4: Net Above ground Production of the Central Himalayan Forests along an Elevational Gradient of 300-2200 m (based on Rana and Singh 1984)

Forest	Altitude (m)	Net Above ground Production ($x10^6$ kcal/ha/yr)
Sal old growth forest	300	65.1
Sal seedling coppice forest	330	74.3
Pine-mixed broad-leaf forest	1350	41.5
Pine forest	1750	66.1
Mixed oak pine forest	1850	67.0
Rianj-dominated mixed oak forest	2150	76.7
Tilong-dominated mixed oak forest	2200	103.2

inputs is able to raise the net primary productivity levels of the agro-ecosystem of a region, this success is presumably realized only on agricultural land that has not been severely degraded.

The above comparison is based on total net primary productivity. However, in an agricultural ecosystem, the aim is to maximize the agronomic yield--usually grains and tubers. In forest ecosystems, wood (trunk and major branches) is of greater significance, for it is the material of commerce. From this standpoint also, forests are far more productive than croplands.

Energy Linkages Between Agro and Forest Ecosystems

In this region, cultivated land is the "nucleus" of human settlements. Because of the dynamic interdependence between cultivated and the adjacent uncultivated lands, it would be useful to examine energy flow relations to understand the Central Himalayan situation. An energy-flow diagram given in Fig. 2* roughly represents the average situation, though several values are based on inadequate samples, the number and size of which also vary from one parameter to another. However, all such samples are from the agricultural zone, also called the mid-mountains (1000 to 2200 meters), which is the zone of major environmental problems. The model of energy flow is that designed by Pandey and Singh (1984c). In this representation, quantities of all possible inputs (human and animal labor, manure, chemical fertilizers, seeds, etc.) outputs (yield of edible crop products, crop byproducts, and milk), sources and supply of animal fodder, and the human use of firewood have been considered. The input and output

* The average energy flow through the human use system for the Central Himalayan rural areas. All values are in 10^5 kcal/yr/ha of cultivation for method of computation, see Appendix 1.

Table 5: Net Above ground Production (x 10^6 Kcal/ha/yr) of herbaceous vegetation in Central Himalaya

Site	Author	Net Annual Above ground Production Live	Currend dead	Total
Kumaon Himalaya (between 1000-2000 m)	Saxena and Singh (1980[a])			
Open grassland		16.96 - 26.22	3.85 - 6.09	20.81 - 32.27
Chir pine forest		1.08 - 4.16	0.16 - 0.83	1.29 - 4.99
Mixed forest		0.92 - 2.52	0	0.92 - 2.52
Banj oak forest		0.39 - 1.74	0.03 - 0.67	0.42 - 2.40
Tilong oak forest		0.13 - 0.91	0.01 - 0.56	0.14 - 1.47
Kumaon Himalaya	Khanna, R.K. and S.P. Singh. (unpubl[b].)			
Grassland around cultivated land				
- protected		34.34		
- un-protected		15.85		
Kumaon Himalaya (between 1000-1800 m)	Singh (1984[c])			
Chir pine forest with relatively closer canopy		4.83		
Chir pine forest, open canopy with few seed bearers		10.37		
Chir pine forest, open canopy with no adult tree		12.91		
Open grassland near streams	18.36			
Grass mixed with <u>lantana</u> <u>camara</u>	10.55			
Adjustment with cropland		22.01		
Single species grasslands on terrace faces	Gupta (1967[a])			
Bhatta, Mussorie average of seven stands				37.53
Gopeshwar	V. K. Shah (Pers. Communication)			43.22
Garhwal Himalaya (1500 m)				
Alpine grasslands	Jeet Ram (Pers. Communication)			14.71

a Production in terms of peak biomass, sites relatively undisturbed
b Production computed on the basis of time-interval harvests
c Only grasses considered (production in term peak-biomass)

Table 6: Net Aboveground Production (agronomic yield plus byproducts) in croplands of the Central Himalaya)

Village	Production (X 10^6 kcal/ha/yr)	Author
Khurpatal	47.13	Panday & Singh (1984)
Balutia	17.25	
Mehragoon	5.81	
Siloti	20.34	
Chanoti	18.71	
Average	21.85	

Table 7: Rate of exploitation of various resources from the entire Central Himalayan forested area (14.64 x 10^5 ha)

Resources/Causes of exploitation	Quantity
Total aboveground production	82.00
Firewood[a]	14.90
Timber	1.47
Fodder[b]	16.43
Losses associated with harvests[c]	1.12
Minor products[d]	2.77
Forest clearance	
- due to agricultural expansion[e]	12.40
- due to the constructional works	?
Burning and natural catastrophe	?
Total known exploitation	49.09

a At the rate of 2.5 kg per capita per day, which has found reasonable for the entire geographical area by Nautiyal andBarbor (1985)

b Only the amount harvested from forests considered, and it includes requirements of goat and sheep.

c Leaves and minor shoots unused but destroyed due to the harvest of major woody parts.

d Resin, medicinal plants, bamboos etc.

e Rate of forest clearance is 0.9% of the area for the period, 1958-1973 (Shah, 1982). Data which were not referred to above derived from (Anonymous 1983)

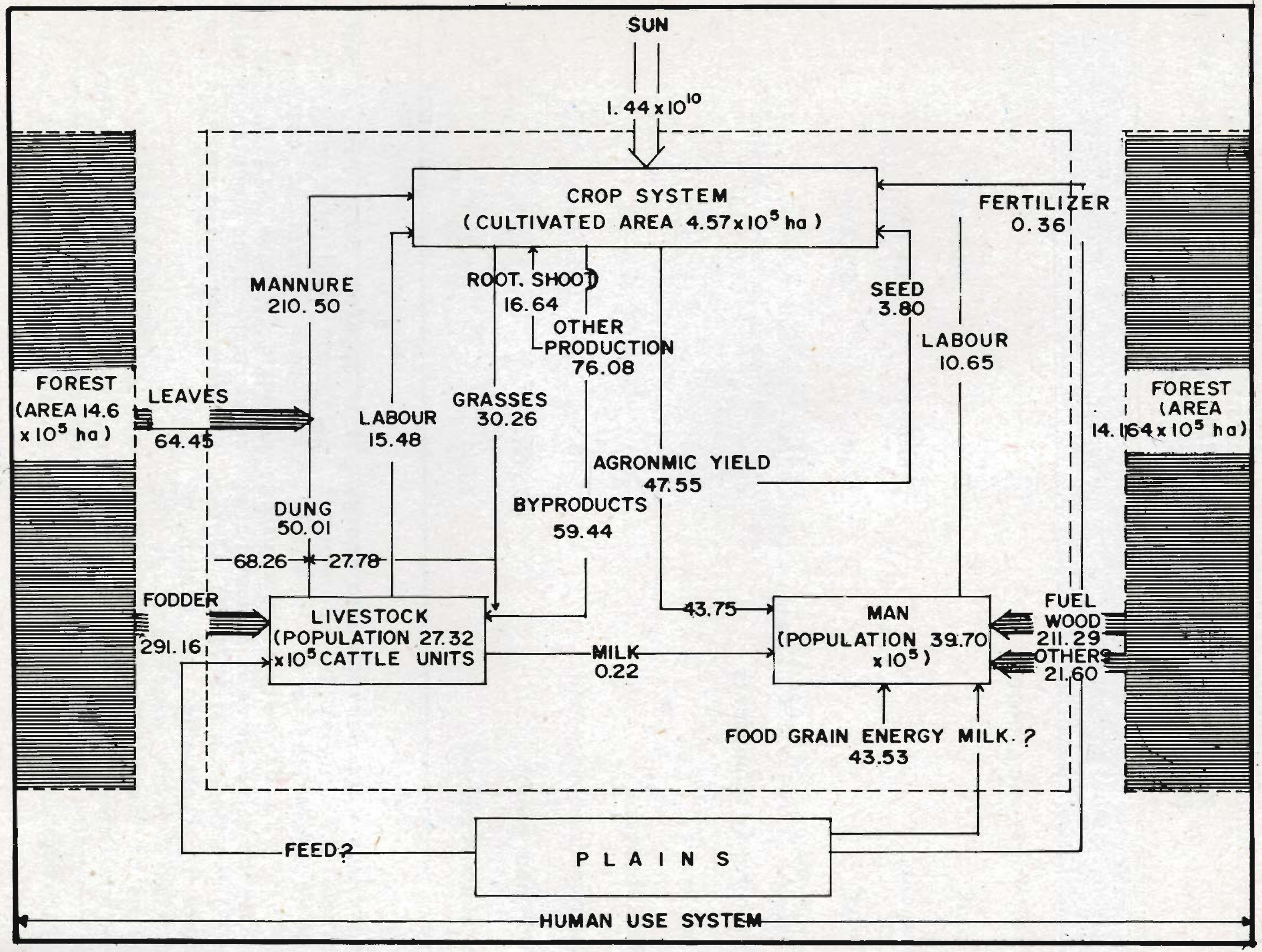
Table 8. Partitioning of average Aboveground Net Production (x 10^6 Kcal ha -1 yr -1) across seven representative forest types (e.g., sal, pine, oak, and mixed forests) between 300-2200 m elevation of Kumaon Himalaya (computed from Rana and Singh, 1984)

Aboveground components	Average	Range
Tree: Woody components		
Trunk	22.89	9.8-36.5
Branches	8.70	3.4-19.7
Twigs	12.06	5.6-20.4
Shrub: Woody components	1.44	0.3- 2.3
Total Woody components	45.09	21.3-77.3
Tree leaves	19.97	13.2-25.8
Shrub Leaves	1.53	0.2- 3.3
Herbaceous aboveground	3.50	2.2- 4.9
Total non-woody	25.00	0.2-25.8
Total aboveground	70.09	0.2-77.3

quantities were converted to energy values, multiplying by appropriate caloric equivalents given in Mitchel (1979), who developed them using mainly the values given in Pimentel et al (1973) and Gopalan et al (1976). All the values are represented per hectare of cultivated land, which exclude the plains of Nainital and Dehradun Districts. Details of the method followed for computing various values are given in Appendix 1.

It is apparent from Fig. 2 that the agronomic yield (plus milk) 47.5 x 10^5 kcal per hectare of cultivation is adequate for only half a year's food requirement of the mountain population; the remaining half is imported from the plains.

The urban population per hectare of cultivation is nearly 0.6, compared to 7.0 for the rural population. However, the pressure of population can be in the



SUN
1.44 x 10^10
CROP SYSTEM (CULTIVATED AREA 4.57 x 10^5 ha)
FERTILIZER 0.36
MANNURE 210.50
ROOT. SHOOT 16.64
OTHER PRODUCTION 76.08
SEED 3.80
LABOUR 10.65
FOREST (AREA 14.6 x 10^5 ha)
LEAVES 64.45
LABOUR 15.48
GRASSES 30.26
FOREST (AREA 14.164 x 10^5 ha)
AGRONMIC YIELD 47.55
DUNG 50.01
BYPRODUCTS 59.44
68.26
27.78
FODDER 291.16
LIVESTOCK (POPULATION 27.32 x 10^5 CATTLE UNITS
43.75
MAN (POPULATION 39.70 x 10^5)
FUEL WOOD 211.29
OTHERS 21.60
MILK 0.22
FOOD GRAIN ENERGY MILK ?
43.53
FEED?
PLAINS
HUMAN USE SYSTEM

Figure 2

range of 12 to 17 per hectare of cultivated land in certain parts of the mid-mountain belt, where the import of food grain can be up to 75 percent of the requirement (Ashish 1983).

In total, for each unit of energy employed in agronomic (plus milk) production, about 12 units[3] of energy are expended from the forest ecosystem mainly in the form of fodder and fuelwood requirements. Here, the forest also includes those forests which have been recently converted into degraded land with grass and scrubs. This is higher than the average values of seven units reported by Pandey and Singh (1984c) and Singh et al (1984a) for three villages of the mid-mountain belt of Kumaon Himalaya. However, Pandey and Singh (1984c) admitted that the value of energy from the forest was likely to be higher, if the amount of tree leaves collected for manuring was included.

An ecosystem is stable as long as its net ecosystem production (NEP) is not negative (Melillo 1985). The sum of manure input and the amount of unharvested crop is about twice as much as the total harvest. However, in order to calculate NEP, heterotrophic respiration and losses of organic matter as a consequence of erosion also need to be accounted for. According to the estimate of Shah (1982), nearly 85 percent of cultivated land is suffering from severe erosion problems.

Further, the stability of the support system of cultivation, i.e. the forest system, is being increasingly threatened. The total forested area of 14.64 x 10^5 hectares contains 1363 x 10^{12} kcal in above-ground live biomass and maintains a net annual production of about 82 x 10^{12} kcal. Approximate information of forest exploitation including fuelwood, timber, fodder, minor production, and clearance of forests due to the expansion of agriculture are given in Table 7. However, it is not known how much forest is destroyed annually for construction work, burning, natural or man-made landslides, deposition of debris, etc. The known forest harvests (49.09 x 10^{12} kcal) amount to about 60 percent of above-ground annual production. According to Shah (1982) about 6.8 percent of forest growing stock is exploited annually, which converts to 93.6 x 10^{12} kcal per year. which is 14 percent greater than net above-ground production. Using this rate of forest exploitation, Singh et al (1985) concluded that the Central Himalayan forests show a net release of 4.6 x 10^{12} gega calories (g. c.) per year. Whether or not the annual forest harvest is greater than the annual production, it is beyond doubt that the harvest far exceeds carrying capacity and forest stock is diminishing with time (Singh and Singh 1984). The processes associated with even 60 percent harvest of above- ground annual production would involve corresponding losses of nutrients and organic matter and the adverse effects of trampling, browsing, grazing, lopping, erosion, etc., on the regeneration of forests. Biomass quantities cannot measure the potential adverse effects of loss of a seedling on forest regeneration. The perpetual biotic stress, even at a small scale, impedes recovery, which in its absence would have occured at the expense of rapid release of energy stored in forest litter mass (22 x 10^{12} kcal in entire forested area) and soil (530 x 10^{12} kcal in entire forested area). Thus, the unregulated biotic stress is not only removing the biomass directly, it is also resulting in the loss of structural component of soil, and the energy capital which would have supported the initial ecosystem development (Bormann and Likens 1979).

Apart from the above, unregulated exploitation leads to large-scale changes in forest composition involving conversion of old-growth to second-growth forests, dominated by a few light-demanding species and to concomitant reduction in diversity and population of fodder species (Saxena et al 1985).

Further, the intensity of exploitation of forest resources would be maximum in easily approachable areas. Airy and Shastri (1984) observed that the denudation of forest is directly related to development. We assume that the forests exploited by villagers belong to the poor category (with crown cover of 10 to 30 percent). Distributed over 4.71×10^5 hectare, these forests are reported to attain an average ANP of about 34×10^6 kcal per hectare per year. Thus the energy available in terms of ANP per hectare of cultivated land is about 35×10^6 kcal per year from this category of forest, compared tothe annual village requirement of about 59×10^6 kcal per hectare of cultivation. Consequently, denuded areas around cultivated land are widening over time.

A WORKABLE MODEL FOR ECOLOGICALLY SUSTAINABLE DEVELOPMENT IN VIEW OF SOCIOPOLITICAL CONSTRAINTS

Theory alone is not sufficient to discover an integrated model of development that is both ecologically sustainable and sociopolitically feasible. Results of practical experiences need to be added to theoretical parameters. Any development model for the Central Himalaya needs to consider that the region is inseparable from the adjacent plains. Keeping in view ecological sustainability, we assign a protective role to mountain ecosystems. Protective systems in mountains will check the flood-peaks and downhill movement of soil, silt, and stones; the productive systems of plains will take care of the needs for food and fibre of the mountain people, in addition to that of the plains population. The necessity of this arrangement partly originates from bad planning in the past. The buffer zone of adjacent *terai* and *bhabar* with thick cover of forests and marshy vegetation was converted into usable land in order to rehabilitate primarily refugee populations, subsequent to the division of the Indian subcontinent. The forests were alien to the culture of the predominantly agricultural population; consequently, they were altogether removed. This zone could have been used to alleviate increasing agricultural pressure in the mountains by shifting the population from the mountains in a regulated and gradual manner, although the eventual solution of population problems lies in checking population growth. That the problems of mountain degradation can assume far larger dimensions, compared to the refugee problem, was not realized by planners. The environmental problems partly lie in the fact that political leaders seldom think holistically. Political success has traditionally been best served by focus on problems immediately at hand (Cladwell 1984).

To summarize the landscape situation, more than two-thirds of the adjacent plains are under growth systems (croplands). In the mountains, the protective systems (mainly forests) occupy only 28.7 percent of the area; however, except for a small fraction of about 4.4 percent of the mountain area, the entire area of new-growth forests is dominated by a few sun-demanding early successional species and a large chunk of originally forested area now supports a vegetational structure far simpler, more stunted, and sparser than the original one. Consequently, it is of little protective or productive use.

The task of reviving the forest cover is becoming increasingly difficult. There is something wrong with existing development programs which seek to transform the subsistence economy into a cash economy, while the support system of the subsistence economy itself is on the verge of collapse. Consequently, crop productivity in the mountain region is on the decline (Khanka 1985), and efforts to replace native cows with higher milk-yielding cows at high government subsidies have failed (Jackson 1981, 1985).

A Case for an Alternative Form of Cultivation

The present situation calls for a major change in the development pattern: primarily the replacement of the crop system with the tree-farm system. The following reasons support this:

1. The crop system, though failing to meet the food requirement of the mountain people for even half of the year, leads to massive deforestation, which in turn is impairing the very support base of fodder and fuel, and water sources are becoming scarcer.

2. The present form of agriculture cannot be transformed into fossil fuel-powered agriculture primarily because of small land holdings and lack of irrigation.

3. Replacement of agriculture with horticulture also has overall limitations. First, the pressure on forests would not decline, for packing cases would be required to transport fruits, and fruit trees would not meet fodder and fuelwood needs.

4. Thus, the form of cultivation which is least dependent on natural forests is needed. This can be tree farming, as it can ensure the supply of fuelwood, timber, and fodder.

5. The net primary productivity even in unmanaged forests is several times greater than that of crop systems (Tables 4, 5 and 6), even in terms of commercial yields. Multispecies tree farms can be designed to utilize solar radiation most of the year, while in crop systems, solar radiation is not utilized much of the year.

6. Tree plantations involve far less soil disturbance than crop cultivation which requires frequent ploughing. Further, the amount of inputs per unit of production would be the least in tree farming. Deeper tree roots by promoting water infiltration and checking flow may prolong the life of springs, the major source of water to villagers.

7. Since tree cultivation does not need animal power, fodder which is largely derived from forests would be required in similar quantities. In that situation, the livestock population, which would primarily consist of milk-producing animals, would be reduced. Once motivated for quantity animals, villagers may adopt stall feeding, which is less destructive than grazing.

Prerequisites for the Model

In order to motivate people to adopt tree farming, it is supposed that the plains will meet the foodgrain requirements of the mountain population free of cost. There needs to be a mutualistic relationship between the mountains and plains, in which the plains will provide "ghost crop acres" for mountains and the latter, in a state of recovered forest cover, would save the plains from the hazards of floods, siltation of water bodies, and damage of productive croplands. Further, the entire region would be benefitted by the increased and relatively stabilized yield of outputs from forests, and by the revival of the eroded gene pool.

The other prerequisite involves expansion of private lands for farm forestry. Private forestry is preferred to community forestry in view of the well-documented tragedy of the commons (Odum 1983; Jackson 1985). At present, the size of cultivated land is about 0.8 hectare per household of six people. By distributing the land under damaged ecosystems (1,137,400 hectares, Table 2) to villagers, the size of tree farms can be made up to two hectares. The damaged lands also include original village forests, as well as the State Revenue Forests now denuded of tree cover.

Composition of Farm-Forests

Tree farms need to be developed primarily to meet the requirements of fuelwood for cooking, fodder for milk animals, and timber for village-level construction work. On the basis of relatively undisturbed stands of various types in the Central Himalaya, Rana and Singh (1984) reported an average net production of about 70 x 10^6 kcal per hectare per year, with about 45 x 10^6 kcal in woody components and 25 x 10^6 kcal in terms of leaves of woody species and herbaceous matter (Table 4). It is assumed the fodder requirement would be reduced to half of the present requirement subsequent to the replacement of agriculture with tree farms, as bullocks would no longer be required, and the dung production earlier needed to manure the fields would be minimal. In that case, the fodder requirement per household per year would be 19.2 x 10^6 kcal. The fuelwood and timber requirement per household per year amounts to 18.6 x 10^6 kcal. This total requirement of about 38 x 10^6 kcal can be met from slightly more than half a hectare of broad-leaf forest, such as oak forest (Table 4). In case the land available is severely degraded, it can be initially colonized by stress-tolerant and disturbance-adapted species like *chir* pine (Rao and Singh 1984; Nautiyal and Barbor 1985). However, *chir* pine forests would not provide tree fodder, although grass production would be greater than in broad-leaf forests (Saxena and Singh 1980). In order to meet the fodder requirements of the dry season when grasses are not available, additional land would be required to raise broad-leaf forests. However, these forests would take a long time to be ready for harvest, so until then, fast-growing native and exotic species need to be raised (Chaturvedi 1985; Dwivedi 1985) to meet the needs of the subsistence economy.

Each household can use the remainder of the two hectares of land for raising forests for commercial purposes. Depending upon the quality of land, availability of inputs, and the long-term ecological sustainability, multispecies tree farms can be raised to produce resin, timber, honey, paper pulp, medicinal products, etc. Studies are needed on management to maximize total output by making fullest use of diverse food chains that occur naturally. For example, from a multispecies tree farm, products as varied as fodder, silk-fibre, honey, and resin can be derived by designing an appropriate multi-foodchain model (Odum 1983).

The success of private tree farming would largely depend on the ability to develop a matching social system and management practices that are not only sound from conservation standpoints, but also require low inputs. Application of appropriate successional models, for instance, can facilitate attainment of management goals. Rosenberg (1984) has shown how the inhibition model of Connell and Slatyer (1977) can be profitably used for conservation and land-use management. This model proposes that any arriving colonist may establish itself, however, once established, a colonizer tends to inhibit the invasion of subsequent species. Normally, in order to exclude the invasion of undesirable species; one has to use biocides or hand-weeding, involving fossil fuel energy or human labor. According to the inhibition model of succession, desired species can be introduced so the subsequent successional sequence and replacement patterns are regulated.

Furthermore, it is possible to interrupt and regulate the successional sequence and rates, or to revert to earlier successional stages, with proper management practices. These management practices would minimize plantation work and other inputs. For instance, controlled herbivory may be used to stimulate vegetative reproduction of certain woody species, as there is evidence of herbivory initiating shoot growth (Dyer and Bokhari 1976; Barbour et al 1980). More than half of the woody species of the Central Himalaya are known to regenerate vegetatively (computed from Troup 1921) by coppicing, or through root-suckers and root-tubers.

A successful tree-farming program would not only conserve the land around villages, it would also keep the present forested area that accounts for 28.7 percent of the land free from biotic stress due to the local population, provided the present rate of population growth is reduced substantially.

Once the life-support systems are

repaired and basic energy needs of the people satisfied, limited and specific types of industrialization can be introduced to improve the economic level of the people. The industries need to be small and pollution-free. The components required and produced should be lightweight, and the water demand minimal. In order to minimize industry-associated increase in population pressure, it is necessary to introduce industries which maximize the use of services of the local population. It also calls for training the local youth to meet the requirements of the industries to be introduced.

Finally, we address the point of whether or not the above model is practically feasible. Preliminary studies relating to ecodevelopment in the area indicated that the villagers were willing to replace their cultivated land with tree plantations (Singh 1985). In this village, the literacy level was high, and a large percentage of the population was employed in the plains. The animal population has declined considerably from about 20 per household three decades ago to about six per household at present, partly in response to the decline in the availability of forest stock. All these factors in a cumulative way have led to the area under cultivation declining to less than half of the original size. It appears that people in the mountains are forced to bear the drudgery of the present non-viable agriculture, and would be ready to abandon this traditional profession provided appropriate and concrete alternatives exist.

Politically, it may seem difficult for the state to provide the necessary grain subsidy to the mountain population, but the state is already giving huge subsidies in various forms (e.g. cattle improvement, grazing and lopping rights in the state forests, provision of fuelwood and timber supply, subsidy of money for industries, etc.). It is possible that the burden of these subsidies and the maintenance costs of various defunct development agencies may amount to more than the cost of providing grain. Further, it may also be pointed out that the fossil fuel-based agriculture in the plains is being maintained at a sizeable subsidy from the state. In mountain agriculture, use of fossil fuel is negligible, and according to our model, the mountain people are going to be deprived of subsidy from the State Forests. The political problems associated with the grain subsidy can be solved by making people aware of the fact that the costs of environmental regeneration of the mountain region need to be considered as low ; the resources at stake belong to the mountains as well as the plains region.

USE OF ALTERNATIVE SOURCES OF ENERGY

For the protection of the Himalaya and sustainable ecodevelopment for the central region, it is imperative that alternative energy sources be found to achieve these goals. The level of per capita energy consumption in the hills is so low that it cannot be lessened further. At present, leaving aside some townships, almost total energy consumptiom of the villages depends on forest resources. Fuelwood contributes about 60 percent of the total energy in rural areas, including plains districts (Barthwal and Bhatt 1985); of this about 85 percent is used for cooking. Biogas has not been successful, and except for a few demonstration sites, it is seen nowhere in the hill regions. However, in Garhwal, the Nainidanda and Jharikhal blocks have some biogas facilities. Solar energy is mainly used for the natural production of biomass and to some extent for drying grains and household purposes. In effect, this source of energy has not been technologically harnesed. Although it is inexhaustible and, for the most part, available; does not damage land; has few problems of disposal and transmission; and is pollution free, some sociological and technological problems will always limit its use for cooking.

First, availability of solar energy may be erratic, and second, religious traditions regarding eating habits may stand in the way. Still, in places where firewood is scarce, solar cookers may be acceptable.

There has been a suggestion that to save fuel, pressure cookers should be supplied in the hills. If proper arrangements are made so that parts can be replaced and repairs can be done easily, we would advocate the use of pressure cookers at subsidized rates. Similarly, new types of

chullahs manufactured by various agencies are being supplied at subsidized rates by the Uttar Pradesh government. It is claimed that whereas the indigenous **chullah** has an efficiency of 8 to 9 percent, the improved **chullah** (like **priyagini** which is not smokeless, but portable) has an efficiency of about 26 percent.[4] If supplied on a large scale, they can make an impact on the fuel consumption in the hill region, and will involve no social problems. Unfortunately,it is reported that unlike what is being done in the **terai-bhabar** region, the distribution of improved **chullahs** in the hill region is suffering from many setbacks due to organizational bottlenecks. The smokeless **chullah** has apparent advantages, but some people raise the objection that smoke helps maintain the quality of timber used in the household. We believe that this is a small problem which can be removed with extension work.

Although the yearly input of solar energy is reported to be about 7000 times more than the total human energy demand of today, which must also be true of the hills, solar energy cannot be used except in small amounts for cooking and pumping water due to several constraints. The alternative energy sources in rural areas need to be easily available, of lower costs than others, not too technical under present circumstances, and not far removed in use from local socioreligious traditions. It is for these reasons that women in some hill areas still prefer obtaining fodder and firewood rather than nonconventional alternatives 260 days a year (Barthwal and Bhatt 1985).

GeothermalEnergy

The Department of Nonconventional Energy Sources believes that geothermal power is likely to be the main, ifnot be the only, answer to energy needs of the hill areas of the country (Dayal 1985). Investigations of geothermal energy potential in some parts of U.P. are being conducted by the Wadia Institute of Himalayan Geology, the National Geographical Research Institute, and The Geographical Survey of India. No details are yet available, but except in Tapovan and Badrinath, the possibility of geothermal energy making any dent in energy consumption of the hills appears to be remote. For the present, all activities under the exploitation of geothermal resources are likely to be limited to research and development. Even if breakthroughs in technology are achieved and more sources of geothermal power are found, it is futile to hope that this will help solve the energy problem in any substantial way. It may, however, provide energy to remote places where both fuel and hydroelectric power would be difficult to supply.

Wind Energy

Energy available in the form of wind power is reported to be equal to four times the energy consumption of the world in 1985. Wind energy is available in plenty in the Central Himalaya and it is particularly abundant in the northern part, where fuel and electricity problems are acute. The Society of Science for the People (Jagdish 1985) has conducted experiments to see the effect of slope on wind speed, for example, which suggest that the combined effects of height and slope may make it easy to locate mountain sites which experience moderate to high wind in the Himalaya region. Unfortunately, little information is available on wind speeds in the region. Though the survey work is costly and time-consuming, wind speed data could be obtained by using Dines Pressure Tube Anemograph (DPT) at selected sites. After identifying the suitability of the site, wind farms (clusters of windmills), for power generation of the order of 1 MW can be set up at various places in the Himalaya region. This will reduce transmission costs, but as in the case of solar energy, the technological breakthrough is still awaited. National Aeronautical Limited (NAL), Bangalore is engaged in research and development of power generation through windmills. Alternatively, small windmills can be provided in many villages to do manual work like wheat grinding and to provide some light in the **Panchayat ghar** where people can gather and watch television or have social gatherings. Much is hoped for DNES in the matter of harnessing wind energy in the Himlayan region. Our estimate is that, presently, laying emphasis on harnessing wind energy will be more profitable than geothermal or even solar energy for remote places. The problem of storage of energy is acute here as well as in solar energy systems. Like solar energy, both wind and geothermal are clean, free of pollution, and have few transmission problems.

Biomass Fuel

Another way in which forest fuel can be saved is by using minor products of the forest and fields. In the hills, the use of such minor products for direct energy purposes is not popular. Although minor forest products like leaves are used as fertilizers, they have not been used in a form that can relieve the pressure on forest fuel. In large areas, the **chir** pine forests have abundant needles which are hard to degrade and are slightly acidic in nature. They are the main source of fire hazard in the Central Himalaya. In spite of considerable interest shown intermittently, this has not been put to use. It is true that with the help of the Indian Institute of Technology, Delhi, some fuel briquettes are being manufactured and are reported to be economically viable, but their use is confined to an extremely limited population. It would be interesting to evaluate the utility of this method of using pine needles for cooking purposes and consider the feasibility of mass production in a decentralized manner. In other words, if the method is found to be economically viable (or even nearly so) in a small cluster of villages, machines could be installed for supplying these briquettes to the villagers at a reasonable cost. Use of other forms of biomass, like sewage, sludge, gobar bagasse, etc., is not possible in the hills above 1000 meters or so, and is not dealt with further in this section. However, the use of pine needles as an energy source is not a sound ecotechnology, as depletion of nutrients from the forest ecosystem would destabilize its functioning.

Gobar gas is an appropriate source of energy below 1000 meters where fermentation can take place and both in Garhwal and to some extent in Kumaun region river valleys, **dun** valley, **terai**, and **bhabar** are making appreciable use of biogas. In statistical terms, there is a saving of three trees per family per year, and much time is saved in labor which women otherwise spend in fuel collection. With modification of techniques, biogas may be usefully produced at higher altitudes.

Microhydel

The exploration of microhydel units dates back to the British period. However, systematic exploration of microhydel generation was taken up only in the Second Plan for meeting local demands. It appeared that the microhydel projects were intended as a rapid solution to the problem of electrification, while the focus lay essentially on developing major power capacities (Joshi and Sinha 1981). However, in view of the capacity of available land and considerable objection to big dams, microhydels are essential for many areas.

Next to forest, the swift-flowing rivers (both snow-fed and those originating from the Lesser Himalaya) constitute the major resources for energy. Leaving aside major projects for hydroelectric generation on the River Kali, little use of the Bhagirathi and Jamuna has been made for power generation. There are various projects under consideration using both the technology of big dams and surface-flow tunnels. There is some opposition toward the big dams to be constructed in the hill region. The total generation capacity in the Central Himalaya may be around 20,000 MW. However, since all these cannot be easily harnessed due to difficulties in terms of site, power transmission, and cost, gravitation energy is being lost. A socioeconomic study of the implications of some microhydro power systems in the hills has been made by Joshi and Sinha (1981), and their report is not optimistic.

Since the power generated by microhydel stations is mostly used for lighting purposes, the maximum load is for several hours after sunset. There are no local industries except a few sawmills and flour mills, and in some cases pumpsets for irrigation. The chances of setting up of forest and agro-industries are remote and so far no worthwhile success has been achieved in these fields. The power generated the rest of the time is not used. It cannot be connected to the general grid on account of high cost. Further, microhydel power generation is more costly.

The smaller units require comparatively high running costs per unit of energy generation, as more human resources for management are needed than in bigger ones. Even for small units of 50 kW at least four persons are required to look after the unit according to the labor laws. The cost per unit of energy works out to be about Rs. 5.

The energy is utilized for a shorter time as there are no industries in the neighborhood which require power during the day. Furthermore, there are difficulties of repair and technical assistance at remote places and the water flow is not constant throughout the year. The administrative problems could be solved if the units are run by the village community where strict labor laws may not apply. One such example is in the village of Dasholi, in Chamoli, where the entire microhydel system is set up and run by the village community. The study of Joshi and Sinha (1981) shows that firewood consumption has not been reduced to any perceptible extent with the introduction of microhydel energy. However, the consumption of resinous pine sticks, or **chilka**, and kerosene, both of which are used for lighting purposes, has been reduced.

The search for renewable resources for energy is highly desirable for the survival of the population in the hills and for reducing the pressure on forests. Of the renewable low-cost technologies, microhydel power, in spite of the difficulties mentioned above, would be highly desirable provided changes are made in working and management. The untapped potential for microhydel is high, and suitable sites can easily be available. It would reduce transmission cost and be helpful to villages situated in remote areas. Today, electricity constitutes a small part of energy consumption by the rural household. There appears to be no hope for using electricity for cooking purposes in near future. Although we believe that in some cases where abundant supplies of surface waterflow are available and power cannot be used for any other purpose, it must be used for cooking purposes supplied at very cheap rates.

In brief, a decision on decentralization of energy production and distribution should be taken for meeting the energy demands of the dispersed hill population. As envisaged in the state's Sixth Plan (1980-85) such an energy system would have to be based on a systems approach. The available electrical energy in a given location may be utilized even in a nonconventional manner (e.g. besides flour mills, pumps, and sawmills, it may be given at cheap rates for preparing tea, beating water, etc.). The intermediate technology development groups in the country and elsewhere, such as in the U.K. (Khanha 1985) and BIT group in Nepal, have developed suitable microhydel plants and watermills. Possibly, these could be used even for power generation in springs and would be useful in small ways in the villages. In the name of development, the traditional watermills are being replaced by diesel flour mills. What is needed is an improvement in the traditional watermills. Small changes (e.g. in the ball bearing design of water turbines) would make a great difference in performance. But to encourage diesel machines by replacing renewable water resources is not a healthy development (Pant 1981).

Chapter VI of the U.P. Hill Development Seventh Five-Year Plan makes the interesting statement that not only for socioeconomic development of the hill region is power one of the most important infrastructures, but also it is required to reduce pressure on forests for fuel. High priority is given to accelerating the pace of power development, especially for rural electrification. However, no study project for household consumption to save fuel is envisaged. It is proposed that besides some tapping of nonconventional energy sources on a selective basis, soft coke, kerosene oil,and cooking gas will be provided by extending financial support. It is learnt that DNES proposes to set up **Urja Grams** (energy villages) on a large scale for using the best mix of nonconventional energy-saving procedures in order to improve the energy situation in villages. We hope that the Central Himalaya will be included in the program.

Progress during the Sixth Plan has not been implemented as well as planned and constraints which existed before still exist. However, Rs. 12.5 billion have been provided for power development of which Rs. 1.0 billion are for microgeneration hydel schemes in the Seventh Plan. It is not necessary to detail hydel and other nonconventional energy projects here. The emphasis on reducing the pressure on forests for fuel is a welcome aspect of the development plan.

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ENDNOTES

1. It is an irony that the chairman of the conference was the late Homi J. Bhaba of the Third World.
2. Personal communication.
3. This is assuming that the amount of tree leaves collected from forests mostly accounts for the difference between the values of manure input and sum of dung input plus fodder waste.
4. Personal communication.

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APPENDIX - I

1. The energy value of agronomic yield, 47.6×10^5 kcal per ha per year includes energy values for the yield of grain, pulse, and potato crops as given in the Government records (Uttar Pradesh Statistical book 1983-84). A value very close to it was obtained with an indirect method of computation. In this the average (48%) of several values reported for proportion of foodgrain imported in the region to meet the total requirement (Ashish 1983; Joshi 1983; Airy and Shastri 1984; Pandey and Singh 1984 a; ----- Jackson 1985; Singh and Negi unpubl.) was multiplied with total amount of foodgrain energy required by the population, to obtain the absolute amount of energy imported (40.3×10^5 kcal per ha per yr.). The total amount of foodgrain energy required was calculated by multiplying the minimum average across the population per capita per day foodgrain energy requirement, 2930 kcal (Pandey and Singh 1984 a) with total hill population. The amount of energy imported was subtracted from the total energy requirement to obtain the agronomic yield of 45.5×10^5 kcal per ha per yr. We also reached similar value of agronomic yield on the basis of amount of foodgrain imported in the mountain region of Nainital district (Food Corporation of India, Nainital Office, personal communication). The value of import for this region was used to calculate the total import in the mountain region of eight districts of Uttar Pradesh. Thus it appears that our value of agronomic yield, 47.55 x 10/5 kcal ha per yr must be close to the actual value.

2. For computing the crop byproduct energy, average ratio of agronomic yield to the byproduct energy reported for five villages by Pandey and Singh (1984 a) and Singh and Negi (unpubl.) was used. The amount of unharvested biomass, as reported by Singh and Negi (unpubl.) was used after appropriate adjustment to calculate the crop energy that returned to crop field.

3. Energy from forest is derived mainly to meet the fodder and fuelwood requirement. On average the livestock population per hectare cultivated land consists of 2.30 adult cattle, 2.20 young cattle, 0.76 adult buffalo, 0.77 young buffalo and goat or sheep* (a total of about 7, derived from livestock population of 1978 in mountain region and proportions of different categories given for an area of Kumaon Himalaya, see Jackson 1985). This size of livestock population is similar to that reported for a mid-mountain region (7.7 per ha; see Jackson 1985) and those reported

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1. **It was assumed that one-third of the total sheep plus goat population is associated with settled agriculture. (6.01 and 8.36 per ha) for some village of mid-montane belt by Pandey and Singh (1984 a), and Singh and Negi (unpubl.). While estimating the fodder requirement, the population of stall-fed fodder (about 40%, Jackson 1985) diverted to manure was also accounted for.**

4. While calculating dung production and assumption of 20% energy efficiency of dung production (Rogers 1983 in Pandey and Singh 1984 a) was followed. It was assumed that 80% of dung production is used as manure, and the rest villagers fail to collect.

5. The difference between the amount of manure input and sum of dung input plus unutilized fodder represented leaves collected from forest for preparing animal-bed, refuse of household and ash generated from fuelwood.

6. The per capita fuelwood requirement taken for this calculation was 1.61 kg (average of values given by Shah, 1982; Airy and Shastri, 1984; Singh and Negi unpubl.).