Development Ecology of the Arun River Basin In Nepal

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ABBREVIATIONS USED IN THIS REPORT/PUBLICATION

ADB	Asian Development Bank
DFAMS	Department of Food and Agriculture Marketing Services
FAO	Food and Agriculture Organization
HMG	His Majesty's Government
ICIMOD	International Centre For Integrated Mountain Development
JICA	Japan International Co-operation Agency
KHARDEP	Kosi Hill Area Rural Development Programme
LRMP	Land Resource Mapping Project
PAC	Pakhribas Agricultural Centre
UNICEF	United Nations International Children's Emergency Fund

Foreword

Just over two years ago, I was particularly pleased as Director of ICIMOD to be able to announce the award of the Centre's first Senior Research Fellowship to Dr. Tirtha Bahadur Shrestha of the Royal Nepal Academy. Dr. Shrestha is already well known to his colleagues throughout the world for his many scientific publications as a Himalayan botanist and ecologist of international distinction. His arduous journeys throughout these mountains on botanical research have taken him, very much in the grand traditions of the great plant hunters of the Himalayas, to the remotest areas of this mountain Kingdom. He has fully earned the respect in which he is clearly held by the international community of Himalayan botanists. More recently, he has been a most welcome contributor to regional and international conferences on the practical scientific management of highly vulnerable, and often perilously degraded, mountain eco-systems.

His Senior Research Fellowship at ICIMOD was intended specially to enable him to pursue these broader interests in the field of development ecology. This important and most interesting monograph, for which I am privileged to write a brief Foreword, is ample evidence that he has used to the full the opportunity for expert reflection on the environmental consequences of mountain development in a specific area of Nepal. His choice of the Arun River Basin in Eastern Nepal is relevant and opportune - particularly given the large-scale investments now being undertaken by His Majesty's Government, assisted by the international aid consortium, in the Arun III Hydro-electric Project and the associated major road construction through the

Kosi Hills. Dr. Shrestha's professional analysis of the ecology of the Arun and his careful conclusions on environmental management will doubtless be read with great interest by those concerned in both Government and the aid community.

This present monograph is being published in a new Monograph Series at ICIMOD for similar reports and studies specifically resulting from the Centre's Senior Research Fellowship Programme. With a very generous grant from the Ford Foundation, ICIMOD has been able to award similar Fellowships to eight outstanding scientists of the Hindu Kush-Himalayan Region. Each Fellowship provides the scientist concerned with a sabbatical period of research and publication on a subject of personal choice, but of direct relevance to the basic ICIMOD objective of promoting the integrated and sustainable development of mountain communities. I feel sure all will agree that this fascinating field study in Nepal by Dr. Shrestha has got this Series off to an excellent start.

Colin Rosser
Director

Acknowledgements

I would like to extend my sincere thanks to Prof. Colin Rosser, ICIMOD Director, not only for awarding me the Senior Research Fellowship but also for his continued interest to see that my experiences and knowledge on Himalayan botany and vegetation get integrated with other professional knowledge in an effort to build up an environmental management perspective. I very much benefited from various discussions, seminars, and workshops organized by the Centre. I am indebted to a number of professional staff of ICIMOD, particularly Prof. Z. Rongsu, Prof. S.R. Chalise, Dr. Kk. Panday, Dr. T.B.S. Mahat, and Dr. H. Bista. For valuable critism and advice, I am indebted to Mr. John Dunsmore. I am very thankful to Mr. Mohan Raj and Ms. Rica Llorente for editing this work to improve its contents and style. I also wish to acknowledge the support and co-operation of Mr. Surendra Shrestha, Chief Administrator, during my period of work at ICIMOD. I am also grateful to the Secretarial and Cartographic staff of ICIMOD for their appreciable job in typing and preparing the report.

My colleagues and friends, specially Dr. P.R.Shakya (Botanist), Dr. D.R.Kansakar (Geologist), and Mr. H.S.Nepali (Ornithologist), have made their significant contribution to this work and I owe them a debt in their special field of expertise. Mr. Prabhakar Shah of the Integrated Survey Section of HMG/Nepal was extremely helpful in compiling and interpreting land use data, for which I am very grateful.

Last but not least I would also like to acknowledge the generous support of the Ford Foundation for the Senior Research Fellowship Programme at ICIMOD.

Summary

1. **The Arun Basin** has a catchment area of about 36,500 sq km, of which over 85 per cent lies in the Tibet autonomous region of China and an area of 5,028 sq km, representing 14.17 per cent lies in Nepal. The 510 km long river carves its way through the great Himalaya and forms a dendrite type of drainage on the south of the main Himalayan range, where it travels 155 km in north-south alignment before merging into the Kosi system. It is an antecedent river and its downcutting has kept pace with the uplifting of the Himalaya. It has been estimated that at least 8,000 m of a thick rock sequence has been eroded by the river.

The range of altitudinal variation from 150 m to 8,470 m within a span of 120 km is typical of the eastern Himalaya. The tropical climate of the low-lying valleys gradually passes into the Temperate, the Alpine, and the Arctic climate with the progression of the altitude towards the crest of the Himalaya. Meteorological stations are few and far between. There are less than 20 stations for recording rainfall in the whole of the Arun Basin. Biological evidence supports the belief that it is one of the wettest basins in the Nepal Himalaya, with over 4,000 mm of annual rainfall in certain regions. The rainfall pattern is typi cal of the eastern Himalaya, where the premonsoon thunderstorms of April and May mingle with the monsoon during June, July, and August. Most of the valleys have a cloud cover above 2,000 m, thus limiting crop cultivation. This is in great contrast to most of the catchment area lying in Tibet, where the climate is dry, cold, and arid.

2. **Slope characteristics** are determined by various tectonic movements and other geological processes such as glacial, fluvial, gravity (mass movements), and the base level of erosion. The effects of climate, vegetation, and human interventions contribute to the dynamics of those slopes. The Arun Basin in Nepal may be divided into two distinct zones, i.e., the Northern and the Southern on the basis of slope characteristics, climatic conditions, and population distribution. The northern zone consists of Great Himalaya and Fore Himalaya, and the southern zone of Midlands and Mahabharat range. The Arun III hydroelectric site lies near the dividing line of those two zones.

3. **Hydropower potential** of the Arun river at its six sites is estimated to be of the order of 1,185 megawatts. The Arun III scheme, at a location near Num village, will have an installed capacity of 400 megawatts and is believed to be the most economical scheme among 52 hydropower schemes identified in the Sapta Kosi Basin. In an area of such high hydroelectric potential, it is essential to install a network of research and monitoring sites for developing an early warning system of hazards (natural/man-made).

4. **Data on land-use** vary greatly in various studies. Most landuse maps do not cover the whole country, except the ones under the Land Resource Mapping Project. According to LRMP data, major landuse types appear as following :

o	Forest land (inclusive of shrub land)	2,538 km^2	(50.49%)
o	Agricultural land	1,272 km^2	(25.31%)
o	Grass land	500 km^2	(9.95%)
o	Others (rocks, snow, water bodies)	716 km^2	(14.25%)
	TOTAL	5,026 km^2	(100%)

The ratio between agricultural land and the vegetated land is of the order of 1:2. This however, varies greatly from one watershed to another. The watershed condition in the northern region is rated to be 67% excellent and 30% good, whereas in the southern-most region it is 4% excellent, 76% good, and 20% fair. Intervening midlands have 53% excellent, 47% good (Nelson 1980).

5. **Data on soil erosion** are meagre and inadequate. The annual soil erosion rate of Sapta Kosi at Chatra has been of the order of 7.8 to 36.8 t/ha/yr and the annual

denudation rate for Arun has been estimated to be 1.9 mm / yr (Ramsay 1986). The percentage of land-slide area is estimated to be 1.16% (JICA 1985), sedimentation load is of the order of 970 $m^3/yr/km^2$ (JICA 1986). Those figures suggest that the Arun Basin is comparatively better than the adjoining Tamur Basin in terms of soil erosion. However, a systematic study on the issue is needed both for a more realistic evaluation and for developing a monitoring system in soil erosion.

6. **Biological resources** in terms of genetic diversity form a unique treasure in the Himalaya, with a number of rare and endangered species. Over 3,000 species of vascular plants which include about 25 species of *Rhododendron*, 50 species of primroses, 45 species of orchids, 80 species of fodder trees and shrubs, 60 species of medicinal plants, and a number of wild edible plants, occur in this Basin. Besides, over 25 species of mammals, including the musk deer, tree bear, magnificent flying squirrel, water shrews, and jungle dog, occur in the wilderness of the Arun Basin. Over 200 species of birds were sighted on a 6-week trip and over 130 species were alone reported from the Barun valley. The fish fauna is rather poorly known. However, one could expect 84 species of fish, including 14 economical species for edible purposes in the waters of the Arun river. Conservation of those biological species has been attempted through designating a large part of the north-west Arun Basin as an extension area of the Sagarmatha (Mt. Everest) National Park, under the "Heart of the Himalaya" project.

7. **The diversity in vegetation** is exemplified by the occurrence of over 30 types of natural vegetation from Tropical Hill Sal Forest to the Alpine Grasslands. On the basis of vegetation types and corresponding altitude, 6 bioclimatic zones may be identified (Table 1). The Tropical zone corresponds to the *Shorea* zone, the sub-tropical to *Schima-Castanopsis* zone, the Temperate to *Quercus* zone, and the sub-alpine to *Abies* zone. The Alpine zone is essentially a zone of herbs and grasses. However, thickets of rhododendrons and junipers occur extensively on slopes with efficient drainage and thick soil cover.

   The sub-tropical and the temperate zones have a large number of forest types, mainly dominated by oaks, chestnuts, rhododendrons, alders, and laurels. Coniferous forests are generally secondary in origin.

Vegetation depletion, mainly through slash-and-burn agriculture, is a contributory factor in destabilization of slopes. However, a forest weed called *Eupatorium adenophorum* (Banmara) is aggressively colonizing all cleared slopes, thus helping to conserve soil from erosion. Information on the succession pattern from *Eupatorium* to original tree vegetation would provide a very useful basis for rehabilitating degraded slopes through afforestation or agroforestry. The vegetation map' (Dobremez & Shakya 1975) provides a broad framework of 'isopotential zones' for such endeavours. Stewart (1987) has produced landuse maps of existing vegetation. A combination of those two works would be a useful tool to produce a forest management plan for the Arun Basin.

8. **Subsistence agriculture**, with a mixed farming system, is the main economic activity in the Arun Basin. Farming systems vary greatly according to altitudinal variation. Crops are grown up to 4,000 m altitude, where the main crop is naked barley and potato. Those high altitude areas are used more extensively as pastures for yak, yak hybrids, sheep, and goats.

   The main activities of agriculture take place at middle altitudes between 1,000 m and 3,000 m. There are two basic cropping patterns : paddy-based for irrigated land, and maize-based for rain-fed land. Transhumanne is practiced at altitudes lying above the upper limit of the cropping zone (3000 m approx.). Livestock is an integral part of the agricultural system.

   Average land holding is 0.5 ha per family and the yield has been decreasing for all the principal crops, i.e., paddy, maize, and millet. Slash-and-burn agriculture still relieves people from food deficiency. This practice is rather detrimental to the ecosystem. Therefore, a management strategy that addresses the socioeconomic problems of the mountain people has to be developed to support other developmental activities.

   Three cash crops are well developed in the Arun Basin. Of these, citrus fruits, specially tangerines and sweet oranges are most developed. The southern region of the basin, specially Dhankuta and Bhojpur districts, produce large amounts of these. The marketing mechanism and storage facilities and fruit processing units are rather poorly developed. Big cardamom has recently become very popular as an inter-crop along alder forests. Cardamom cultivation has proved to be quite successful both economically as well as ecologically in the adjoining Tamur basin. Agronomic support and loan facilities of the HMG/Nepal have encouraged a large number of families to grow cardamom.

Potato is perhaps an important crop for the farmers of all agro-climatic regions. Production of a disease-free and high-yielding variety, through tissue culture techniques developed in Nepal, is entirely possible. However better co-ordination among various institutions is needed to ensure a regular flow of plantlets from flasks to fields.

The interdependence of crop production, livestock management, and use of forest resources is well recognized in the Arun Basin. The role of livestock as the principal source of draught power and manure is crucial in the farming system. The livestock population exceeds the human population and the pressure on forest land is on the increase. Forest areas lying between the alpine pasture land and the cultivation zone suffer greatly from double pressure of grazing from the down-coming high altitude herds (Yaks, sheep, goats) during winter and the upgoing cattle during the summer and monsoon.

All accessible grasslands are in a seminatural condition and a varying degree of succession, both retrogressive as well as progressive, is to be observed in the four different zones of grasslands. Grassland management of those zones should be based on the lessons learnt from the natural succession of plants. There are a large number of native trees and shrubs (over 75 species) that are already in use as fodder. Among them ten species, including the "gogane" *(Sauraja napaulensis)* and the "Nimare" (*Ficus auriculata*), are cultivated as village trees. Otherwise they have almost been wiped out from natural habitats.

9. **People**, indigenous to this basin are the "Kiratis". They are represented mainly by two ethnic groups, i.e., the Rais and Limbus. They inhabit the middle mountains. Upper reaches of the basin at higher altitudes are inhabited by Bhotea people who have a close affinity with the Sherpas and the Tibetans. Southern valleys of the basin have Brahmins, Chhetriyas, and associated occupational castes of the Hindus. Trading centres have isolated groups of Newars from Kathmandu Valley.

A population of just over 450,000 people is distributed rather unevenly. The density per sq km varies from 8.2 in the sub-alpine zone to 133.44 in the sub-tropical zone. The southern district, Dhankuta, is densely populated (145.7/ sq km) while the northern district, Sankhuwasabha, is sparsely populated (37.2/ sq km). Bhojpur district (127.9/sq. km) lying in between, closely follows Dhankuta. Over 40% of the families farm at below subsistence level. They seek additional employment, such as portering, labouring on construction projects, gathering and selling medicinal herbs and firewood, preparing and selling handicrafts, quarrying semi-precious stones, and also serving in the army inside or outside Nepal.

10. **Development activities** in the three districts in the basin are aimed at fulfilling the basic needs of the people, by improving upon agriculture and extending education and health services; local development activities are concentrated on construction of mountain trails, suspension bridges, drinking water, irrigation schemes, and so on.

    The Kosi Hill Area Rural Development Programme (KHARDEP) and the Pakhribas Agricultural Centre (PAC) have been actively engaged in a number of local development activities. The Dharan- Dhankuta Road (51 km) and its extension to Basantapur (35 km) is a major work of infrastructure development for the region.

11. **The Arun III hydroelectric project (400 MW) and the access road** (about 70 km) is regarded as priority project of HMG/Nepal, and the first phase is scheduled for completion by 1994. This project would obviously exert a massive interference in the environment and, therefore, the utmost care should be taken during planning, construction and operational phases. Inhabitants of the Arun Basin will certainly have a special role to play in managing the environment particularly with reference to landuse and slope stability. Schemes for watershed management, nature conservation, and socioeconomic upliftment should, therefore, be an integral component of development activities of national importance. Therefore, an Action Plan for the environmentally sound management of Arun River Basin should be considered.

TABLE 1: ARUN BASIN ECOSYSTEM

Alt. m./ft.	Ecological Zone	°C	Soil Type	Vegetation Zone	Farming System	Altitudinal range of crops	Altitudinal range of live stock	Hazardous activities
	NIVAL			SNOW & ICE	SNOW & ICE	SNOW & ICE	SNOW & ICE	
5000 (16500)	ALPINE	0	Rankers	*Juniper-Rhododendron* Juniperus indica bushes. Rhododendron scrubs less than 0.5 m. tall. Herbs, grasses, sedges	Livestock Based Yaks, Dzos, Sheep, Goats (Transhumance)	Barley	Yak/Chauri	Firewood for: (i) Mountaineering (ii) Shepards, Pasturage
4000 (13200)	SUB-ALPINE	4	Podzol	*Fir and Birch* Abies spectabilis Betula utilis Rhododendron shrub-land over 1m. tall			Sheep/Goat	
3000 (9900)	TEMPERATE	9	Acid-brown brown organic materials	*Deciduous broad-leaved* Acer (maples), Magnolia, Sorbus (beam) Tetracentron	Crop/Livestock Based Potato and Barley Cattle (Cows, Buffalos)	Potato, Millet, Buck Wheat		
				Evergreen oaks Quercus lamellosa Daphniphyllum himalayense	Shifting Cultivation			
2000 (6600)	SUB-TROPICAL	16	Red and acid-brown	*Schima-Castanopsis* Schima wallichii Castanopsis indica Castanopsis tribuloides Engelhardtia spicata	Crop (Rice/Maize/ Millet) and live stock Based (Cattle/ Goats/Pigs)	Maize, Rice	Cows, Buffalo, Pigs, Goats	Slash and Burn for (i) Terracing (ii) Shifting cultivation; Fodder, Firewood, Litter collection; Establishment of New Cattle Herds "Goth"
1000 (3300)	TROPICAL	20	Tropical	*Shorea robusta* Terminalia alata Pandanus nepalensis Duabanga grandiflora Bombax malabaricum	Crop (Double cropping Rice). Livestock (Cattle, Goats, Pigs)	Wheat		
0								

Introduction

The Himalaya is well known for eternal snow, for the mysterious abode of the abominable snowman, and for adventures offered by its majestic heights. A sharper focus on the Himalaya, however, reveals that it is also an abode of deprived people, millions of whom have an integral social relationship with the mountains. The interplay between human activities and mountain resources has emerged as a critical factor in sustaining the mountains and the people living in and around the region.

This pronounced need to search for social and economic objectives with ecologically sound management prompted the establishment of ICIMOD in December 1983. Among its various activities, the Senior Research Fellowship Programme provided special opportunities to the scientists of this region to participate in the endeavour of integrated mountain development. The present study on the "Development Ecology of the Arun River Basin in Nepal" was undertaken as the first fellowship programme of the Centre.

The Arun river is an antecedent river with respect to the Himalaya. The entire basin covers some 36,500 sq km in China and Nepal. The area of the present study lies largely on the south of the main Himalayan range in the territory of Nepal. It covers some 5,000 sq km of eastern Nepal in the Kosi zone. Such a large area of mountainous terrain would require a huge effort of research and exploration to arrive at quantifiable results for management options. Besides, a complete study of an ecosystem could conceivably have no end. Therefore, attempts have been made in this study merely to elucidate the principal features of physiography, geomorphology, vegetation, fauna and flora, vis-a-vis the human population of the basin. Observations have also been made on (i) how peasants obtain their subsistence, (ii) what is their calendar of operation in their field, and (iii) what factors determine their choice of site for raising crops, grazing animals, and utilizing vegetation resources. The role of different natural communities eg., forests, shrublands, grasslands, and meadows was examined in the context of environmental management. Attempts were made to extract lessons from the self-recovering system of nature, through regeneration of vegetation on degraded slopes. The study has reaffirmed the need to protect the Makalu-Barun area from further human encroachments, in order to preserve some of the pristine areas of natural wilderness. The biological resources of the basin have been duly outlined, without going into detailed academic exercises.

The need for incorporating environmental concerns into the management of water resource development has been discussed in the context of the proposed Arun III hydroelectric project and its approach road. This project will have a profound effect on the ecosystem of the basin, which has not yet been adequately anticipated.

Information on natural as well as transformed ecosystems is as yet either too meagre or much too uncoordinated to define sound guidelines for better management systems. The disconformity of available data further aggravates the problem. Besides, quite a few of the available data, specially on ecology, need to be reprocessed so as to make them compatible for an integrated approach. The study has been aimed primarily :

- o to discuss the area in biophysical terms, to provide the basis and background for further studies;
- o to integrate the available information on natural and transformed ecosystems; and
- o to identify issues related to development ecology.

Physio-geographical Characteristics

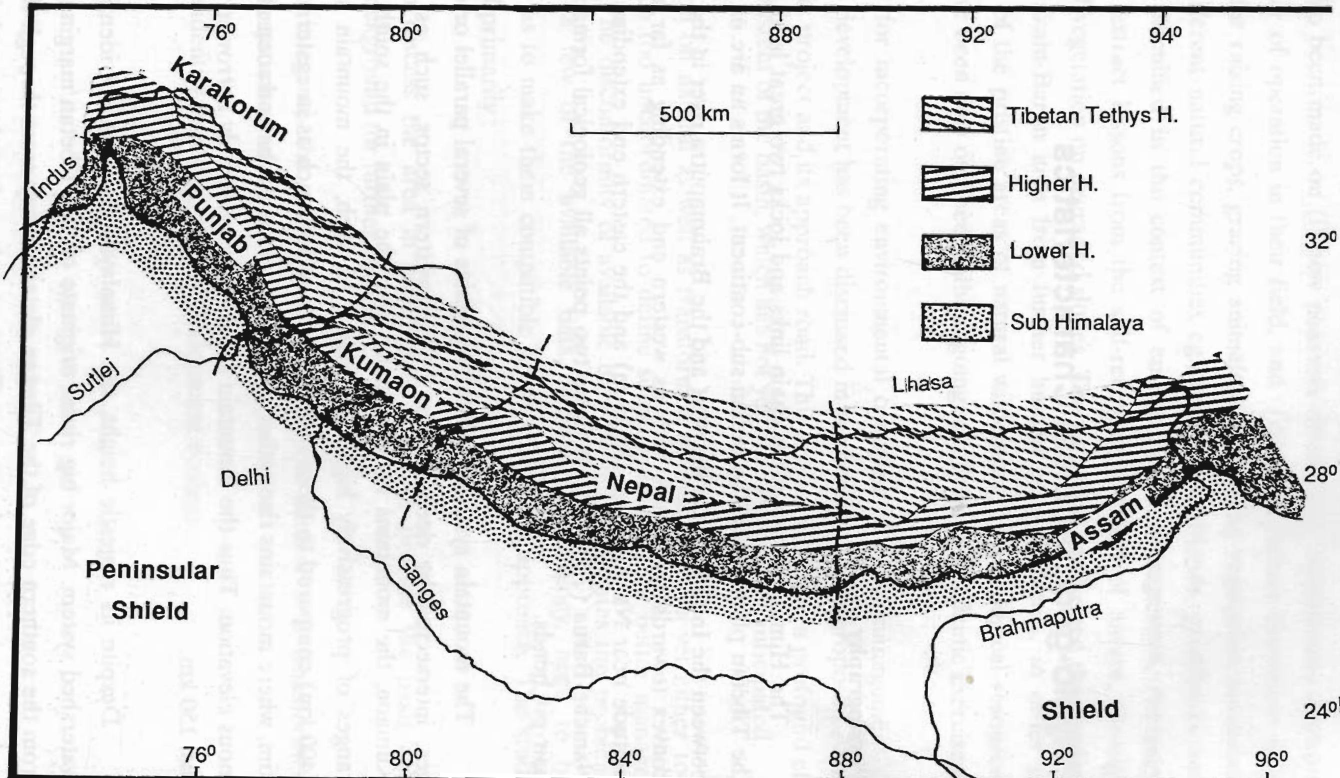
Physiography

The Himalayan mountain chain links and locks two great land masses of Asia, the Tibetan plateau and the Indian sub-continent. It forms an arc of about 2,500 km between the Indus river in the west and the Brahmaputra river in the east. The arc is convex towards the south, with its western end extending as far north as 36^0 N latitude near Nangaparbat (8,126 m) and the eastern end extending to 26^0 N near Namche Barua (7,756 m). At those two points all geological formations take sharp hair-pin bends.

The mountain system constitutes a series of several parallel or converging ranges, intersected by deep valleys. In the western sector, such as in Punjab and Kumaon, the mountains rise gradually from the plain in the south with numerous ranges of progressively higher altitudes. As such, the mountain system is wider (400 km) compared to those in the eastern sector, such as in eastern Nepal and Sikkim, where mountains rise rather abruptly from the plains and soon attain their enormous elevation. Thus the mountain system is considerably narrower with a width of just 150 km.

Despite its majestic height, the Himalayan range is not identified as a main watershed system. Major big rivers originate on the Tibetan marginal range or even from the southern edge of the Tibetan plateau. They cross through the much higher main range in spectacular gorges. There are altogether eleven such large rivers col-

FIG. I **THE GENERAL SUBDIVISION IN THE HIMALAYA** (Modified after Gansser, 1964)



lecting on the Tibetan Plateau or marginal ranges or northern slopes of the great Himalayan range, and they subsequently cross the Himalayas to the south.

The traverses of such major rivers are conveniently used to delineate various sectors of the Himalayas. Tichy (1968) has made four divisions of the Himalayas as following (Fig. 1):

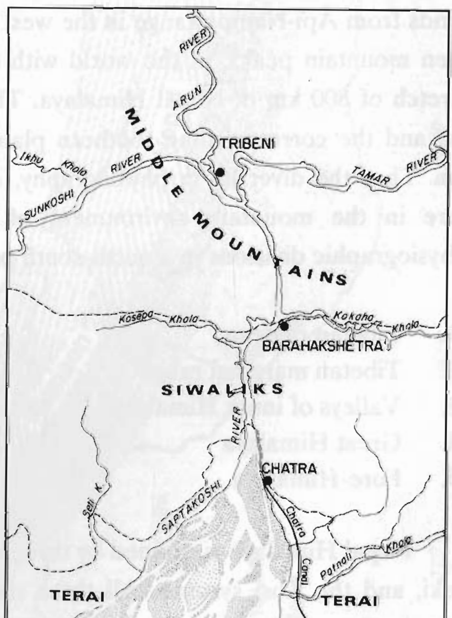
Divisions	Limits	Length (km)
Punjab Himalaya	From Indus to Sutlej	592
Kumaon Himalaya	From Sutlej to Kali	352
Nepal Himalaya	From Kali to Tista	800
Assam Himalaya	From Tista to Brahmaputra	752

Nepal Himalaya

Nepal Himalaya constitutes the central sector of the mountain chain, which extends from Api-Nampa range in the west to Singhalila in the east. Seven of the fourteen mountain peaks, in the world with over 8,000 m altitude are located within a stretch of 800 km of Nepal Himalaya. The world's highest peak Mt. Everest (8,848 m) and the corresponding southern plain (60 m), lie well within a distance of 150 km. Thus the diversity in physiography, climate, and biota presents a complex picture in the mountain environment of Nepal. Hagen (1969) has suggested 10 physiographic divisions in a north-south profile of the Himalaya.

1. Tibetan plateau
2. Tibetan marginal range
3. Valleys of inner Himalaya
4. Great Himalaya
5. Fore-Himalaya
6. Midlands
7. Mahabharat Lekh
8. Dun Valleys
9. Siwalik Range and
10. Terai

Nepal Himalaya is drained by three major river systems -- the Karnali, the Gandaki, and the Kosi systems. All these river systems have their watershed extended into the Trans-Himalayan region. The Kosi river system has seven major affluents, of which three originate in the Tibetan plateau. They are the Sunkosi, the Bhote Kosi and the Arun Kosi. The other four, the Indrawati, the Tamba Kosi, the Dudh Kosi, and the Tamur Kosi, originate in the cis-Himalayan region. These rivers get unified at Tribeni (26^0 54' 55" N 87^0 9' 45"E) and flow down into the Terai plains as the



A remote-sensing imagery showing the confluence of the Arun river with the Tamur and the Sun Kosi to form the Sapt Kosi that traverses the Terai plain of Nepal and goes further South to join the Ganges in India
(Courtesy of V. Galay)

Fig 2A

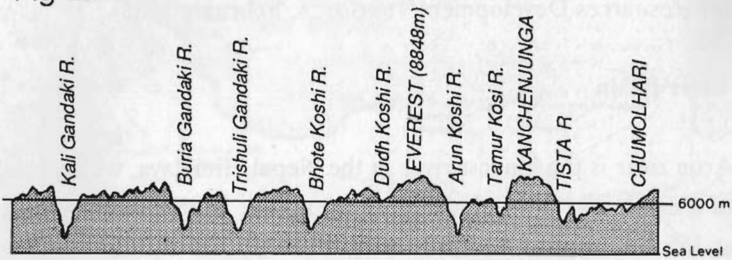
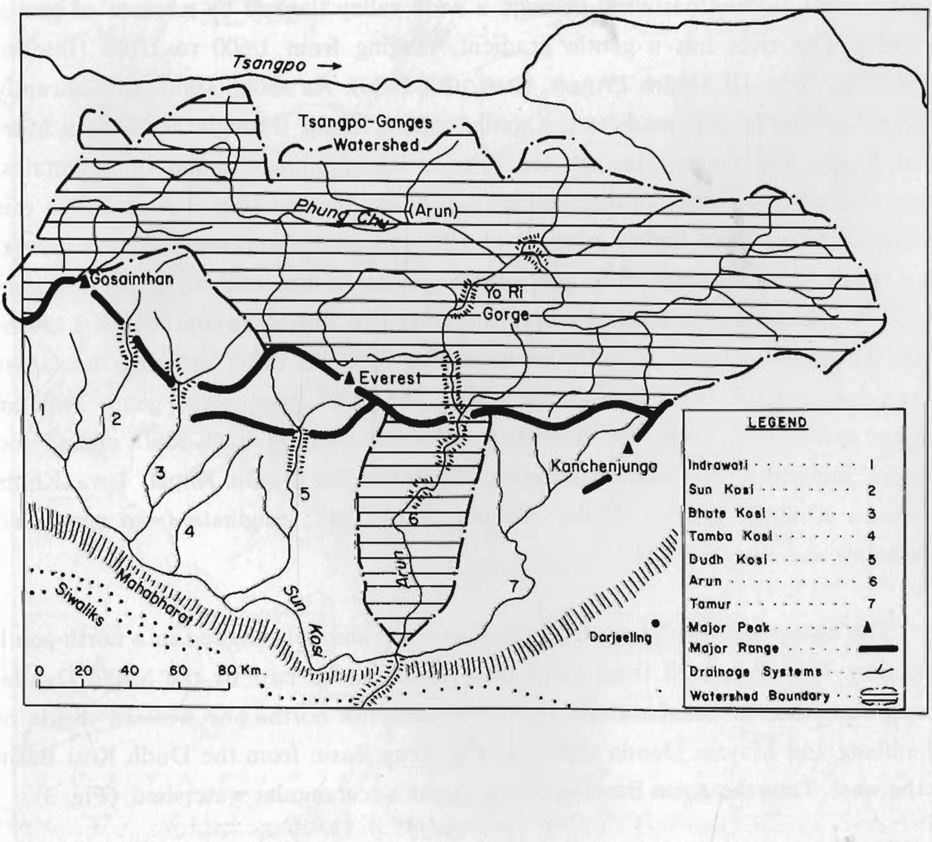


Fig A Section along the Great Himalaya of Nepal, showing the dissection of the Range by rivers. (After E.H. Pascae in Holmes 1972)

Fig. 2B Sketch map of the Arun River Catchment showing the gorges (After Holmes 1972)



Sapt Kosi. The Sapt Kosi has a drainage area of 61,000 sq km, and the Arun has a share of 59 per cent, i.e., 36,000 sq. km. (Source: Master Plan Study on the Kosi River, Water Resources Development, HMG/JICA, February 1985).

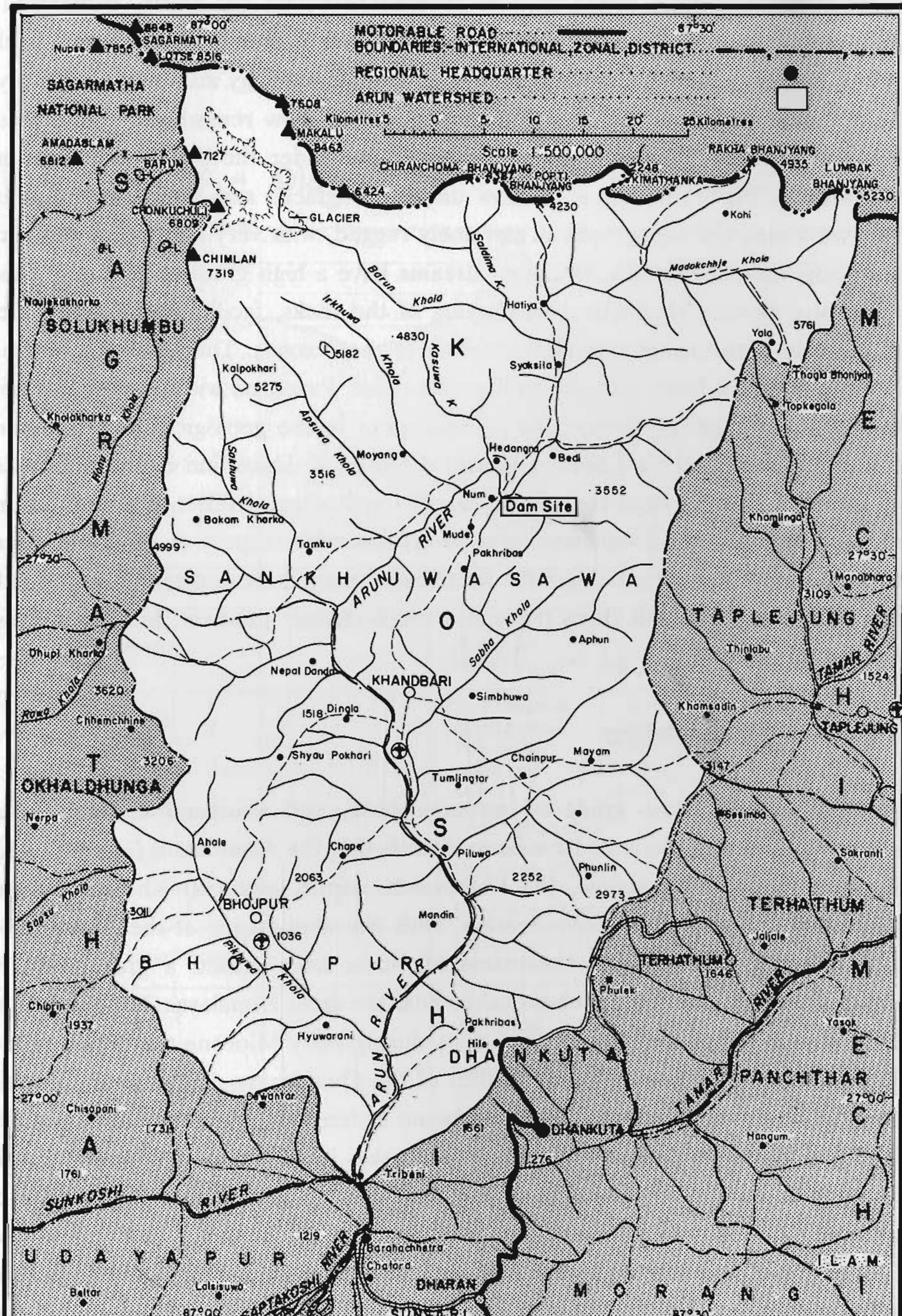
The Arun River Basin

The Arun river is the longest river in the Nepal Himalaya, with a total length of 510 km and a catchment area of about 36,000 sq km. Within Nepalese territory, the river is just 155 km long, with a catchment area of 5,028 sq km, which amounts to 14.17 per cent of the total catchment.

The Arun river starts its journey from the southern edge of the Tibetan Plateau at an elevation of about 6,700 m, and after dropping to about 4,270 m it becomes a braided river flowing eastward through a wide valley flanked by terraces of gravel deposits. The river has a gentle gradient, ranging from 1/600 to 1/100 (Interim Report on Arun III Hydro Project. HMG/JICA 1986). At about 3,960 m, it abruptly changes its course and heads to the south, cutting firstly, through the Tibetan Marginal Range and thence through the Everest-Kanchanjunga group of mountains. Deep and narrow gorges of formidable nature are formed (Fig. 2 A & B). In this section the river has a higher gradient of 1/50 and attains enormous erosive power. As a result, it has formed deep and narrow gorges; in fact, one of the deepest gorges in the Himalayas is formed where the river bed lies at an altitude of 2,136 m while the mountains rise to altitudes exceeding 8,000 m. After crossing the Great Himalayan and the Fore Himalayan ranges, the river flows more gently with an average gradient of 1/360. The river then maintains a nearly north-south course and collects numerous perennial tributaries, of which the Barun Khola, Iswa Khola (Irkhuwa Khola), Apsuwa Khola, Wakang Khola, etc., originate from snow-clad mountains and are glacier fed.

The watershed divides of the Arun Basin are uniquely aligned in a north-south direction. It is separated from the Tamur Basin in the east by the Milke Danda, which continues as Lumbasumba Himal towards the north. The western divide of Chamlang and Mayam Danda separates the Arun Basin from the Dudh Kosi Basin in the west. Thus the Arun Basin in Nepal forms a rectangular watershed. (Fig. 3)

FIG. 3 **MAP OF ARUN BASIN**



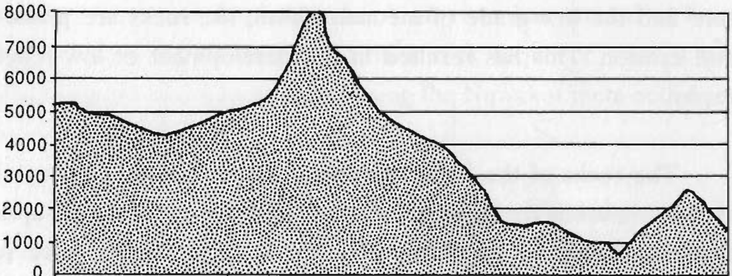
Four physiographic zones may be recognized within the Basin, namely, (1) Great Himalaya, (2) Fore Himalaya, (3) Midlands and (4) Mahabharat Lekh (Fig. 4). Due to variations in elevation, relief, climate, geology and tectonic history, hill-slope characteristics and drainage characteristics show remarkable differences. While the great Himalayan areas are continuously under the action of glaciation processes, the Fore Himalayas are now under peri-glacial and fluvial activities. In these two zones, the topography is extremely rugged, with very high relief and serrated rocky mountain peaks. Drainage streams have a high gradient and thus have high erosive power. Mechanical weathering of the rocks, facilitated by high relief and the cold arctic climate, is characteristic of these zones. The Midlands, on the other hand, have a lower altitude and gentler relief. Favoured with warmer climatic conditions and relatively lower rate of upliftment in the geological past (Quaternary), the Arun river has passed a phase of sediment deposition in the Midlands. The tributary streams have concave (upward) longitudinal profiles, and their riverbeds have reached the local base level of erosion with respect to the main river. However, the Mahabharat Lekh in the south has a much increased relief and ruggedness. The Arun river thus flows through a much steeper gradient, forming narrow valleys in this section.

Geology and Geomorphology

Based on lithology, grade of metamorphism, and structural characteristics, three main litho-tectonic units have been identified in the Arun Basin (Hagen 1969). They are: (i) Nuwakot nappe, (ii) Kathmandu nappe, and (iii) Khumbu nappe. These units are piled one above another, with Nuwakot nappe at the bottom and Khumbu nappe on the top. These tectonic units have moved a great distance towards the south and their "root-zones" lie near the great Himalayas. It is this southward thrust movement of the tectonic units during early Miocene that has resulted in the Himalayan orogeny. Recent studies of the Quaternary deposits, geomorphic features, and geodetic surveys of this mountain system show that the Himalayas are still active. The occurrence of frequent earthquakes in the region also supports this fact.

The Nuwakot nappe rocks are exposed in a tectonic window in the middle part of the Arun valley between Diyale (north of Dhankuta) to Chandanpur, and between Dingla and Chainpur. The Nuwakot nappe rocks are surrounded by the rocks

FIG. 4 Diagrammatic Profile of Arun Basin



	Tibetan Marginal Range	Great Himalaya / Fore Himalaya	Midlands / Mahabharat
ARUN River gradient	1/600 to 1/100	1/50	
Hill Slope angle		Steep(>40⁰) = 73% Moderate(<40⁰) = 27%	Steep 41% Moderate 57.25% Gentle 1.75%
Land use		Cultivated land 2.5% Grazing land 20.0% Forest land 34.5% Shrub land 12.75% Others 30.25%	45.0% 4.5% 41.25% 8.75% 2.0%
Geology		Gneiss, Migmatite, Calc-gneiss, Mica schist, Granite	Phyllite, Quartzite, Slate, Mica schist, Gneiss
Climate		Sub-Alpine to Nival	Tropical to Temperature
Active Geomorphic Process		Glacial, Fluvi-glacial and Mass movements	Fluvial and Mass movements
Major Mass movement Processes		(i) Rock slide (ii) Rock fall (iii) Talus creep (vi) Solifluction (v) Creep (vi) Debris and debris avalanche	(i) Debris fall and flow (iii) Earthslump (vi) Rock fall (v) Mud flow.
Population density per Sq. Km.		37.2	145

of higher tectonic unit, the Kathmandu nappe. In the east, near Chainpur and Phakuwa, the Nuwakot nappe rocks occur between Kathmandu nappe rocks as tectonic scales. The Nuwakot nappe rocks are characterized by low grade metamorphism (epigrade), and the rock types include (1) green-grey and dark grey phyllites, (2) silicious phyllite, (3) calc-phyllite, (4) argillaceous quartzite, and (5) limestone. These rocks are interbedded with each other. Because of their dominantly pelitic nature and the low grade of metamorphism, the rocks are prone to easy weathering and erosion. This has resulted in the development of low relief and gentle topography.

The rocks of the Kathmandu nappe unit, which are tectonically superimposed on the Nuwakot rocks, are more metamorphosed, reaching up to garnet grade and occasionally up to kyanite grade. These rocks, being more recrystallized during metamorphism, are relatively more resistant to weathering and erosion. Such rocks are exposed in the Milke Danda, Dhankuta, Bhojpur and Mayam Danda area. The rock types are (1) Muscovite-Biotite Schist, (2) Garnet-Muscovite-Biotite Schist, (3) Calc-Schist, (4) Quartzite, (5) Augen gneiss, and (6) Porphyroblastic gneiss. At places, pegmatite veins and basic intrusive rocks are seen traversing these rock-types, both along and across the foliation plane. From the economic point of view, this rock unit bears much importance, as numerous deposits of precious and semi-precious stones like aquamarine, beryl, garnet and tourmaline occur in this unit and a number of small-scale mining operations are taking place in the Chainpur-Hyakule area.

The rocks of Khumbu nappe occur in the northern part of the Arun valley. The rocks are hard, resistant, and massive in nature. They include (1) Garnet mica Schist, (2) Kyanite mica Schist, (3) Micaceous quartzite, (4) Migmatites, (5) Augen gneiss, (6) Porphyroblastic gneiss, (7) Calc gneiss, and (8) Crystalline limestone. The Makalu granite, constituting the Makalu group of mountains, is an intrusive leucogranite body of Tertiary age. The intrusive veins of the off-shoot of this granite intrusion are seen in the Jyak Kharka area also.

Major Geologic Structures

The Arun transverse anticline and the Lumbasumba-Milke Danda and Bhojpur transverses syncline are major geological structures that have substantially influenced the physiography, climate, and consequently the biota of the region. The Arun Anticline has dictated the course of the Arun river, as the anticlinal hinge provided an easy path for erosion and excavation by the river. The Arun anticline is believed to be a pre- Himalayan structure (Lombard 1958), that has been reactivated during the Himalayan orogenic movement (Hagen 1969). The down-cutting of the Arun river kept pace with the rise of the Himalayas at most times (Wagner 1937; Hagen 1969). It has been estimated that the Arun river has eroded at least 8,000 m (Hagen 1969) to 15,000 m (Bordet 1961) thick rock sequence since it has formed a tectonic window in the midland zone, exposing the Nuwakot meta-sedimentary rocks of the lowermost tectonic unit.

The thrust planes along which the three tectonic units (Nuwakot nappe, Kathmandu nappe, and Khumbu nappe) travelled to the south have produced effects of shearing in the rocks of its vicinity. As a result, these thrusts provide weak zones, which are susceptible to erosion and instability.

Drainage Characteristics

Drainage is one of the most important sculpturers in the Himalaya. The drainage pattern in the Arun basin may be described as dendritic in form. In the Great Himalayan as well as the Fore Himalayan regions, rivers mostly follow geological structures like foliation and joints. Besides, the relief ratio and the quotient of height to length of the tributaries like Barun Khola, Kasuwa Khola, Apsuwa Khola, etc., are quite high. As a result, the longitudinal profiles of these streams are straight. Active down-cutting becomes inevitable for those rivers, thus rendering the valley slopes a steep angle. Mass wasting is favoured in such a situation. The main valley of Arun is also deep and v-shaped in areas lying north of Num. The river, with its gradient of 1/50, is quite active in down-cutting, while the tectonic upliftment is also quite active in this area. Thus the valley has become v-shaped, with numerous hanging tributaries (water falls), which could not keep pace with the Arun River in its down-cutting activity.

The drainage pattern in the midlands is quite different in character. The river, with its gentler gradient (average 1/360) shows a riffle and pool character. The valley is broader and the slopes are gentle. This is a favourable feature for intensive agriculture. The tributary streams also have a gentle gradient, and the L-profile has its concavity towards the sky.

The Arun has formed a number of flat terraces, composed of alluvial plain deposits of Quaternary time. The Tumlingtar air strip itself is about 180 m above the riverbed, and the river is still cutting down these alluvial plain deposits without reaching the bed rock. The river is reactivated for powerful down-cutting in the Mahabharat region, which could well be attributed to the relative upliftment of the region.

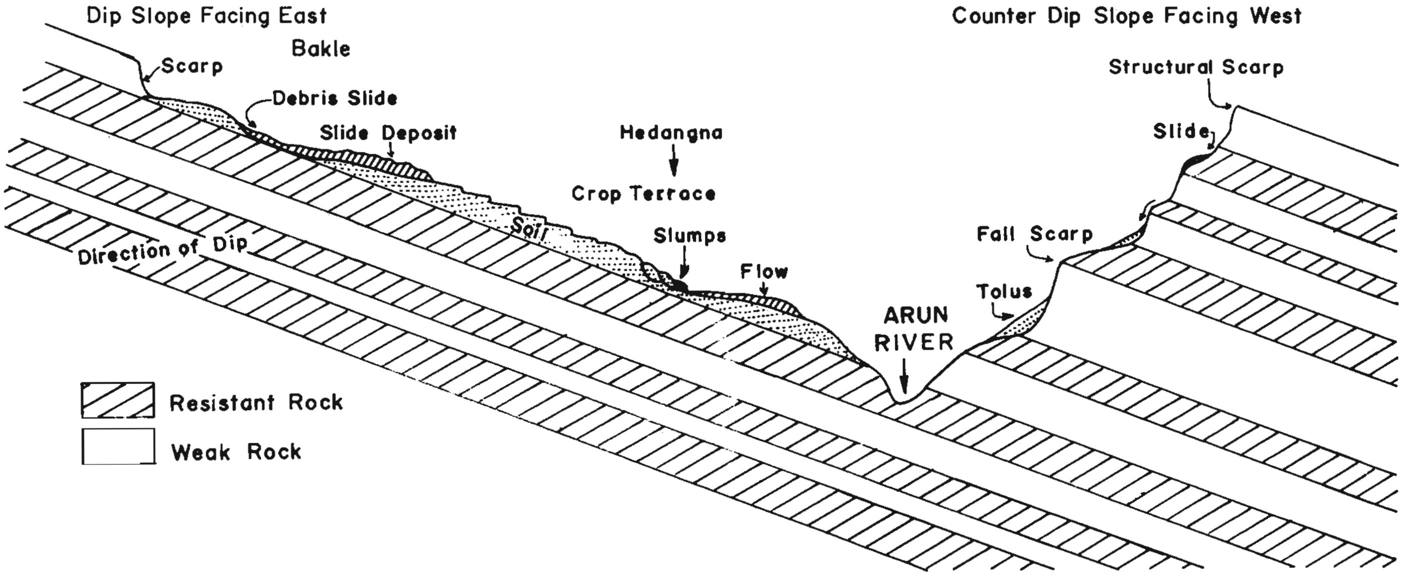
The Arun drainage in Nepal has three distinct zones: (i) northern zone of the Great Himalaya and the Fore Himalaya, where the river is flowing with active down-cutting through steeper gradients and deep gorges; (ii) the midland zone of wide valleys, with depositions of thick alluvial sediments of old age and with tributaries, which form extensive alluvial fans near confluences; and (iii) the Mahabharat zone, with narrow and deep valleys, which are being actively subjected to down-cutting.

Slope Characteristics

Hill slope characteristics are determined by various tectonic movements and other geological processes, such as glacial, fluvial, gravity (mass movements), and the base level of erosion. The effects of climate, vegetation, and human interventions contribute to the dynamics of those slopes. The Arun Basin may be divided into two distinct zones on the basis of slope characteristics - (i) the northern zone of Great Himalaya and Fore Himalaya, and (ii) the southern zone of Midlands and Mahabharat range.

1. **The northern zone:** The northern part of the Arun Basin, lying north of Num, is characterized by high elevation (more than 2,500 m), high relief (3,000 m), cool-temperate to Nival climate, and lower population density (37.2 inhabitants per sq km). Most of this region had been affected by past glaciation, and a variety of glacial, periglacial, and fluvio-glacial landforms can be observed in this area. About 73 per cent of the area is steeply sloping ($>40^0$ slope) and 23 per cent has a moderate slope ($<40^0$ slope) as can be seen on the LRMP maps. Most of the streams are along the geologic lineament structures, i.e., foliation, joint, or fault planes. Because of the extreme relief (height difference between valley bot-

Fig.5 IDEALISED CROSS-SECTION ACROSS UPPER ARUN SHOWING TYPICAL MASS WASTING FORMS ON DIP AND COUNTER-DIP SLOPES



tom and ridge top) and cold climate, mass wasting processes in the form of rock-fall, rock-slides, debris fall and flow, solifluction and soil-creep are to be seen at various places. The relationship between geologic structure, hill slope form, and geomorphic processes may be illustrated in a cross-section diagram designed for Hedangna areas (Fig. 5). The rocks have a NNE-SSW strike with dip amount of 35^0-40^0 due east. They are jointed mainly along three sets; N 30^0 - 50^0W /90^0, N 70^0 W/90, and N 20^0 - 40^0 E/70^0 S - 90^0. The Arun river, particularly from the village of Uwa to Pheksinda, has an almost straight course, flowing from NNE to SSW and follows the strike of the country rock. The east-facing slopes of Bakle-Hedangna villages are situated on the east dipping foliation surface of the gneissic country rock, whereas the west-facing slope on the left of the Arun river is a counter dip slope (Fig. 5). Thus, the interaction of geologic features with geomorphic processes and the climate has given rise to a sequence of landforms from the ridge top above Bakle village to the riverbed, which is quite different from those on the eastern-side slope of the river valley. The rock fall and rock slide, aided by freeze- thaw cycle at suitable elevation produce rock scarp with rock debris, which ultimately slides and gets collected at favourable slopes to form soil cover on the bed rock. Such sites are generally terraced for agriculture. The toe parts of those terraces are susceptible to slumps and flows from excessive moisture content and increased slope angle near the river. On the other hand, the counter dip slopes have only narrow patches of talus deposits available for cultivation. Thus most villages and agricultural fields are located on the western side of the valley, where various processes of mass-movement are operative.

The southern zone: In the southern zone, the Arun river and its tributaries have formed relatively wider valleys, flanked by gentler valley slopes. Chemical weathering has played an important part in shaping the landscape of this zone. The topography is more mature, with thick soil cover and red-clay formations. However, physical denudation is, nevertheless, also an active process, which is manifested by gully and rill erosion on the slopes, and by the active down-cutting of earlier flood plain deposits and bed rock by the streams. In this zone, about 57.25 per cent of the land area constitutes moderate slopes (<40 slope), 1.75 per cent alluvial plains (Tars) and fans and 41 per cent steep slopes (>40 slope).

Terracing a steep slope in the Arun Valley is a futile effort for farmers. The picture shows a steep slope (near the confluence of the Barun) under heavy human pressure and its consequences

Soil Erosion Processes

Soil erosion has been recognized as a major problem confronting mountain development, and lack of reliable data compounds the problem. This is further aggravated by contradictory data on measurements of land resources, soil erosion, sedimentation, forest coverage, and so on.

Soil erosion, in terms of both surface erosion and mass wasting, has been observed in the Arun Basin during the field expedition of August-September 1986. Sufficient attention to surface erosion, which is more damaging to the rural communities in their agriculture, forestry and livestock, has not yet been paid. Erosion is especially severe in the tropical and sub-tropical area, which is dominated by red soils. Streams flowing through red-soil hill-slopes and river terraces (Tars) virtually 'bleed' during rains. Slopes without adequate terracing and without dense coverage of trees and shrubs are turning into bad lands through sheet erosion. Even forested areas with Pine, Sal, and Schima have bare forest floor with exposed tangles of tree roots, as observed near Legua Ghat. Altitudinally, such areas lie below the range of '*Eupatorium*' coverage and no equivalent weed cover is available. Some farmers use *Jatropa* shrub as a contour hedge. This plant seems to be very effective in protecting contour bunds.

Slopes lying between 1,000 m and 3,000 m are rather heavily terraced, and abandoned areas also are luxuriantly covered with *Eupatorium adenophorum*. The detrimental effects of slash-and-burn are also curtailed by the invasion of *Eupatorium*. Thus the soil loss of 8 mm estimated for slash-and-burn areas (Carson 1985) would not be true for the Arun Basin. Surface erosion above 3,000 m does not seem to contribute a lot to the general loss of top soil in the Arun Basin. It has been observed that even heavily grazed areas are rapidly colonized by unpalatable plants. Vast stretches of colourful meadows with *Primula, Potentilla, Ranunculus*, and other beautiful herbs can be attributed to over-grazing by sheep and yaks.

Loss of shrublands from the sub-alpine zone due to mountaineering expeditions, however, contributes to various processes of erosion, ranging from rock fall to landslides. Surface erosion in the Arun Basin has yet to be studied or measured systematically in order to build up reliable data. The data from Chatra Research Centre (vide Ramsay 1986) show that the annual erosion rate has been in the order of 7.8 to 36.8 t/ha, but the period of measurement and number of plots are unknown. Other data, compiled by Ramsay (1986), show that the denudation rate in the Arun catchment is lower, i.e., 1.9 mm/yr than in the adjoining Tamur catchment where the denudation rate is from 2.56 to 5.15 mm/yr. This seems to correlate with the higher percentage of landslide area (13.85 per cent) in Tamur compared to 1.16 per cent in the Arun catchment (HMG/JICA 1985). Similarly, sedimentation load in the Arun ($970 m^3/yr/km^2$) is much less compared to that of the Tamur ($5{,}000\ m^3/yr/km^2$) (Table 2).

Table 2. SEDIMENTATION AND LANDSLIDE IN KOSI CATCHMENT

	Catchment area (km^2)	%	Total sedimentation load (m^3/yr)	annual sedimentation ($m^3/yr/km^2$)	landslide area (km^2)	% to total catchment
Sunkosi	19,000	31.1	$54x10^6$	2,840	642	3.38
Arun	36,000	59.0	$35x10^6$	970	419	1.16
Tamur	6,000	9.8	$30x10^6$	5,000	813	13.85
Saptkosi	61,000	100.0	$119x10^6$	1,950	1,801	2.95

Source : Master Plan Study on the Kosi River Water Resource Development HMG/JICA, February 1985.

Surface erosion has a detrimental effect on agriculture, horticulture, forestry, and livestock. Mass-wasting processes, on the other hand, cause more dramatic damage to the lands and lives of people. Although there are limited things that man can do to control those natural processes, there is a lot of scope for men to escape from disastrous effects of floods and landslides. It needs knowledge to do so. Studies and research generate such knowledge, which is transferred from people to people through training.

In the Arun Basin, mass movement may be categorized inot two zones:

(i) Southern zone (South of Num)

Type of Mass Movement	Type of Land Forms	Examples observed
1. Rock fall	Structural scarp	Along embankments of major streams and tributaries e.g.,Leguwa khola
2. Debris fall	Colluvial deposits and alluvial deposits	Near Diale, along Arun banks
3. Earth slump	Gentle to moderate slopes	Dandakharka
4. Debris slide	Moderate to steep hill slopes	Arun river banks
5. Debris flow	Alluvial plains and tars	Tumlingtar

(ii) Northern zone (North of Num)

Type of Mass Movement	Type of Land Forms	Examples Observed
1. Rock fall	Structural scarps	Upper Barun valley, Bakle, Ala, Uling
2. Debris fall	Talus, scree deposits, morainic deposits	Upper Barun valley, lower valley slopes of Arun
3. Rock slump and rock slide	Rocky terrain with steep slopes and highly fractured rocks	Kikila pass, Jark kharka, eastern slopes at Num
4. Soil creep	Gentle to moderately sloping mountain slopes	Near Tashigaon and other places in Kasuwa valley
5. Solifluction	Talus and scree aprons, gently to moderately sloping mountain slopes, slopes with soil and saprolite cover	Upper Arun valley, Barun valley

Climatic Features

Physical factors of the mountain environment, particularly latitude, altitude, and position in relation to seas and land-masses, determine or limit not only the dis-

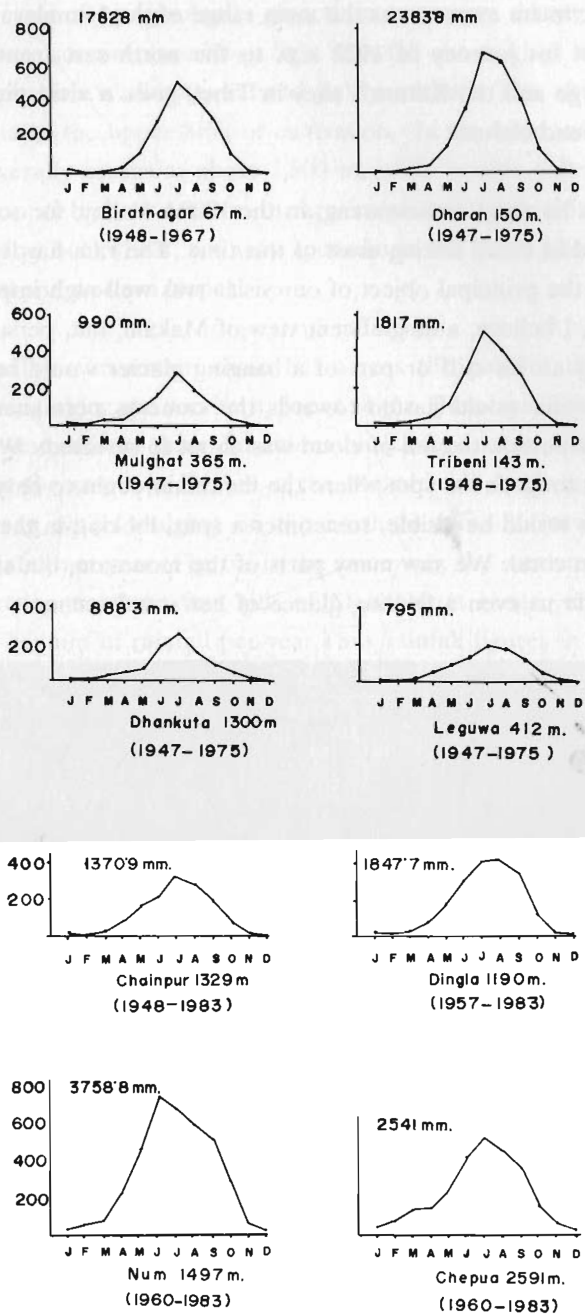
Down-cutting is very active along the Barun river. Slopes are unstable and erosion is a natural phenomenon

Leaning trees in an aldar forest (*Alnus nepalensis*) indicate soil-creep on the slopes of the Kasuwa Valley, a tributary of the Arun tribution of plants, animals, and natural resources but also the activities of human beings. Many of the most important physical factors of land environment are understood in terms of climate. The climate of an area is generally expressed in various meteorological parameters, considering the whole range of weather conditions, temperature, rainfall, evaporation, sunlight, wind, and so on. Unfortunately, the terrain and topography of mountains, coupled with the lack of material resources and educational base among the people, have resulted in a serious paucity of meteorological data in the Hindu Kush-Himalayan region. The Arun Basin has less than 20 meteorological stations along its river course of 510 km, and most of them record rainfall only. Pakhribas Agricultural Centre is the only place to have initiated systematic records on meteorology in the whole of the Arun basin.

The Arun Basin falls in the eastern Himalayan regime, where the monsoon starts early and lasts longer. The premonsoon rainfall during April and May is also much more pronounced. It is often accompanied with hailstorms and thunderstorms. The premonsoon rain gradually passes into the full force of the monsoon by the first ten days of June. The premonsoon precipitation plays a significant role in initiating the growth and spread of protective vegetal cover of weeds and grasses on land surfaces, before they are subjected to the heavy downpour of monsoon rains. Besides, the spring rain is indispensable to hill agriculture for planting maize, millet, and potato. Stainton (1972) found the Arun and the Tamur Valleys to be far wetter than he had experienced in other parts of Nepal during April and May. Winter rain, which is rather conspicuous in the weather system of western Himalaya, plays a much diminished role in the Arun Basin.

The annual rainfall amount in the Arun Basin suggests that midland regions, as exemplified by Bhojpur (1,200 mm/yr), Chainpur (1,370 mm/yr), and Dingla (1,850 mm/yr), have a medium range of rainfall comparable to other midland regions such as Okhaldhunga (1,800 mm/yr), Kathmandu (1,324 mm/yr), and Dailekh (1,300 mm/yr) (Fig. 6). Areas lying closer to the main range of the Himalaya show much wetter conditions. Num, for example, has an average annual rainfall exceeding 3,400 mm/yr. At times, the record goes as high as 6,300 mm/yr. Thus a pocket of heavy rainfall is to be identified in the upper Arun. The occurrence of tropical monsoon forests, with tree ferns at lower altitudes and big leaved species of *Rhododendron* at higher elevations shows a close resemblance between the upper Arun and northern Pokhara Valley, which has been known to be a pocket

Fig.6. Rainfall records of various stations located in Arun Basin



of heavy rainfall in Nepal (Dhar and Mandal 1986). Unlike the Pokhara pocket, the Arun Valley allows the monsoon rain to penetrate far towards the north, creating a corridor of humid climate even across the main range of the Himalaya. Colonel C.J. Morris's account of his journey of 1922 A.D. to the north-east frontier of Nepal, along the Arun gorge and the Karma Valley in Tibet, gives a vivid picture of a wet season towards the end of June:

"We had been in camp at Sakyateng, in the Kama Valley, for some days, and had been enveloped in cloud during most of this time. The rain hardly ever ceased, and photography - the principal object of our visit - was well-nigh impossible. From Sakyateng, there is, I believe, a magnificent view of Makalu, but, personally, I never saw it. Occasionally an ice cliff or part of a hanging glacier would be visible for a few moments, and one would hasten towards the cameras permanently set up in readiness - in the hope that the fall of cloud was about to be lifted. We spent hours in this way, looking towards the spot where the mountain ought to have been visible; sometimes the base would be visible, sometimes a spur, looking in the evening glow as though carved in coral. We saw many parts of the mountain, but she was always too shy to vouchsafe us even a fleeting glance of her stately summit" (Northey and Morris 1928).

The glacial valley of Yangle (upper Barun), unlike other inner valleys of Nepal, is extremely wet. It is used as a summer pasture for yak and sheep

The months of August and September were similarly wet and snowy during the 1986 scientific expedition of the present author. The shower of rain at the subtropical and temperate zones gradually passed into a misty drizzle in the sub-alpine region, which was soon replaced by a light snowfall above 4,000 m altitude. Thus the kind of precipitation is directly related to the altitude.The altitude at which the cloud hangs marks the upper limit of cultivation. In the main valley of upper Arun, cultivation generally ceases at about 1,800 m, while in side valleys local conditions allow cultivation as high as 4,000 m in rare instances. High altitude crops, such as naked barley and buckwheat, are very sporadic in the Arun basin, as compared to those in central and western Nepal.

The Himalayan mountain chain lies across the path of the monsoon, which flows east to west along the southern slopes of the Himalaya. Thus mountain ranges that run east-west enforce drier conditions on leeward areas. For example, Dharan Bazaar lying at the southern foothill of the Mahabharat Lekh receives 2,380 mm of rainfall per year, while Mulghat on the northern foothill (leeward) receives only 990 mm of rainfall per year (Fig. 6). In the same way, the southern edge of the Arun basin lying on the northern foot-hills of Mahabharat range, such as Leguwaghat, receives only 790 mm of rainfall per year.Thus rainfall figures in the Arun Basin increase progressively from south to north until the Himalayan crest screens off the Tibetan plateau from the monsoon rains.

Altitudinal gradient is the most apparent and conceivable of all the parameters in describing mountain environments. Changes in climate with change in altitude are always noticed by a mountain traveller. On an average, the air temperature falls by 0.6^0C per 100 m. Based on the correlation between altitudinal distribution of vegetation zones and air temperature, various authors have classified Himalayan mountains into various bioclimatic zones. It should be noted here that although temperature in general falls with increase in altitude, other environmental conditions do not mirror precisely all along the Himalayas. This is well illustrated by the differing flora and vegetation along the Himalayas. The effect of latitude, for example, is readily observed in the distribution of vegetation patterns on various slopes. In the western Himalaya, south-facing slopes and north-facing slopes have totally different types of vegetation. In the eastern Himalaya, this aspect is rather diminished. In the Arun Valley, forest vegetation on southern slopes, hardly differs from those on northern slopes, especially at tropical and sub-tropical levels.

There are many features of mountain climate that are not understood even today. Our knowledge of these features will improve only when we acquire more data and better monitoring facilities. With remote sensing technology at hand, better information on the climate of Himalaya would build up more rapidly. However, more data from field stations will have to be generated to supplement data from remote sensing in order to understand the functioning of ecosystems in the Himalaya.

Water Resources

The Himalayas shoulder vast seas of snow and ice, which are renewed annually by monsoon clouds. A large quantity of water, in the order of 200 billion cubic metres, goes back to the sea as surface runoff (B.K. Pradhan *et al.* 1983) through innumerable rivers which drop thousands of metres before reaching the plains. It is estimated that Nepal has 6,000 rivers distributed into three river basins -- the Karnali, the Gandaki, and the Kosi basin. Government estimates place the theoretical hydroelectric development potential in Nepal at 83,000 megawatts; economically feasible schemes amount to 25,000 MW only. However, the existing power- generating capacity in Nepal, as of 1985, is approximately 128 MW (Master Plan Study on Kosi River HMG/JICA 1985).

In the Kosi basin, 52 sites have been identified with an installed capacity of 10,909 MW. The Arun basin has six sites for installed capacity of 1,185 MW. Among them, Arun III has been regarded as the most attractive scheme in the Kosi basin. The feasibility study on Arun III Hydro-electric Power Development Project (Nov. 1986) has worked out a scheme with 400 MW capacity. This scheme is the run-of-river type hydropower project, and the construction cost is originally estimated to be U.S. dollars 472.6 million. The cost includes an access road of about 170 km, transmission lines and sub-stations.

The project site is located 40 km south of the Nepal-China border, and three village panchayats, Num, Pathibhara, and Diding in Sankhuwasabha district of Kosi Zone, come into direct contact with this site. The catchment area at the dam site has been estimated to be 29,310 sq km., of which 90 per cent lies in the Tibetan region. The area under heavy monsoon rainfall amounts to some 10 per cent of the catchment, and the monsoon flood does not seem to be so severe. Numerous glaciers and snow-packed mountains serve as the source of feeding for this river. The annual average discharge is calculated to be 321 m^3 per second at the project site. (H.M.G./JICA 1985.). A large part (almost 68 per cent) of Sapt Kosi River lies above 3,000 m, where the drainage area is covered by perennial snow and glaciers. Thus the larger part of the basin produces an insignificant portion of the runoff, especially flood runoff, resulting in a low specific flood discharge (HMG 1982). In the Tamur basin also, summer runoff due to seasonal snowmelt was found to be insignificant (A.N.. Dhar *et al.* 1986). The run-off fluctuation in the Arun River is small in comparison to the Tamur and the Sunkosi rivers. (Master Plan Study on Kosi River HMG/JICA Feb. 1985). However, heavy siltation and steep topography do not favour a large reservoir type dam on this river, and thus a simple Run-of-River (SRR) type was recommended for hydro-electric developments.

The annual discharge of water from the Arun River constitutes 36 per cent (18,300 million cubic metres) of the Sapt Kosi discharge which is of the order of 50,900 million m^3. Annual average discharge is estimated at 600 m^3/sec. Thus the water resources of the Arun for hydro-electric power has great potential in Nepal. The active process of down-cutting by the river, steep slopes, heavy rainfall, and progressive deforestation in the area make it imperative to make an efficient management of the watershed, consisting of afforestation, soil conservation, slope and landslide protection works, and mitigation of riverbank erosion. The special focus of management should lie in the area traversed by the Arun between Chepuwa and Num.

Water mills, locally known as "Ghatta", are most popular as a power device for grinding maize, millet, wheat, etc., and also for turning prayer wheels and for carving out wooden blocks to make small pots and cups. It has been estimated that over 2,500 water mills are in operation in Nepal (Joshi 1983). The watermill survey team of Toshitaka Chuma and Akihiko Namura (Numata 1983 a) did not report a single one from the Arun Basin. However, the author did find a water mill in Syaksila village where various kinds of wooden pots were skillfully made by the use of water as a motor force. Similar mills designed to produce juniper paste by rubbing against stone was recorded from Thudam. Furer- Haimendorf (1975) mentions that in November 1957, verandahs and homes were full of heaps of powdered pulp and large balls made of juniper. Juniper pulp is an important ingredient of the incense used in Buddhist rituals. The development of such traditional devices for harnessing water resources at the rural level would have far-reaching effects on the local economy as well as ecology.

Irrigation, Drinking Water and Fisheries

The Arun Basin on the whole depends on direct precipitation for irrigation in the hilly regions. Rivers and streams are used in low-lying alluvial plains and river-beds. A number of terrace lands, "Tars", could well be converted into fertile lands if irrigation could be provided for them. Quite a number of villages in Sat Tar and Tumling Tar have to rely on the Arun river for drinking water, which flows 100-200 m below their village level. In most of the other parts, hill streams and natural springs are prime sources for drinking water. Local townships and new settlements lying on the ridges and saddles have to lay pipes for long distances. Such locations are few and far between. In fact the beneficiaries of piped water by the end of Sixth Plan (1980-85) amounted to only 18 per cent in the rural sector (HMG 1986).

Fish resources in the waters of Arun have not yet been studied. It is generally accepted that the Arun has a large number of native fish (84 species) and a number of them (14 species) have commercial potential. The fish fauna will be discussed later in this study.

Natural Vegetation And Forests

Natural Vegetation

Vegetation analysis is one of the basic analytical tools for developing an understanding of mountain environments. Vegetation is an overall expression of various environmental factors, which operate continually or in a cyclic fashion. It is well known that areas that are climatically similar will be characterized by similar plant forms. Therefore, observations on dominant vegetation and their response to human interaction would provide useful clues to identify environmentally homogeneous or heterogeneous areas. Identification of similar areas for similar treatments is basic to all management practices.

In the Himalaya, changes in vegetation type occur not only with respect to altitude, latitude, slope angle, slope aspect, and soils but also with respect to rainfall patterns. On the basis of vegetation maps, Dobremez (1976) has provided an interpretation of the ecology of various parts of Nepal. Alpine and sub-alpine zones along Nepal Himalaya and the tropical zone along the Terai and foot-hills show uniform pattern of vegetation distribution all along Nepal, from east to west. However, the intervening area lying between 1,000 m and 3,000 m (sub-tropical and temperate zones) exhibits a great degree of diversity. There is a pronounced difference in vegetation type between west, central and east Nepal (Fig. 7). Above all, this zone (1,000 m-3,000 m) is the principal area of human occupation and cultivation.

Challenges of mountain development lie largely in the biophysical diversity of mountains. Classification of differing ecological regions and providing them with appropriate names have, however, been caught in a complexity of differing opinions and concepts. One of the most simple and convenient methods for describing ecological conditions of a mountainous region is to define "life zones" in terms of temperature and elevation. With the change in altitude, we find a complete range of change from tropical to arctic conditions, and natural vegetation has become a useful tool to identify and delimit various zones. Dominant plants or vegetation types are generally employed as bioclimatic indicators. Various authors have attempted to define climatic zones in terms of altitude (fig. 8). In the Arun Basin, six zones have been identified and they are characterized in Table 3.

Table 3 : BIOCLIMATIC ZONES IN ARUN BASIN

Bio-climatic zone	Altitude (m)	Indicator plants
1. Tropical	below 1000	Shorea robusta, Lagerstroemia, Duabanga, Terminalia sp.
2. Sub-tropical	1000-2000	Castanopsis tribuloides, C. indica, C. hystrix, Schima wallichii, Alnus nepalensis, Engelhardtia spicata
3. Temperate	2000-3000	Quercus lamellosa, Q. lineata, Daphnephyllum himalayense, Acer campbellii, Magnolia campbellii Machilus sp.
4. Sub-alpine	3000-4000	Abies spectabilis, Betula utilis, Rhododendron shrubland over 1 m tall.
5. Alpine	4000-5000	Herbs, grasses, Rhododendron shrubs of less than 0.5 m, Juniperus indica
6. Nival	5000 +	Permanent snow and ice

FIG. 7 : VEGETATION PATTERN IN NEPAL HIMALAYA

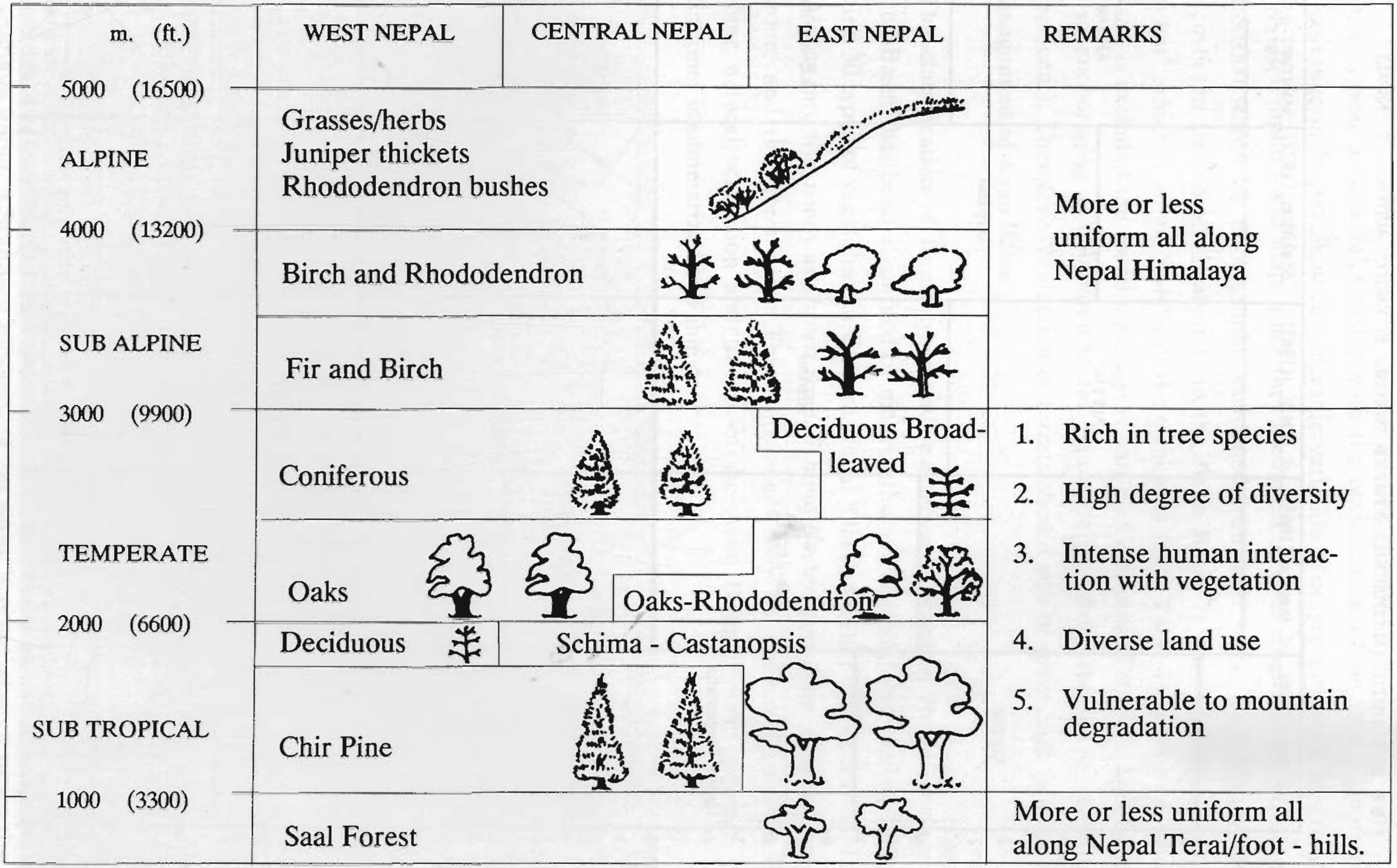
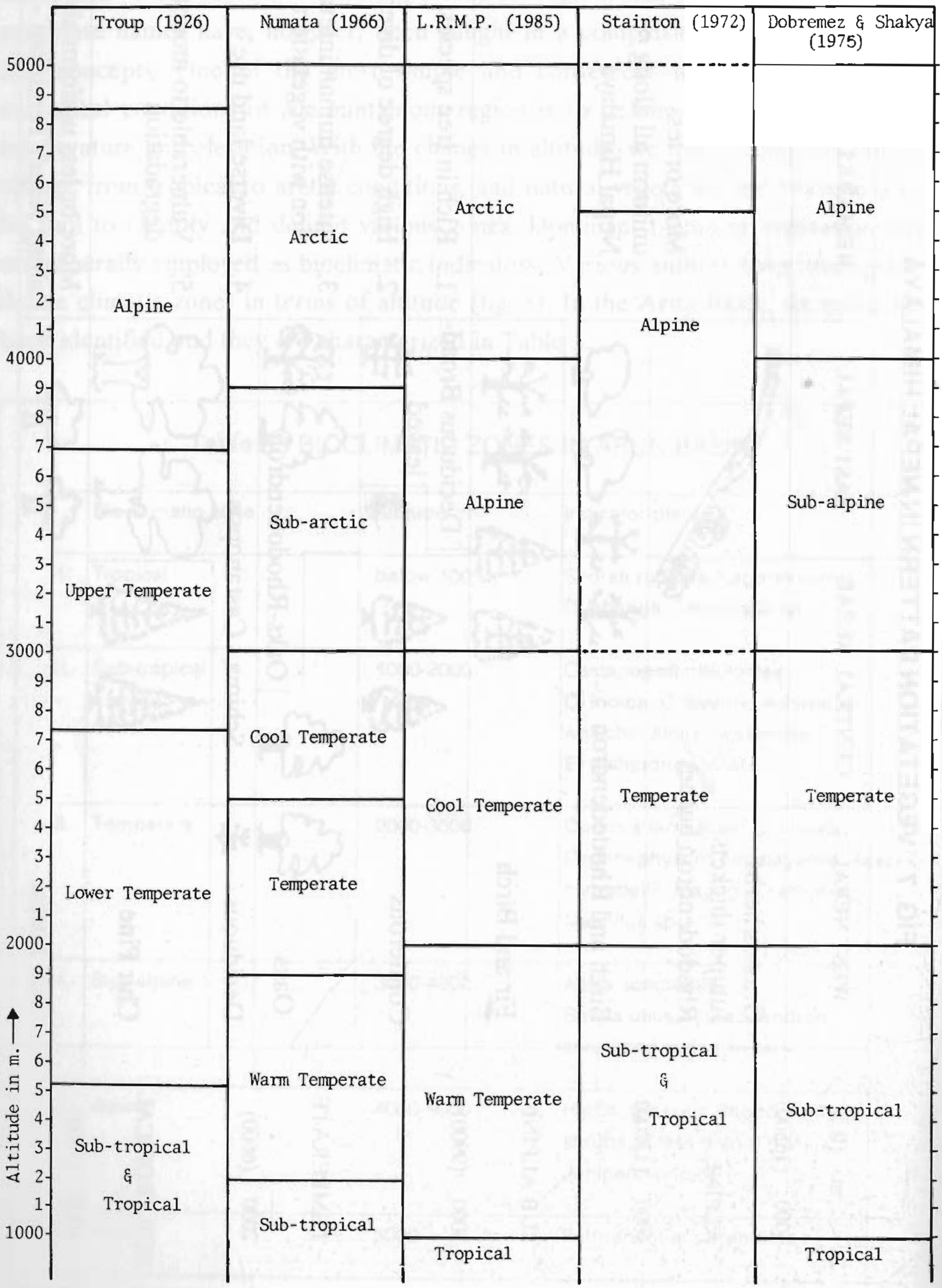


FIG.8 BIOCLIMATIC (ALTITUDINAL) ZONATION PROPOSED BY VARIOUS AUTHORS. (E. NEPAL)



Forests bear a close relationship with the environment of an area. Figures on forest coverage in Nepal show considerable variation. The present work has relied more on LRMP figures and maps since they are based on data from a broad coverage with 1:50,000 stereo air photographs, combined with field work. Accordingly, the forest coverage (including shrubland) in the Arun Basin is estimated to fall near 2,538.6 km^2, which is about 50.48% of the total area (vide Table 7). However, when shrubland is excluded the forest coverage is only 32.5 per cent (Table 4). This figure is not so encouraging as compared to the figure estimated for the whole of Nepal (42.7 per cent). Therefore, protection of forests should still be given high priority in the management of Arun Basin.

The classification of forest types and vegetation of Eastern Nepal (including the Arun Basin) has been attempted by many authors. Dobremez and Shakya (1975) identified 30 types of vegetation in Eastern Nepal. Ohsawa et al (1983) classified the Arun Valley into five zones as *Shorea* zone, *Schima-Castanopsis* zone, *Quercus* zone, *Acer* zone, and the *Abies* zone. These life zones may be used conveniently for describing natural vegetation and forests of the Arun Basin. Forest coverage by climatic zones is summarized in Table 4.

The Sabahaya khola, a Southern tributary of the Arun, is quiet when it nears the confluence. Impressive Saal forest (*Shorea robusta)* is seen in the valley

A. Tropical zone (below 1,000 m)

Although the Himalaya does not lie strictly within the tropics, natural vegetation and climatic conditions more akin to tropical regions do prevail in areas lying below 1,000 m altitude. The occurrence of Dipterocarpus forest, supplemented with palms, cycads, tree ferns, bananas, etc., does characterize the tropical zone. Mean temperature for the coldest month does not drop below 18^0C, and frost is totally absent. In most of the Arun Basin, the aspect of slopes does not exhibit any great influence on vegetation as one might expect in other parts of Nepal. *Shorea robusta,* "Sal", is the dominant tree of this zone, and the hill sal forests, which have developed on laterite slopes along river courses and along shaded gullies, give an impression that the Arun Basin is well maintained in this zone. The tropical area covers about 1,347 km^2, i.e., 22.74 per cent of the total area covered by the three districts (Dhankuta, Bhojpur, and Sankhuwasabha). Forest coverage may be estimated to fall near 8.29 per cent in the tropical area (Table 4).

Table 4 : DISTRIBUTION OF LAND, FORESTS, AND PEOPLE BY BIOCLIMATIC ZONES

	Climatic zone	Tropical (< 1km)	Sub-tropical (1-2km)	Temperate (2-3km)	Sub-alpine (3-4km)	Alpine (> 4km)	Total
1.	Land Area in km^2	1347.32	1996.82	1081.82	596.43	924.74	5920
	(Percentage)	22.76%	33.73%	18.27%	9.62%	15.62%	100%
2.	Forest Area in km^2	450.00	494.2	623.8	211.90	-	1779.8
	(Percentage)	8.3%	9.00%	11.4%	3.8%	-	32.5%
3.	Population Density per km^2	11.53	133.44	46.74	8.20	-	73

Source :

1. Based on contour maps of three districts - Dhankuta, Bhoj-pur, and Sankhuwasabha
2. Based on LRMP maps no. 72 M/1 to 72 M/8. Total 8 maps covering 5470 km^2.
3. Point-by-point population map (1981 census), updated to 1987

B. **Sub-tropical Zone (1,000-2,000m)**

This zone is characterized by the occurrence of *Schima wallichii*, the "Chilaune" tree. The Area of this zone amounts to 1,997 km^2, of which only 9 per cent is under forest cover. Population density of 145 person per km^2 in Dhankuta, 127 person per km^2 in Bhojpur, and 37.2 person per km^2 in Sankhuwasabha (Central Bureau of Statistics, 1986) refers mostly to this zone. Most of the terrain with less than 40^0 slope is terraced. Spring thunderstorms followed by monsoon rains allow intensive agricultural practices.

Of the 30 vegetation types of eastern Nepal (Dobremez and Shakya 1975), six types are represented in this zone. However, four major types of forests will be discussed here.

(a) *Schima -- Castanopsis forest*

The Arun Basin is a country of *Castanopsis*, i.e., chestnut trees. Trees of *Schima wallichii* form forests with *Castanopsis indica* at lower levels below 1,500 m, and with *C. tribuloides* at the upper levels of 1,500-2,000 m. *Schima* forest develops on all aspects of the slope, unlike in central Nepal where it is limited to northern aspects only. Undisturbed forests attain a canopy height of 25 m, while disturbed forests have heavily lopped trees hardly reaching to 10 m. A number of shrubs and trees, like *Engelhardtia spicata, Callicarpa arborea, Rhus javanicus, Osbeckia stellata, Mallotus phillipinnensis,* get associated with *Schima* when forests are used by villagers. Forest floors have a dense undergrowth of *Nephrolepis* fern on drier habitats, and of *Eupatorium* on wet ravines and gullies.

Schima wallichii has a good capacity for self-regeneration and hence it may be employed as an afforestation species. Ohsawa (1983) observed abandoned paddy terraces being replaced by *Schima* after some 70 years, and the trees have attained a height of 21 m. The rate of growth comes to some 0.3 m per year. In Kathmandu, in the forest at Nagarjun, Kanai et al (1975) observed that the chir pine forest was gradually replaced by *Schima wallichii* on north-facing slopes.

b) *Semi-evergreen Hill Forest*

Water courses and steep slopes indicate a very mixed type of broad-leaved forest, with some *Schima wallichii* and *Castanopsis* trees mixed largely with a number of other trees like *Betula ulnoides, Choerospondias axillaris, Saurauja napaulensis, Cedrela toona, and Talauma hodgsonii.* A large number of epiphytic orchids (*Coelogyne, Cymbidium, Dendrobium, Bulbophyllum, Erica)* and climbers occur in such forests. Ohsawa (1983) listed 16 species of climbers from this zone alone. Such forests provide a valuable source of indigenous genetic material for fruit, fodder, bamboo, and grass.

c) *Alnus nepalensis Forest*

It has a wide range of altitudinal distribution from 1,000m to 2,500 m. In the sub-tropical zone, are found rapid colonizer trees on unstable slopes, fresh landslides, and wet ravines. This species can colonize abandoned slopes in about five years time, attaining 8 m height. It has often to compete with *Eupatorium adenophorum* at seedling stage but later both grow well in mutual association. It is a favourite tree for villagers due to its straight poles, fodder leaves, and firewood. In natural succession, *Alnus* forests give way to *Schima - Castanopsis* after the slope has stabilized. Strips of *Alnus* forests along streams and gullies provide an excellent habitat for the cultivation of cardamom.

d) *Castanopsis tribuloides Forest*

Castanopsis tribuloides, in its undisturbed natural state, forms a closed canopy of monospecific forest with very tall trees of 25-30 m. Such forests are largely limited to inaccessible areas due to large distances from villages. The process of burning down the forest for extending cultivable land is diminishing this type of forest at altitudes of about 2,000 m.

e) *Other forest types*

Pure forests of *Rhododendron arboreum* are to be seen on drier south-facing slopes. The grandeur of this flower is best observed on the Milke Danda during April and May. Although it is the National Flower of Nepal, people hardly spare it from burning and lopping. At times it is mixed with oak trees. Water streams are scarce in *Rhododendron* forests.

Pinus roxburghii, which is so important in western and central Nepal as an afforestation tree, is rather scarce in the Arun Basin. It develops in areas with less than 1,000 mm of rainfall per year and with high radiation on south-facing slopes. *Pinus roxburghii* is generally replaced by *Schima wallichii* in natural succession.

Lagerstroemia parviflora, a small tree of 3-5 m or rather a shrub, occurs in highly degraded and rocky slopes in southern Arun. Moist slopes with rich soil conditions, however, favour the *Albizzia mollis* tree. Occurrence of this tree suggests that tea cultivation would be promising in the sub-tropical side valleys of the Arun.

The sub-tropical zone has over 1,600 species of plants. About 60 species of them are being currently used as fodder trees. Besides, some rare and endangered species, such as *Talauma hodgsonii, Cythea spinulosa, Podocarpus nerifolius, Quercus fenestratus*, and *Gnetum montanum*, are surviving a precarious existence in narrow gullies and gorges in the Arun Basin.

The Milke-danda ridge, which separates the Arun Watershed from the Tamur, is rich in rhododendrons. Grassy slopes are interspersed with rhododendron forests

C. **Temperate zone (2,000 m-3,000 m)**

This zone lies just beyond the altitudinal limit of general agricultural/cereal cultivation. Winter is pronounced with frost and some snow. Mean annual temperatures vary between 8^0C and 15^0C. The ground generally remains overshadowed with clouds during the growing seasons. This becomes the main limiting factor for crop cultivation. However, floristic diversity, with over 1,400 species of plants, makes it an important area of genetic resources. At about 2,000 m altitude, forests of Arun are subjected to double pressure of grazing, i.e., from highland livestock (yaks and yak-hybrids, sheep) and from lowland livestock (buffaloes, cows/goats). Over 40 different types of trees and shrubs are used as fodder plants.

Dobremez and Shakya (1975) have identified 10 types of vegetation in the temperate zone of eastern Nepal and they could well be grouped into two categories.

a) *Lower Temperate Mixed Broad-leaved forest*

Forests of *Schima-Castanopsis* gradually pass into an oak-laurel forest, with a number of Magnoliaceae plants. Humid conditions are conspicuously expressed in terms of rich moss flora, epiphytic orchids, and vines. Forest floors have moss-carpeted rocks and fern infested ravines. The first canopy of trees (*Quercus lamellosa*) grows to a height of 35 m or 40 m, while the second storey of lauraceous trees and magnolias remain at 12-15 m in height. Disturbances due to human pressure promote the growth of bamboos on drier steep slopes ($>40^0$) while, on gentler slopes, big-leaved shrubs and trees such as *Mallotus nepalensis, Ehretia macrophylla* and *Leucoceptrum canum* form a secondary vegetation. Plants of good economic value, such as *Lycopodium clavatum* (medicinal), *Daphne sp.* (paper plant), *Girardiana diversifolia* (fibre plant), may be promoted by partial disturbances of temperate forests of the Arun Basin. Ravines and shaded slopes are generally occupied by *Alnus nepalensis* at lower levels and *Daphniphyllum himalaica* at higher altitudes. Both trees grow well in association with cardamom.

b) *Upper Temperate Mixed Broad-leaved forest*

At about 2,400 m or 2,500 m, the temperate forest is conspicuously enriched with a number of deciduous trees. Among the most important ones are the gigantic maple trees (*Acer campbellii*) and *Magnolia campbellii*, reaching 25 to 40 m in height. A number of other trees, such as *Sorbus cuspidata*, the Himalayan bean, *Tetracentron sinense*, a primitive flowering plant which is restricted to eastern Himalayas, *Prunus nepalensis,* and *Pentapanax sp.* and so on, are frequently encountered. The low altitude birch (*Betula cylindrostachya*) and the high altitude birch (*B. utilis*) interpenetrate in this zone. In addition, a large number of smaller trees and shrubs belonging to evergreen broad-leaved categories occur as a second layer. Some of the important ones are *Osmanthus suavis, Ilex dipyrena, Corylus ferox, Symplocus* sp., and some laurels like *Lindera* sp., and *Litsea* sp. On some drier places, *Lyonia ovalifolia* and *Rhododendron arboreum* form patches of forests. Towards the head of river valleys, *Tsuga dumosa,* the Himalayan hemlock, occurs in isolated stands on drier slopes.

This zone is also good for bamboos when natural vegetation gets disturbed. In wetter areas, disturbed grounds are covered with rambling raspberries (*Rubus* sp.). This zone has been identified as cool-temperate deciduous broad-leaved forests by Ohsawa et al (1973). Their occurrence in the Iswa valley and the Kashwa valley adds a remarkable feature to the forest ecology in the Arun Basin.

Cattle breeding activities and pasture management in the *Acer* zone is of considerable significance. Flat pieces of land and gentle slopes are cleared to establish 'Goths' and they are used mainly during the summer and the monsoon.

D. Sub-alpine Zone (3,000-4,000 m)

This zone is characterized by the occurrence of silver fir (*Abies spectabilis*), all along Nepal Himalayas. This zone essentially falls between the tree-line and the upper limit of cereal cultivation. Winter is severe and snowfall is heavy enough to knock down branches and trees. Drizzling rain and enveloping clouds become a regular feature during the monsoon period.

Patches of *Abies* forest develop on alluvial fans, as well as on moraine deposits. They are rather shallow rooted, and one often sees quite a few fallen trees in a fir forest. At lower elevations towards 3,000 m, fir trees give away to dense thickets of bamboos when the forest is destroyed by fire or by other hazards like landslides. At higher elevations about 4,000 m, especially in moraine valleys, patches of fir forests are seen among the shrubland of willows and rhododendrons. Open grasslands of the sub-alpine zone are principal areas of animal husbandry. Gentle slopes of sub-alpine valleys above 3,200 m have generally a sweep of rhododendron thickets, with a tangling mass of gnarled stems and a blanket of green leaves and flowering branches. Species commonly found here are *Rhododendron campanulatum, Rh. wallichii, Rh. campylocarpum, Rh. wightii, Rh. fulgens*, etc. Stainton (1972) classifies this type of vegetation as "moist alpine scrub".

The sub-alpine zone in the Arun Basin is very rich in birch forest (*Betula utilis*) which has often a number of other deciduous trees like *Acer* spp., *Sorbus* spp., *Virburnum* spp. etc. At places, this deciduous forest of birch is supplemented by evergreen coniferous species like *Tsuga dumosa* and *Abies spectabilis*. *Tsuga dumosa* sometimes forms a pretty forest, with *Rh. hodgsonii* and *Rh. barbatum* as undergrowth on drier ridges.

The sub-alpine zone is also a rich source of medicinal herbs, which are collected by shepherds for selling in nearby markets. Commercially important medicinal herbs are listed in Appendix I.

The sub-alpine zone of the Arun Basin is remarkably different from adjoining Dudhkosi valley where there is a preponderance of *Quercus semecarpifolia* and *Tsuga dumosa* in the *Abies* zone (Yoda 1967), and is also different from its eastern adjoining Tamur valley where *Lithocarpus pachyphylla* and *Tsuga dumosa* are very pronounced in the forest flora. The Arun valley, which lies between the Dudhkosi valley and the Tamur valley, has a more humid environment as is shown by the preponderance of *Rhododendrons* and deciduous trees.

E. **Alpine zone (4,000 - 5,000 m)**

This zone represents a treeless country, with vast stretches of shrublands interspersed by rocky slopes and grassy meadows. The floristic richness of this zone, in terms of colourful flowers and medicinal herbs, is quite remarkable. About 450 species of flowering plants have been recorded from this zone. Pasture lands of alpine valleys become a crowded place during the monsoon season due to sheep and yak grazing on the one hand and, mountaineering teams on the other. Large areas of

Saldima Valley shows a transect of alpine and sub-alpine vegetation on its slopes. The birch forest, the fir forest and rhododendron shrubland are seen in a row of succession shrubland (*Rhododendrons, Junipers*) are cleared by people collecting firewood. One load of firewood would need about 25 m^2 of shrubland clearance.

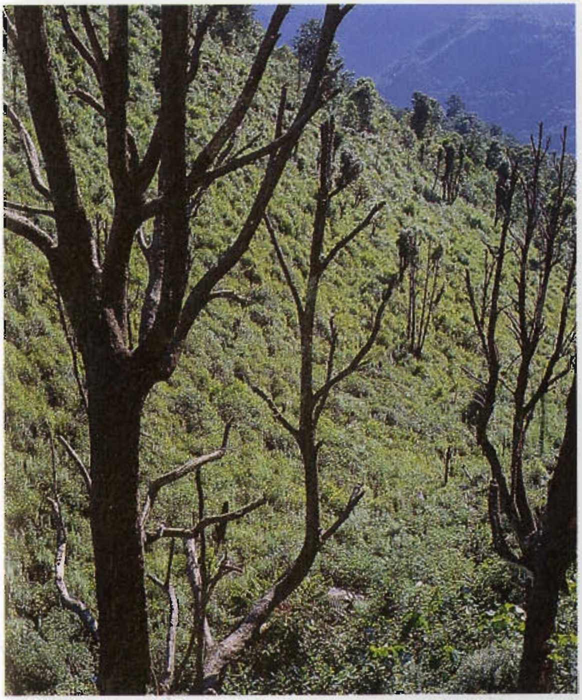
The lower part of the alpine zone in the Arun Basin is generally covered by a thick blanket of "moist alpine scrub" (Stainton 1972), which is composed of about half a dozen *Rhododendron* species (*Rh. campanulatum, Rh. campylocarpum, Rh. fulgens, Rh. nivale, Rh. wallichii, Rh. wightii*). This vegetation is characterized by a tangled mass of interwoven gnarled stems, which create a safe refuge for alpine birds and small mammals. It can hold large amounts of snow as reservoirs of water for downstream valleys.

The grasslands of the alpine zone have 90 per cent ground coverage, and generally consist of four important grass species, i.e., *Carex* sp., *Calamogrostis* sp., *Agrotis micrantha, Festuca leptogonum,* with a large number of flowering plants like *Primula sp., Androsace* sp., *Potentilla* sp., *Gentiana* sp., and so on. Heavily grazed grasslands soon get converted into colourful carpets of *Primula* sp., *Potentilla* sp, etc. It is not known if such colourful alpine meadows of flowering plants would revert back to grasslands. However it has been observed that burning and clearing of shrublands (*Rhododendron* and *Juniperus*) give rise to grasslands suitable for grazing. The Arun Basin does not have a steppe zone of cushion vegetation with thorny plants like *Caragana* sp., and *Astragalus* sp.

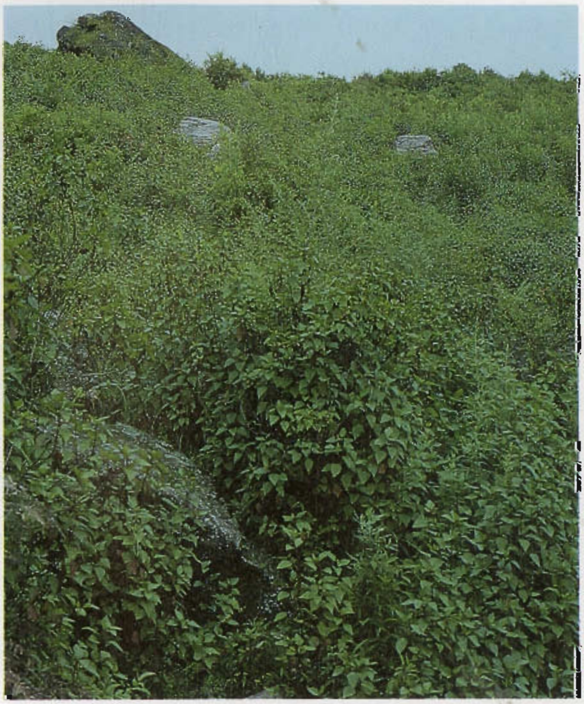
Role of *Eupatorium adenophorum* (Banmara)

No story of the ecosystem of midland hills in eastern Nepal will be complete or comprehensive without taking note of the role played by a newly introduced forest weed called Banmara, meaning forest killer. The spread of Banmara in Nepal coincided with the spread of the then Congress activities to overthrow the Rana regime in 1951. Thus, in some areas, this weed is also known as the "congress weed". In plant science, it works out to be *Eupatorium adenophorum*.

Banmara has a remarkable range of altitudinal distribution (800 m to 2,000 m), which overlaps with human settlements. Thus it becomes a central theme in farmland, pasture, and forest management. Abandoned slopes after slash-and-burn cultivation are generally invaded first by the Banmara. This provides a vegetal cover to exposed slopes. Similarly, fresh landslides or areas with deep gully cuttings and



An abandoned slope invaded by the forest weed *Eupatorium*. after slash-and-burn cultivation. Burnt trees are seen on the fore-ground



The Eupatorium gives a blanket cover to the deforested slopes open grasslands are also encroached by this plant. It never invades deep forests, where light becomes a limiting factor for its growth. Heavily disturbed forests, however, allow its growth as soon as forest floors receive adequate sunlight. Then it hampers the natural process of forest regeneration through seeds.

Invasion by Banmara over marginal grazing lands has become the main cry of midland farmers. Attempts to control it through the use of a gall fly (*Procecideochares utilis*) have not yet achieved any great success.

In the Arun Basin, the Banmara is a boon in disguise because it reduces soil erosion. Moreover, it has been used as green manure during the spring, when the plant is heavily laden with leaves. It has also been accepted as a cattle bedding. Dried Banmara may be burnt to yield potash rich fertilizer (Wilson et al. 1985).

Biological Diversity

There has been great awareness and serious concern about the conservation of biological resources and their development in the context of environmental management. Biological diversity in the Arun Basin is not only a source of ecological information on the 'health' of an ecosystem, nor just a source of aspiration for aesthetic luxury or academic exercise, but also a source of many valuable commodities of interest to our own society. A large number of plants or animals are still poorly known despite their high economic potentiality as medicines, oils, fibres, fodder, etc. However, there has been an ever-increasing threat to many biological species from habitat destruction and poaching. It would be a matter of shame to this generation if they become extinct before they were known to mankind.

The Arun Basin marks the beginning of the east Himalayan humid flora, which extends to Sikkim, Bhutan, Assam, and south east Tibet. The preponderance of rhododendron, oak, maple, magnolia, laurel, and orchids adds a distinctive feature to this Basin, as compared to other areas in Nepal. Occurrence of a number of relic plants, such as *Tetracentron sinense* and *Cycas pectinata, Gnetum montanum* and evidences of evolving new species through free hybridization e.g. *Rhododendron campylocarpum x R. thompsonii, Meconopsis napaulensis x M. paniculata* illustrate the significance of this Basin as a biological treasure in the Hindu Kush-Himalayan region. There are some 17 species of oak trees (Cupiliferae) in the Hindu Kush-

Rhododendron arboreum is the National Flower of Nepal (Lali Guras). Flowering period falls between March and May

Rhododendron cinnabarinum is one of the most beautiful shrubs at Sub-alpine regions

Himalaya and 15 of them occur in the Arun and the Tamur Basins of east Nepal. Of them, only 10 species extend to central Nepal, while all of them continue to occur eastwards to Sikkim and Bhutan (Dobremez 1976).

Similarly, of 30 species of Rhododendrons only 15 species occur in central Nepal, while most of them extend eastwards. The distribution of *Primula* (Primrose) also suggests a close affinity of east Nepal with Sikkim rather than with adjoining central Nepal (Shrestha 1982). The wealth of flowering plants and ferns of east Nepal amounts to over 3,000 species which is over 50 per cent of the total Nepalese flora (Shakya 1979). The pattern of vertical distribution (see Table 5) suggests that the sub-tropical and the temperate zones (1,000 m-3,000 m) have a rich flora, with over 1,600 and 1,400 species, respectively. In Nepal Himalaya, this belt is quite heterogeneous from eastern Nepal, to western Nepal as indicated by forest types (Table 5). Besides, this belt is being used intensively for human occupation and agriculture.

Table 5 : NUMBER OF PLANT SPECIES BY CLIMATIC ZONES

Plant Group	Climatic Zone					
	Tropical	Sub-tropical	Temp-erate	Sub-alpine	Alpine	Total No. of Spp.
Pteridophyte	97	191	187	73	12	303
Dicotyledons	683	1048	915	664	327	2196
Monocotyledons	289	380	328	211	102	770
Gymnosperms	3	5	5	5	2	14
Total	1072	1624	1435	953	443	3283

The floral wealth of the Arun Basin has been widely recognized because of the contributions of Japanese scientists (see, for example, Hara 1966 and Numata 1983 a,b, and c). The wealth of wildlife still awaits further exploration and publication. The Arun valley Wildlife Expedition, led by E.W. Cronin during 1970-73, made a large collection of mammals, birds, reptiles and insects (Cronin 1979). The Barun Valley Report (1984) listed 25 mammals, including Musk deer, Snow leopard, Water shrew, Red panda, Magnificent flying squirrel, Himalayan striped squirrel, Himalayan black bear and Assamese monkey. It listed 131 birds for the Barun valley, including, two new records (Spotted wren babbler and Dark slaty-bellied ground warbler). In August-September 1986, the ICIMOD Scientific Expedition to Arun spotted 112 species of birds while traversing north-south. (Appendix II). Among the birds, mention may be made of the largest Himalayan bird, the Lammergeier, which soars even at an altitude of over 7500 m with its huge wing span of 2.7 m, the Spiny babbler (a Nepalese endemic species), Peregrine falcon, and the Long tailed cuckoo dove. The butterflies of Arun Basin are known only meagrely. Murata and Hori (Numata 1983 c) reported 51 species and the ICIMOD expedition added a very rare species 'The Blue Duke' from the Num area in the Arun valley.

Fish fauna of the Arun river has not yet been investigated systematically. On the basis of various publications, Rajbansi (1982) listed 84 species of indigenous fishes for the Kosi Basin. Of them, 13 species may be attributed as special to the Kosi Basin (Appendix IV). The famous Jalkapur i.e. water camphor in Nepalese language, was described as *Barilius jalkapoorei* only in 1977, although its delicacy was widely known in Nepal since time immemorial. This fish is not known outside the Kosi Basin. Similarly "Pothia" (*Puntius clavatus*), "Thed" (*Labeo angra*), "Bogra" (*L. bogra*), Bata (*L. bata*), etc., are also not recorded in other parts of Nepal. The Kosi is also famous for well known game fish, like "Mahasher" (*Tor putitora*), "Shahar" (*Tor Tor*), Asla (*Schizothorax sp.*) and other table fish of high repute like "Rohu" (*Labeo rohita*), and "Katle" (*Acrossicheilus hexagonalepis*). These fish are known to be migratory and are susceptible to any changes in the quality of water. In an area like the Arun Basin, where there is a serious lack of information on physical environment, biological indicators like fish, birds, and plants could profitably be used to examine "the health of an ecosystem" for development planning.

The contemporary world has begun to realize that conservation of biological diversity should be a component of every development scheme. This is more true for mountainous regions in the Himalaya where poverty, hunger, and diseases are displacing poor farmers to regions where they have to destroy rich genetic materials in order to make a living.

Formation of parks and reserves in the threatened areas would be an important element for survival of biological diversity; but such protected areas will survive only if they exist in the context of an economy that can support them (Raven 1986).

The Barun valley has virgin forests even at low altitudes. A typical mixed forest of oak and laurel with some maple is seen at about 2,000 m

Encroachments into the Barun Valley for growing maize. Some remnants of *Saurauja* trees are seen in the maize field

Proper management of national parks is not viable without adequate provisions for the basic needs of rural communities that reside on the fringes of such protected areas (HRH Prince Gyanendra 1985). The Makalu- Barun Nature Conservation Seminar (1985) has emphasized that the Barun valley and its adjoining areas, extending to the Sagarmatha National Park, be identified as a protected area -- a Nature Reserve (Fig. 9A). Strong opinion among scientists and conservationists has already been formed to create a protected area of some 1,400 km^2 in Nepalese territory to preserve a "pristine wilderness" in the Himalayas. About 900 sq km of the proposed area lies in the Arun Basin, and this area provides the much needed ecological support to the Sagarmatha National Park, which has all of its area above an altitude of 3,000 m.

Agricultural System

The agricultural resource base is severely limited due to the mountainous terrain and steep topography. The mainstay of livelihood remains a mixed farming system, which concentrates on subsistence crop production. The main crops are paddy, maize, millet, potato, and wheat. In the KHARDEP region, there is very little land suitable for cultivation which is already being used (Dunsmore 1987). Encroachment for more arable land is taking place in the northern region of the Arun Basin, where virgin forests, even at elevations below 2,000 m, are still encountered.

There are two basic cropping patterns: paddy-based for irrigated land, and maize-based for rainfed land. Livestock and forestry form an integral part of the farming system. Transhumance is practiced at altitudes beyond the upper limit of the cropping zone, i.e., 3,000 m. Below 3,000 m altitude, livestock is the principal source of draught power for ploughing croplands and for replenishment of soil nutrients. An average household with 5-7 people has an equal number of livestock associated with it. The average landholding is 0.5 ha per household. The ratio of cultivated land to forestland (inclusive of shrubland) is 1:2, as estimated from LRMP figures.

Citrus fruits, large cardamom, and potato are promising cash crops for the region. Tobacco, sugarcane, and oilseeds are produced primarily for home consumption. Small amounts are, however, sold in occasional marketing centres where traditional exchange of goods takes place.

Land - use Types

The area covered by field crops in the three districts of the Arun Basin amounts to 157,668 ha as per LRMP, and 70,240 ha as per DFAMS figures. The difference of 87,428 ha is so great that any attempt to justify any of the figures would lead to further confusion. The difference is greatest in the case of Bhojpur district, as compared to its sister districts, Sankhuwasabha and Dhankuta. (Table 6).

Table 6 : CROPPED AREA (in ha, 1978/79)

Districts	Source of Information		Difference
	LRMP	DFAMS	
Sankhuwasabha	45,826	19,240	26,586
Bhojpur	60,854	22,340	38,514
Dhankuta	50,988	28,660	22,382
Total	157,668	70,240	87,428

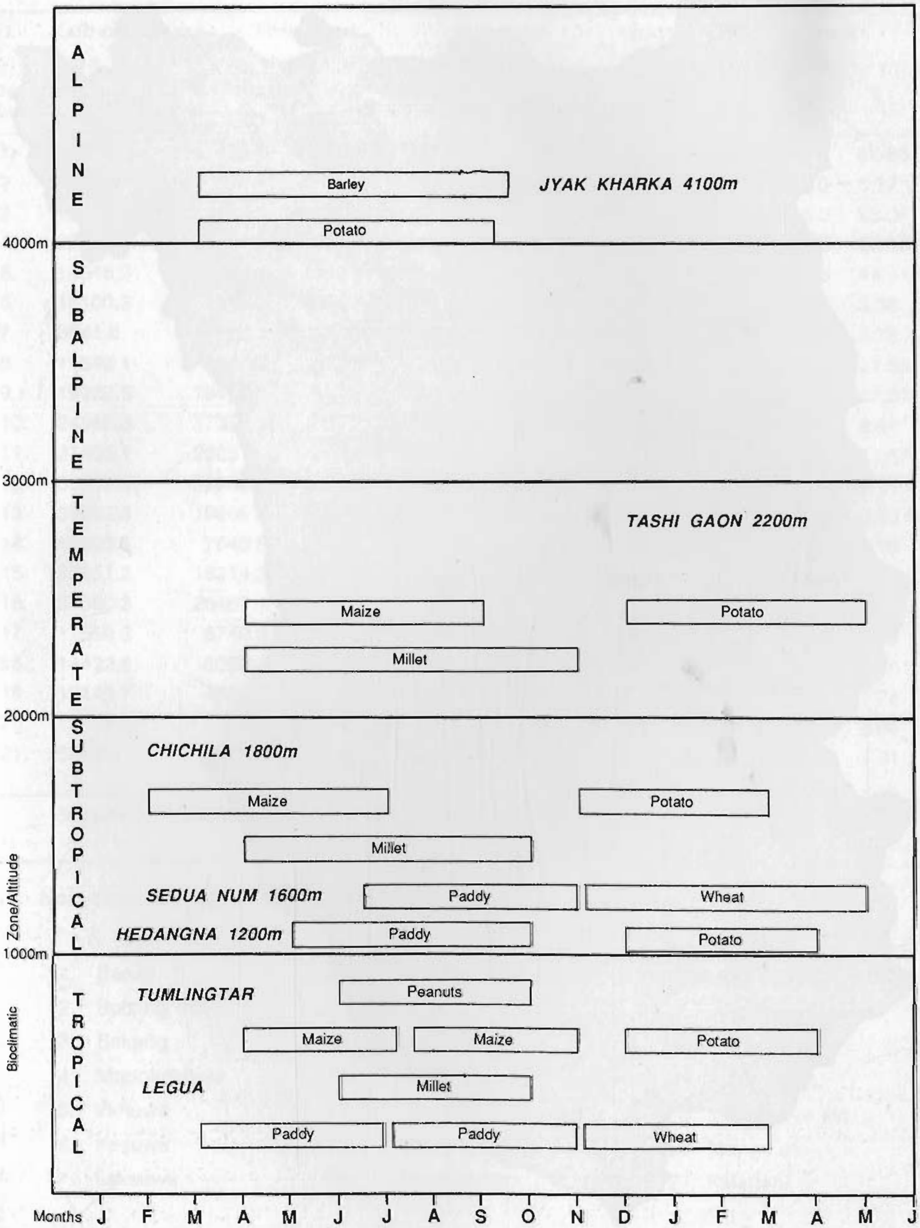
Source:

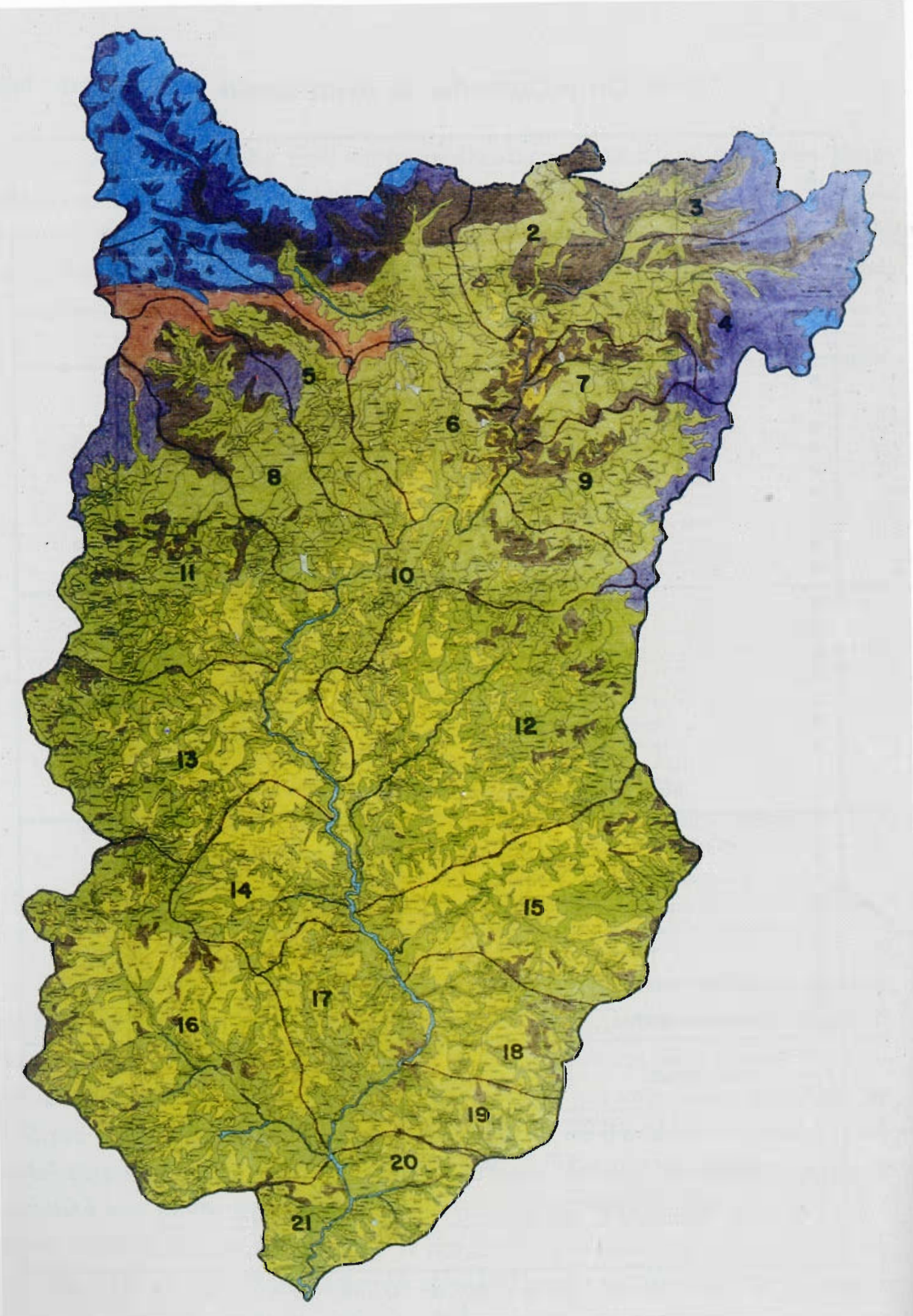
(1) LRMP: - Land Resources Mapping Project, Nepal-Canada 1986

(2) DFAMS: - H.M.G. of Nepal, Department of Food and Agricultural Marketing Services, Agri. Statistics Division, 1986

The Arun Basin lying within Nepal has been divided into 21 subcatchments, and four land-use categories, calculated for each of the sub-catchments (Table 7). The total area amounts to 5,028.34 km^2, where agricultural land covers 25.31 per cent and forestland (inclusive of shrubland) covers just over twice as much, i.e., 50.48 per cent of the entire area. Dunsmore (1987) on the basis of Stewart (1987) has tabulated the arable cultivated area as 41.08 per cent and the forest area (woody vegetation and forest vegetation) as 43.23 per cent of the mapped area of 4171.40 km^2 in the Kosi hills. Approximately 31 per cent of the Sankhuwasabha district was not covered in the map. Sub-catchment numbers from 1 to 10 fall in this area where forestland coverage ranges from 22.35 to 70.75 per cent. (Table 7).

FIG.9B Crop Calendar in Arun Basin





Land utilization in the Arun Watershed showing various sub-catchments (Courtesy P.B. Shah)

Table 7 : LAND USE IN VARIOUS SUB-CATCHMENTS

No.	Sub-catchment Area Ha.	Forestland (incl. shrubland) Ha	%	Agri. land Ha	%	Grassland Ha	%	Others Ha	%
1.	49246.1	11484.2	23.31	322.5	0.65	8456.7	17.17	28982.7	58.85
2.	14663.2	7994.7	54.51	260.0	1.77	6368.5	43.42	40.0	0.27
3.	10954.4	2449.8	22.35	-	-	4889.6	44.63	3615.0	33.0
4.	28539.1	8444.2	29.58	167.5	0.58	5490.6	19.23	14436.8	50.58
5.	19045.9	8790.3	46.15	546.3	2.87	1307.5	6.86	8401.8	44.11
6.	16100.3	12385.2	76.92	2042.5	12.68	1127.6	7.0	545.0	3.38
7.	8641.8	4600.4	53.22	825.0	9.54	2457.5	28.43	759.3	8.78
8.	17548.1	9447.4	53.83	721.3	4.11	3582.3	20.41	3797.1	21.63
9.	19222.5	13416.6	69.79	207.5	1.07	2230.0	11.60	3367.9	17.51
10.	24548.3	17368.4	70.75	5207.8	21.21	1322.0	5.38	650.1	2.64
11.	37401.1	26051.0	69.65	4832.4	12.92	2188.1	5.85	4329.6	11.57
12.	53317.6	32836.3	61.58	18014.9	33.78	155.14	2.9	915.0	1.71
13.	31012.3	19269.3	62.13	10285.5	33.16	1269.4	4.09	188.1	0.60
14.	18590.4	7640.6	41.09	10689.8	57.49	37.5	0.19	222.5	1.19
15.	32951.2	16214.3	49.20	14694.2	44.59	1582.7	4.80	460.0	1.39
16.	57380.3	28467.1	49.61	25520.0	44.47	3393.2	5.91	-	-
17.	17559.8	8749.8	49.82	8172.5	46.54	392.5	2.23	245.0	1.39
18.	14422.6	6093.1	42.24	7359.5	51.02	914.7	6.35	55.3	0.38
19.	12140.7	4550.5	37.48	6712.6	55.28	660.0	5.43	217.6	1.78
20.	13304.9	5045.3	37.92	7543.3	56.69	366.3	2.75	350.0	2.63
21.	6243.8	2565.0	41.05	3123.8	50.02	472.5	7.56	82.5	1.31
	502834.3	253863.5	50.48	127248.9	25.31	50060.6	9.95	71661.3	14.25

Sub-catchments, as identified by serial numbers in col-1, are:

1. Barun
2. Sursing etc.
3. Bakang
4. Madokchheje
5. Irkhuwa
6. Kasuwa
7. Leksuwa
8. Apsuwa & Waling
9. Ikhna
10. Indua etc.
11. Sankhuwa
12. Sabahaya
13. Chirkhuwa etc.
14. Yangua etc.
15. Piluwa
16. Pikhuwa
17. Hanraya etc.
18. Leguwa etc.
19. Mahamaya etc.
20. Munga etc .
21. Kalapani

In the Arun Basin, Nelson (1980) rated the watershed condition to be 67 per cent excellent and 30 per cent good for the northern region, 53 per cent excellent and 47 per cent good for the midland region, and 4 per cent excellent, 76 per cent good, and 20 per cent fair for the southern region. Analysis of land-use types on the basis of sub-catchments broadly supports Nelson's evaluation.

The ratio between agricultural land and forested land has often been regarded as a useful criterion to evaluate the general condition of a hilly region. To support one hectare of cultivated land, it requires 2.8 ha of forestland according to Wyatt-Smith (1982), 3 ha according to Shepherd (1985), and 6 ha according to Applegate and Gilmour (1985).

Cropping Patterns

Farming conditions differ greatly within a short distance. In the tropical zone, irrigated fields lying below 1,000 m yield two crops of paddy and one crop of wheat per year. On slope terraces two crops of maize may be harvested. Potatoes are grown as winter crop. Besides millet, sugarcane, groundnut and some oilseeds (*Guizotia abyssinica*, sesame, and mustard) are also grown in small quantities. Some vegetables and fruits, especially bananas are grown in kitchen gardens. The bananas, of the Arun valley are perhaps the largest and most delicious of their kind in Nepal.

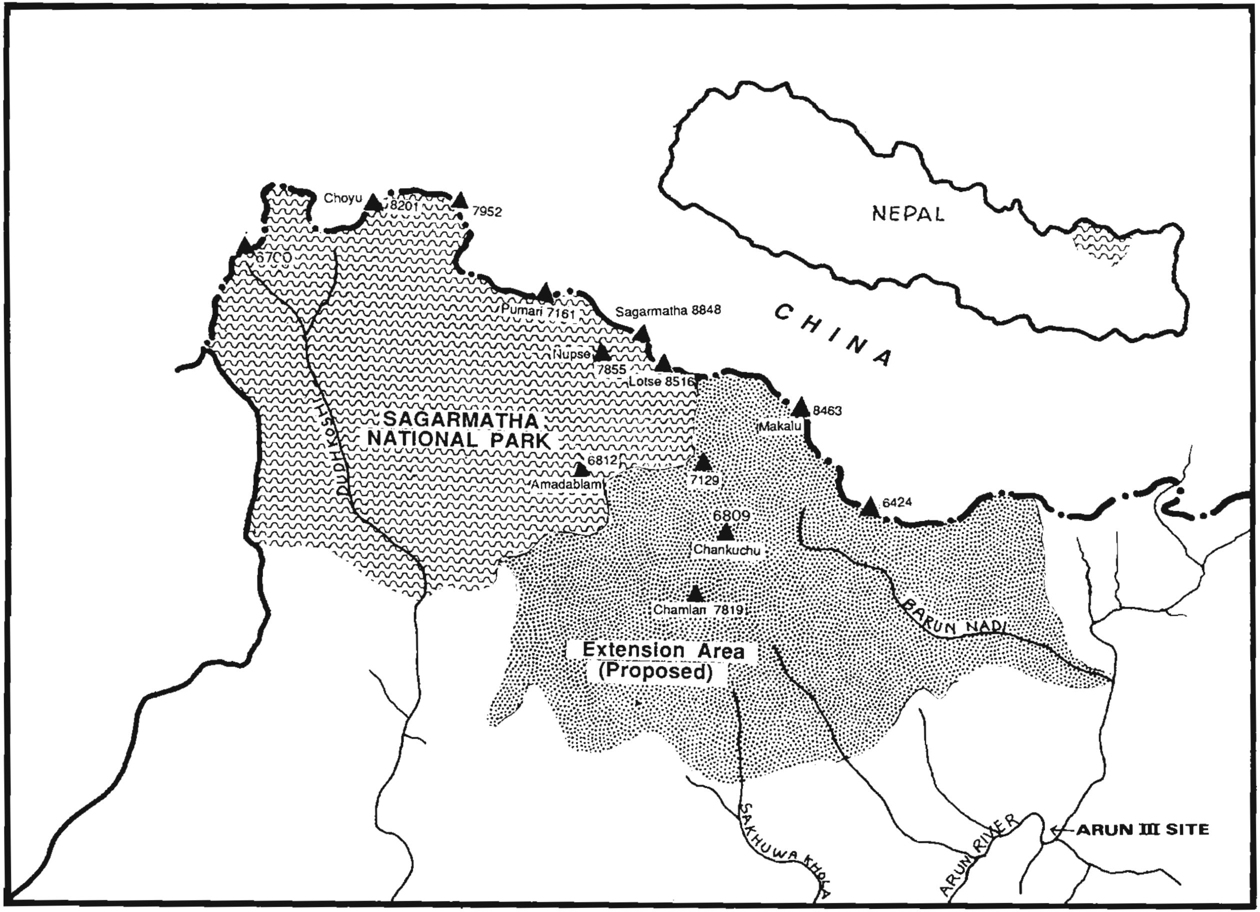
The sub-tropical zone is essentially a zone of maize and millet. Over 33 per cent of the land lies in this zone. Fields with adequate irrigation facilities grow paddy in summer and potatoes in winter. Otherwise over 37 per cent of crop-land is used for maize cultivation, and 26 per cent for millet. The spring rain plays a crucial role for both crops. Frequently, maize and millet are grown as relay crops.

The temperate zone does not grow paddy. Maize and millet remain the principal crops, the growing period for which is longer due to colder climatic conditions. Potatoes are grown in winter.

The sub-alpine zone in the Arun Basin is poorly cropped. For most of the months, this zone is covered with cloud and mist during spring and summer. Snowfall is heavy during winter, and snow stays too late to allow any crop in the winter.

The alpine zone receives some sun during the spring and summer. Naked barley and potatoes are grown from March to September. However, land suitable for cultivation is extremely limited in this zone.

FIG. 9A PROPOSED EXTENSION AREA OF THE SAGARMATHA NATIONAL PARK



The crop calendar (Fig. 9 b), developed on the basis of local information at various places en route to the Makalu Base camp, suggests that March-April are the busy months for all climatic zones. Off-farm labour is available during the middle of monsoon after the transplantation of paddy, and in winter after planting potatoes and wheat.

Figures published by the Department of Food and Agricultural Marketing Services of HMG suggest that agricultural areas have expanded considerably, while the yield has decreased quite significantly (Table 8). Both the indices indicate a process of environmental degradation.

Table 8 : AREA AND YIELD OF IMPORTANT FOOD CROPS IN 1970/71 AND 1985/86

Crops	Years	Area ha	Average Yield kg/ha
Paddy	1970/71	10,610	2400
	1985/86	126,500	1800
Maize	1970/71	24,050	2000
	1985/86	41,910	1600
Millet	1970/71	6,650	1200
	1985/86	12,600	900

Source : DFAMS 1986

The comparison of areas is rather tentative, since district boundaries have changed considerably within the last 15 years. The figures of DFAMS are based primarily on estimations of agricultural officials stationed in the districts. Actual physical measures, through aerial photography or cadastral surveys, would produce more realistic data.

Cash Crops

Three items of cash crops have caught the attention of local farmers in the Arun Basin. Citrus fruits, specially tangerines and sweet oranges, have a long history of production. For this reason the National Citrus Development Programme is located in Dhankuta. Fruit processing units at Biratnagar and Itahari have created increasing demand for fruits and the road link to Dhankuta and further north to Basantapur has facilitated the transport of fruits. Prospects for horticulture in Southern Arun are great.

Big cardamom (*Ammomum subulatum*) has become one of the most promising cash crops in terms of both economy and ecology of the area. Export figures of cardamom show a very encouraging situation. A news item in the Gorkhapatra daily (Nov. 30, 1986) indicated that cardamom worth of N. Rs. 100 million (approx. US $ 5 million) was being exported from a border town (Chandaragadi) in eastern Nepal. Trade statistics from 1971/72 to 1981/82 show that the quantity of exports doubled from 338 tonnes (1972/73) to 685 tonnes (1975/76) in three years time. Exports reached lowest levels, i.e., 305 tonnes in 1981/82 when prices also dropped considerably. Home consumption of all surplus production is not possible, and the alternative use by processing its oil (Cineol) becomes uneconomical due to the fact that this oil is available from cheaper material, i.e., eucalyptus leaves. However, the flavour of cardamom is unique, and its export potentialities remain high. An institutional framework in keeping with the international marketing system has to be developed to safeguard cardamom production in eastern Nepal.

Cardamom is generally grown in wet ravines colonized by the alder trees (*Alnus nepalensis*), which provide shade and fix nitrogen. Alder leaves provide excellent manure and its fast- growing wood provides fuel for drying. Besides, the agro-climatic range of cardamom and alder is sympatric. Thus alder is regarded as an indicator tree for the cultivation of cardamom. At higher elevations above 1,800 m, cardamom is grown in association with the Raktachandan tree (*Daphnephyllum himalaica*). Till now, it is an experimental venture of local farmers.

Cardamom is an established crop in the Tamur Basin, and its introduction to the Arun Basin does not have a long history. However, farmers are attracted towards it and a single panchayat (Madi Mulkharka) is said to have 200 families engaged in its cultivation. The panchayat earned Rs. 1.2 million from the sale of cardamom in 1986. Cardamom is not affected by occasional hailstorms that destroy a number of other crops like maize, mustard, and potato.

Potato is an important crop for the mountainous region of Nepal. Its range of altitude covers all agro-climatic regions from tropical to sub-alpine. At lower elevations it is grown as a winter crop, while at higher elevations above 2 ,000 m it is a summer crop. The average yield of potato in Nepal is rather low, 6 tonnes/ha. Genetic improvements for higher yield and for disease resistance should quickly elevate its productivity. Some tubers, processed through tissue culture techniques developed in the Royal Botanical Gardens, Nepal, have indicated that they can produce over 16 tonnes/ha under normal farming conditions, as experimented in the Pakhribas Agricultural Centre. The cultivars, MS. 91 and Sangema, were found to be least effected by diseases and the yield is considerably higher (Table 9).

Table 9 : TRIALS OF TISSUE CULTURE POTATO IN THE PAKHRIBAS AGRICULTURAL CENTRE, DHANKUTA

Potato Cultivar	Disease per cent	No. of tubers per plant	Yield t/ha
M.S. 42	80	9	10
BR 63.65	80	5	7.92
M.S 82	40	4	9.71
M.S.35	45	6	9.27
L.853	40	5	9.26
M.S. 91	1	6	16.13
Sengema	1	4	13.90

Courtesy : Dr. S.B. Rajbhandari, Dept. of Medicinal Plants, HMG

Tissue culture as a modern technique can produce any amount of disease-free seed tubers for high-yielding cultivars. This technique is also used as a tool to clean potato seeds from their inherent virus diseases. One can easily overcome the problem of genetic erosion in potatoes.

Land Tenure System

The land tenure system in the districts of the Arun Basin is based on a traditional communal tenure system called the 'Kipat' system. Historically, the 'Kipat' authority of the community over-rides any claim the state might extend on grounds of internal sovereignty or state landlordism (Regmi 1978). Kipat rights have been recognized not only on cultivated lands but also on wastelands, pastures, and forestlands. The main characteristic of the system is the non-alienability of land to members outside the Kirat community. Individuals belonging to the community have unchallenged rights to use their land. Thus the practice of shifting cultivation, locally termed as 'khorea' got deeply rooted in the agricultural system. Recent land reform legislation (1964 Land Acts) seeks outright abolition of kipat rights. The cadastral survey of the northern Arun Basin is still going on, and land reform legislation has yet to be implemented in most parts of Sankhuwasabha district. The land revenue raised from this district, which is much lower than that of the other districts of the basin (Table 10), suggests that land administration on scientific grounds is still far on its way in this district.

Table 10 : LAND REVENUE (in N. Rs X 1000)

District	Year	1984/85	1985/86	1986/87
Dhankuta	P	200	200	175
	A	374	383	335
Bhojpur	P	95	80	225
	A	409	396	427
Sankhuwasabha	P	20	20	15.5
	A	9.5	7.9	11

Source : Dept. of Land Revenue, HMG.
P = Projected, A = Actual revenue collected.

Traditionally kipat owners used to clear the forests and prepare cultivable land. Such lands gradually went into the hands of money lenders (non-Kirati) and the feudal lordship of Talukdars (kipat authority for land tax collection and administration). As early as 1834, the government recognized the plight of the kirati debtors and took some relief measures (Regmi 1978). However, the process of pushing poorer families farther and farther into the forestlands for shifting cultivation is still prevalent in the upper Arun. Thus a situation has emerged where shifting cultivation has to be stopped immediately, in order to protect remaining forests, and the indigenous population facing poverty, hunger, and disease require assistance by ex-

Rhododendron trees burned by a forest fire are seen on the foreground while chestnut forests are in the background. In between, a slope abandoned after slash-and-burn cultivation is under natural regeneration with *Eupatorium* as a pioneer plant tending development activities in their area. The integrated rural development programme of KHARDEP does not cover most of those northern areas in the Sankhuwasabha district. Special programmes would be necessary to integrate people's participation in the mainstream of national development.

Slash-and-Burn Agriculture

Slash-and-burn, which is also known as shifting cultivation, has many local names in the Himalayas. In eastern Nepal, it is called Khorea, while in north-eastern India it is known as Jhum. The Rais and the Limbus of eastern Nepal, who enjoyed a special tenure right under the Kipat system, have the tradition of Khorea cultivation, as a supplementary source of crop production to meet the growing demand of the increasing population. Khorea, like the Jhum, is a highly labour-intensive and land-extensive form of cultivation. It is most detrimental to forest ecology and contributes to total extinction of a large number of biological species. The rate and extent of forest destruction through slash-and-burn has not yet been assessed for eastern Nepal. Similarly the ecological as well as economical impact of the slash-and-burn has yet to be studied systematically. However, inferences through general observation would be sufficient to conclude that this practice should be stopped immediately, without any delay, and the local people should get attractive alternatives to use their hard labour for making a living. In N.E. India, the level of income from Jhuming appears to be very low, as compared to prevailing wage rates (Saha 1976). In Nepal also, input of labour is great and production is meagre.

Khorea is mainly concentrated on hill slopes at altitudes between 1,500 m and 2,300 m. Most affected forests are (i) *Schima - Castanopsis,* (ii) *Castanopsis tribuloides,* (iii) *Rhododendron - Oaks and* (iv) *Oak - laurels.*

Forest on a selected site is cut in late winter (February) and left to dry until April. The dried debris is burnt down to ashes. Spring rain settles the ashes, and the field becomes ready for sowing maize/millet. The field is neither ploughed nor irrigated. Cultivators come back as soon as maize cobs are ready by late June or early July. They guard the field day and night to keep bears and porcupines away. Direct encounters with bears are not infrequent. On steep slopes, maize is sown by mouth-spitting in a hole dug by a small stick. The cultivator has to move up and down the hill by means of a rope tied round his waist. The Khorea cycle varies from 4-10 years. However, the tendency to go for a climax forest, rather than returning to previous clearances, is still quite high. In N.E. India, a terrace system cannot be sustained without heavy input of fertilizers and a Jhum cycle under five years is not economically viable and causes serious environmental problems (Mishra and Rama Krishnan 1983). Thus the cultivators must be pushed back to fertile farmlands and be motivated for intensive agriculture.

The deterioration of micro-climatic conditions, surface runoff, ground water runoff and loss of soil fertility are some of the obvious consequences of slash-and-burn cultivation (Lu and Zeng 1986). The loss of forest cover from hill slopes and the direct beating of monsoon rains cause great losses of the top-soil, and it triggers landslides on steep slopes. The water regime of the catchment is severely affected. Soil and nutrient losses by rainfall erosion in Nepal are estimated to be five times greater on lands under shifting cultivation (slash-and-burn) than on sloping terraces (Carson 1985). Although the estimation does not seem to have any experimental basis, it certainly provokes a concern over the practice of shifting cultivation in Nepal.

Based on enquiries with local people, it has been recognized that the land has become too poor to allow any cultivation after two to three years. Khorea lands, when left fallow, are rapidly colonized by *Eupatorium adenophorum* and then natural succession takes place. There is evidence of regeneration of original forest in *Schima-Castanopsis* zone, while most of the southern slopes give rise to *Rhododendron arboreum* forests. The return of original oak forests does not seem to have occurred in the Arun Basin.

Some authors, like Bhowmick (1976), adhere to the opinion that shifting cultivation is a response of the tribal people of the hill areas to the problem of erosion of fertile top soil from steep slopes. This technique is perhaps more scientific than actual ploughing and tilling on steep slopes, where any mechanical disturbances will result in washing away of the fertile top soil. Besides, it has also been experienced by downhill farmers that the slash-and-burn practice on mountain tops enriches their fields.

In a society endowed with primitive technology and absolute poverty, where human labour is the only available resource and "free land" the only option, shifting cultivation remains the most viable method for subsistence. However, the Arun Basin is nearing a point of saturation and shifting cultivation (slash-and-burn) should be stopped immediately. Management strategies should, however, address the socioeconomic problem of the affected mountain population, who are pushed farther and farther due to economic pressures.

Livestock, Pasture, and Fodder situation

Livestock plays a pivotal role in the farming system of mountainous regions. The interdependence of crop-production, livestock, forest management, and the overall ecological condition is well recognized in the Arun Basin. Below 2,000 m altitude, cattle are more vital for ploughing terraces than for their milk. Cow dung is much valued as manure and is not used as a fuel substitute. Over 90 per cent of cow dung is directly used in manure. Milk is produced for home consumption only. Goats, chicken, and pigs are the main source of meat and protein. Thus each household has an average of three to five animals, as was observed on our route between Hile and Tasigaon. A market study in Dhankuta district, however, concluded that 27 per cent of the value of all products sold in the weekly market was of animal origin (Dunsmore 1987). A fortnightly Hat (traditional market at regular intervals) in Seduwa and in Num (Sankhuwasabha district), on the other hand, did not have

Table 11 : LIVESTOCK AT VARIOUS ALTITUDES

Altitude	Animal	Feed dependency	Purpose of livestock
			Commercial
3000-4000 m	Yak	Total grazing on	Milk/Ghee, Wool, Hide,
	Sheep/Goats	pasturelands	Meat, Wool Transport
			Semi-Commercial
2000-3000 m	Bull		Draught power
	Cows	Pasturelands	Milk/Ghee, Manure, Hide
		and	
	Buffaloes	Fodder trees	Milk/Ghee, Manure, Hide, Meat
			Domestic
Below 2000m	Bulls		Draught power
	Cows	Wastelands	Milk, Manure, Hide
	Buffaloes	Crop residue	Milk, Manure, Meat
		and	Hide
	Goats/Pigs	fodder trees	Meat

more than 10 chicken and two goats among some 1,000 people in the Hat. In Khandbari, the district headquarters, meat supply for the Dasain festival was being met by mountain goats and sheep from Chepuwa and Hatia regions in northern Sankhuwasabha. Thus the purpose of keeping animals differs in different ecological regions, which may be summarized as shown in Table 11.

Data on livestock numbers largely remain tentative. However, it has been generally recognized that the livestock population exceeds the human population and the shortage of fodder and feeding materials has been contributing not only to the depletion of natural vegetal cover but also to the retardation of natural regeneration of forests. The data published for the KHARDEP region, when examined against national figures, quickly leads one to think of fodder problems. The livestock population (735,000) has already exceeded the human population (545,000), as per the 1981 Census in the KHARDEP region (Dunsmore 1987).

Table 12 : LIVESTOCK POPULATION IN KHARDEP AS COMPARED TO NEPAL (figures in thousands)

Animal	Nepal*	KHARDEP	Percentage
Cattle	5,986	300	5
Buffalo	2,705	85	3.26
Goats	3,654	250	6.95
Sheep	561	40	7.27
Pigs	358	60	6.66
Yak	?	?	
Total	13,264	753	5.54

* Source : Nepal Agriculture Sector Strategy 1982

Table 12 also suggests that the Arun Basin has a higher percentage of pigs than elsewhere in Nepal. It has to do with the tradition and culture of the Kiranti people (Rais and Limbus). Curiously enough, even the Sherpa community in upper Arun rears pigs. This is rather unusual in Nepal. A random survey of the livestock population in the Upper Arun valley along the caravan route shows that each household had livestock numbers equalling human numbers. However, at high altitudes, such as in Tashigaon, livestock numbers far exceed the human population.

This is to be attributed to the availability of more grazing areas at high altitudes and to the agricultural system based heavily on livestock (Table 13).

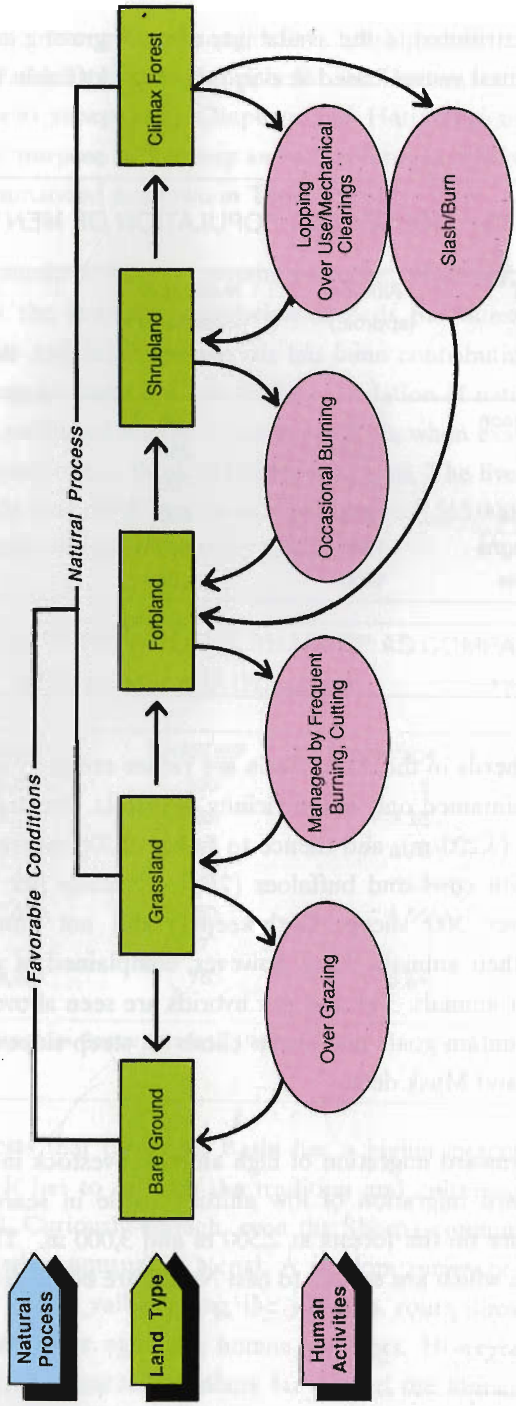
Table 13 : HOUSEHOLD POPULATION OF MEN AND MAMMALS

Village	Altitude (approx.) m.	Number of households (approx.)	Population per household	
			Human	Mammals
Tashigaon	2100	35	8	15
Sedua	1500	250	8	10
Num	1500	700	6	6
Chichila	1800	600	10	10
Hedangna	1200	600	5.8	9.4
Syaksila	1500	84	9.5	9.5

Animal herds in the Arun Basin are rather remotely placed from main villages. Herds are maintained only in the vicinity of forests. Our trek from Dobate (3,660 m) to Gaikharka (3,200 m), and thence to Bakle (2,500 m), took us through more than 25 "Goths" with cows and buffaloes (25 to 27 heads per "Goth") and five "Goths" each with over 300 sheep. Goth-keepers did not complain of fodder/pasture shortage for their animals. They, however, complained of wolves and wild dogs that often kill their animals. Yak and yak hybrids are seen above 4,000 m in the main valley, while mountain goats and sheep climb on steep slopes, competing with wildlife such as Thar and Musk deer.

The downward migration of high altitude livestock in search of a warmer area and the upward migration of low altitude cattle in search of more fodder exert double pressure on the forests at 2,500 m and 3,000 m. Thus the temperate broad-leaved forests, which are unique to east Nepal, are being depleted by livestock.

FIG. 10 General Pattern of Grassland Succession



Grasslands

The ecology of east Nepal grasslands was studied by Tsuchida (1983). Studies of the Arun Basin show that most of the grasslands are occupied by short-grass types (less than 2-3 cm high) and overgrazing has led to the transformation of good grasslands into unpalatable bushlands. Grassland maintenance through burning and re-fertilizing, and also through rotational grazing, is seldom carried out. More studies are recommended for finding concrete methods for grassland management and conservation. The general pattern of succession on grasslands may be predicted as shown in Fig. 10.

There is no evidence of grass cultivation in the whole of the Arun Basin. All accessible grasslands are in a semi-natural condition, with varying degrees of succession, both retrogressive as well as progressive. Cultivation of tall grasses is to be encouraged on slopes lying above 2,000 m, which is generally the limit for cereal cultivation. Burning of forests near Goths for increasing grazing area should be stopped as soon as possible. Studies on the succession of plants in the process of forest regeneration should be initiated so as to identify the right time for intervention in order to promote the growth of desired plant communities.

Zonation of Grasslands

The Arun Basin is more humid than most of the other regions in Nepal. Under such an environment, four zones of grassland vegetation have been identified on the basis of altitudinal variation (Table 14).

A-Zone

Grasslands below 1,100 m altitude are characterized by the dominance of annual plants, which are normally propagated by seeds. Prominent species are *Cynodon dactylon, Chrysopogon aciculatus,* and *Desmodium trifolium.*

Overgrazing of this zone results in a dry type of vegetation, with clumps of *Eupatorium adenophorum, Anaphalis contortus,* and *Artemesia* spp. This zone can well be managed by burning down forb plants and encouraging long grasses. Overgrazing soon leads to bare grounds. On the other hand, if the area is left abandoned,

Table 14 : ALTITUDINAL ZONES OF GRASSLANDS AND THEIR SUCCESSIONAL TYPES AFTER TSUCHIDA 1983

Altitude m.	Zone	Grassland Type	Forbland Type	Shrubland Type	Climax Forest
	D	Calamogrostis sp. Festuca sp. Carex sp. Agrostis sp.	Alpine herbs	Rhododendrons Junipers	Rhododendrons Junipers
3800					
	C	Carex sps. Poa annua Plantago minor Rumex sps.	Senecio sps. Circium sps. Anaphalis sps. Tsuga sps. Abies sps.	Rhododendrons, Rubus sps. Sorbus sps. Betula sps.	Rhododendrons, Accer sps.
2600					
	B	Paspalum Scrobiculatum Setaria pallicifusca Arthraxon sp. Cynodon dactylon Pycreus sp.	Eupatorium sp. Thelyptris sp. Pteridium sp. Artemesia sp. Ageratum sp.	Eurya sp. Maesa sp. Osbeckia sp. Arundinaria sp. Viburnum sp.	Schima- Castanopsis Quercus sp. Lithocarpus sp.
1100					
	A	Cynadon sp. Chrysopogon aciculatum Cyperus sp.	Saccharum sp. Eupatorium sp. Cassia sp. Ficus sp.	Maesa sp. Callicarpa sp. Lantana sp.	Shorea sp. Terminalia sp.

the grassland changes over to shrubland with unpalatable plants. The shrubland leads to form climax forests of *Shorea robusta, Terminalia tomentosa, Engelhardtia spicata,* etc. The climax forest formation is rather unlikely in the face of present pressure on land from men and livestock.

B-Zone

The middle zone, lying between 1,100 m and 2,600 m, is heavily degraded. On well managed grasslands, grazing grasses such as *Paspalum scrobiculatum, Pycreus* *sanguinolentus, Cynodon dactylon*, and *Setaria pallidifusca* are found. Evidence of overgrazing and degradation is obvious due to the abundance of *Eupatorium, Artemesia, Anaphalis*, ferns, etc. In course of time (about 10 years), the forbland changes into shrubland with thorny and unpalatable species of plants. If undisturbed for about 20-30 years, climax forests take the ground.

C-Zone

This zone lies between 2,600 m to 3,800 m, in the temperate region. It is characterized by the dominance of *Carex* spp. and a number of flowering herbs. This zone progresses into a forbland of compositae plants (sunflower family), such as *Circium* sp., *Senecio* sp., and *Anaphalis* sp. Given a long undisturbed period this zone develops into mixed deciduous forests of *Acer* spp., *Tsuga dumosa,* Rhododendrons, and Magnolias.

D-Zone

The area lying above 3,800 m, i.e., between the natural tree-line and the snow line, consists of vast stretches of alpine grassland, with the dominance of *Calamogrostis* spp., *Carex* spp., and *Festuca* spp. This zone is very rich in colourful flowering

Sheep herding on the Milke-danda at 3,500m in July and August

Goats are fed with tree fodder near Tumlingtar

Ficus auriculata is an important fodder tree which grows to 30 m in its natural habitat plants like *Primula* spp., *Gentiana* spp., *Potentilla* spp., and *Geum* spp. Grazing by animals promotes the occurrence of those unpalatable but colourful plants. Vast stretches of ubiquitous cover of *Primula* spp. in east Nepal are the results of over-grazing by sheep and yak.

Fodder Trees

The tradition of using tree leaves as fodder has led to the identification and exploitation of a large number of indigenous tree species in the midlands of Nepal. Panday (1982) has listed 134 species of trees and shrubs used as fodder in Nepal. In the Arun Basin itself, over 75 species of native trees and shrubs serve as a source of fodder (Appendix III). They are distributed from below 1,000 m altitude to 4,000 m altitude. By and large, most of the fodder is collected from public forests in the vicinity of villages or around herding areas, called "Goths". Villages at lower elevations, with limited access to forests, have practiced planting fodder trees. Among the most popular species for village plantation, mention may be made of *Saurauja napaulensis* (Gogane), *Ficus roxburghii* (Neware), *Ficus benghalensis* (Bar), and *Toona ciliata* (Tooni). Twenty-five species (Asterisk marked in the Appendix) of the fodder trees of Arun Basin may be categorized as first-grade species, which have more than 30 % dry matter and less than 10% ash content in their leaves (Bajracharya et al. 1985). A large number of other species still await chemical analysis. The accompanying graph on the distribution of fodder trees shows that the minimum number (less than 10 species) falls in the sub-alpine region, while the largest number of species (40 to 50 spp.) occur at lower elevations (700 m to 1,600 m). Thus it is fortunate that there is a rich resource of genetic material for tree planting in the critical hilly areas of heavy human occupation.

Tree lopping from the public forest generally results in a very degraded forest, with 'mast-like' trees devoid of lateral branches and leaves. The thinning of leaves quickly induces a heavy growth of forest weeds, particularly Banmara (*Eupatorium adenophorum*), which inhibit regeneration of seedlings. It also exhausts nutrients for a healthy growth of trees, which degenerate and die in the course of time. Thus the demand for fodder for the ruminant population in the Arun Basin should be met by afforestation of fodder species and by ensuring wise management practices. Bad management practices result in various hazardous effects. One such effect is observed on a slope near Ahale village at 2,400 m altitude, where a patch of forest consists of nothing but *Lyonia ovalifolia* trees, which produce poisonous leaves for cattle. In the same way, the Gogane village at an altitude of 1,900 m does not have any Gogane tree (*Saurauja napaulensis*) but dry ferns and weeds of no fodder value. In the whole of the Arun Basin, there hardly exists any sizable forest of Gogane except in an small area in the lower Barun valley. Thus there is a clear indication that unless those indigenous fodder trees are brought into cultivation, fodder problems will soon become acute, especially in the midland regions.

A number of fodder trees, with a wide range of altitudinal distribution, are available for planning plantations. The following trees may be considered useful as afforestation species for most parts of the Arun Basin (Table 15). Propagation methods are followed, as per FAO (1959), Campbell (1981), and Kk. Panday (1982).

Table 15 : RECOMMENDED FODDER TREES FOR PLANTATION IN ARUN BASIN

Species	Altitudinal range (m)	Fodder collecting season	Propagation means	Remarks
Quercus glauca	400-3000	Spring	seeds	on northern slopes
Q. lamellosa	1400-2600	Autumn/ Winter	seeds	on southern slopes
Alnus nepalensis	500-2600	"	seeds	in ravines
Ficus auriculata = roxburghii	250-1800	Winter/ Summer	seed/cutting	farmland
Saurauja napaulensis	700-2100	Winter	"	farmland
Bauhinia purpurea	200-1000	" "	" "	" "
B. variegata	150-2200	"	"	"
B. malabaricum	200-1000	"	"	"
Quercus semecarpifolia	1700-3800	Winter/Spring	seeds	Dry rocky slope
Acer campbellii	2100-3600	Summer	seeds	Deciduous, plant on northern slopes

Grasslands that are used for community grazing should be managed through burning down or weeding out unpalatable plants. Similarly, existing forests should be lopped for fodder to an extent as to prevent excessive sunlight falling on the forest floor. Local panchayats should take an active part in ensuring protection of grasslands from overgrazing and of forests from overlopping.

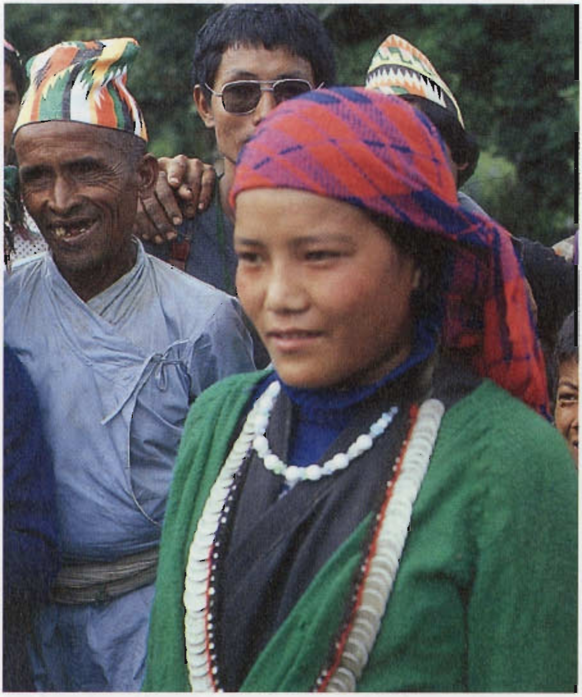
Pasture development activities in the sub-alpine zones should not be directed towards introducing exotic grasses. New areas of pasture lands may be opened up by making mountain trails, and overgrazing should be avoided by rotational grazing.

The demand for meat, milk, ghee, and eggs is ever increasing due to large mountaineering parties and development of market centres along roads and in the headquarters. The realization of the Arun III project will create an unprecedented demand for animal products. Livestock, fodder, and pasture development, therefore, warrants immediate attention from the public and the private sectors.

People And Their Natural Resources For Off-farm Employment

The People

The stretch of midlands and mountains lying in the Kosi Basin of eastern Nepal is generally known as the "Kirat" area, and its indigenous inhabitants as "Kiratis". References to Kiratis may be traced back to sacred Hindu writings, such as Vedas, Ramayana, and Mahabharata. The Kirat region is generally divided into two sections on either side of the Arun river, i.e., "Khumbuan", lying to the west, and the 'Limbuan', lying to the east. The Khumbuan is dominated by 'Rai' people and the Limbuan by 'Limbu' people. In addition, there are other groups of people who have Tibetan characteristics in their language and culture. They exhibit certain endemic features which have emerged from geographical isolation. The lower Arun, however, has gone through a rapid change after the unification of Nepal in the late 18th century. Brahmins, Chhetriyas, and occupational castes of the Hindu society have integrated themselves with the indigenous society. In the same way, the Newars of Kathmandu Valley settled in the principal towns as shopkeepers, businessmen, and craftsmen. The religious indifference among those people was noticed as early as 1799 by Guiseppe and was reconfirmed by Levi in 1905. After over 70 years, Gurung (1980) records his impression of Arun people in the following way, "What I witnessed on that night of May 8th at Phedi in the form of Dhami and Phedangna rituals and secular songs, was a meeting of Hinduistic Khasa and tribal Kirat cultures in the context of hill ecology....."



A Navagaon lady in a "Haat Bazar" at Seduwa

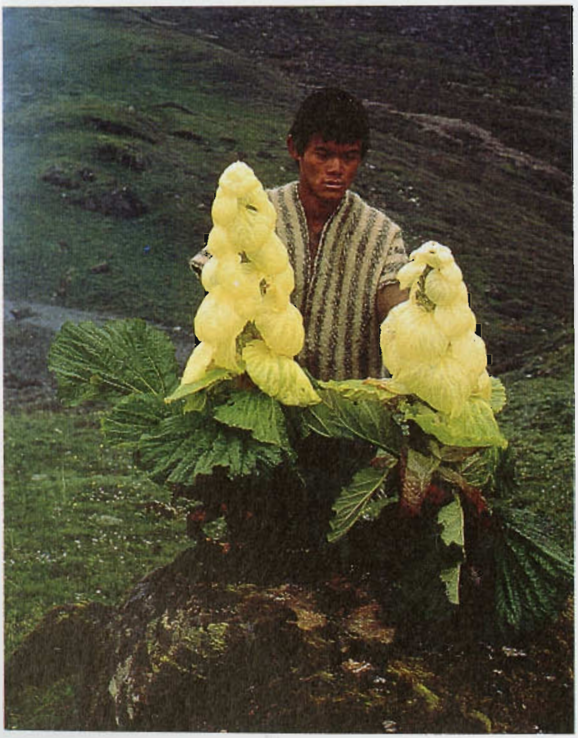
Rai Ladies sell "Chhyang" in the "Haat Bazar"
(Courtesy of Dr. D. Kansakar)

Environmental perceptions of the people and their ecological needs are expressed not only in farming systems but also in traditional rituals and rites. Besides, the evidence from mountaineering and trekking expeditions suggests that a strong component of complementarity exists among the people of various ecological zones. Thus the Rai or Limbus, porters/guides do not go beyond the last village called Tashigaon (2,130 m) along the caravan route to Makalu base camp. They are replaced by Bhoteas for higher-altitude porterage.

The distribution pattern of the various people in the Arun Basin has been largely determined by environmental conditions as well as socioeconomic compulsions. Thus the upper Arun valley is inhabited by Bhoteas, and the middle mountainous region is dominated by Rais and by Limbus. Another small group of Kirati people, of similar culture and race, are the Yakhas, who live in the southern hills of the Arun Basin. People typical of Hindu culture, such as Brahmin, Chhetriya and associated occupational castes live near the valley bottom and on low-lying terraces. A small group of traditional potters called Kumale are to be found in the Kumal gaon area near Tumlingtar.

People of northern Sankhuwasabha are seen with bear skulls. The huge animals, that come to rob the corn in the fields, are trapped to death

The Bhotea people of the upper Arun are considered to be different from those in Khumbu, Pharak, and Solu region, and have not been studied intensively (Furer Haimendorf 1975). A group of those people, locally known as Lhomi (Tibetan generic term for lowlanders) or Kar Bhoteas, have villages 'clinging' to the hill slopes high above the Arun gorge. Their fields are generally located on gentle sunny slopes above 2,000m. Steep slopes and ravines are left for shrubs and trees. They use alpine and sub-alpine pastures for their ruminant animals, while they keep pigs and fowls in their villages. Another prominent group of Bhoteas are found in Ritak, Thundam, Nawagaon, etc. Those Bhoteas are known as Nawa or Nava. Anthropologists believe that they are more akin to the Sherpas of Khumbu, both culturally and linguistically. However, the pig culture of Kirat sets them apart from the Sherpas and the Tibetans. Those people prefer to be called Sherpas in order to get jobs in mountaineering, for which they are most fit and energetic. The Nawas keep herds of sheep and yak. Shepherd boys use their spare time to collect medicinal herbs from alpine slopes. Even a boy, 10 years of age knew how to medicate a sheep poisoned by young leaves of monkshood (*Aconitum* spp.) and how one should collect monkshood tubers for sale.



A Gurung shepherd collects giant rhubarb for its tender shoots which are eaten raw

Another group of highland dwellers in the Arun Basin are the Gurungs and Magars. They have specialized in animal husbandry of sheep. The Gurungs use the sub-alpine and alpine pastures along the upper reaches of Milke Danda.

The highlanders of Arun Basin have a significant role to play in the watershed management of the upper Arun, in order to maintain an ecological balance that would be crucial for the management of the forthcoming Arun III hydroelectric project. The census of 1981 for the three districts of the Arun Basin (population 451,884) indicate that the population pressure in the northern district Sankhuwasabha is low (37.2/km^2) compared to the other two districts, i.e., Bhojpur (127.9/km^2) and Dhankuta (145.7/km^2). It should, however, be borne in mind that low-density areas have limited land for cultivation, and natural processes such as active down-cutting of the river, steep slopes, and higher intensity of rainfall, make the area quite fragile even for a low density of population.

The distribution of population by climatic zones (Table 4) suggests that the sub-tropical zone has a greater population pressure, i.e., 133.44 people per sq km. The reduction of pressure on the temperate and the alpine zone is largely due to natural limitations for agricultural development. In the same fashion, the pressure on the tropical zone (11.53 persons per sq km) is also quite low.

Off-Farm Activities

People living in the Arun Basin have a number of off-farm activities to support their own day-to-day life, as well as to bring in cash income for commodities like clothes, salt, kerosene, spices, utensils, and so on. Those activities may be classified into three broad categories - (i) forest and vegetation based, (ii) labour based, and (iii) skill based. All of these activities have a close bearing on environmental management of the region.

Forest-based activities

Resources from the wild, such as medicinal herbs, wild edible fruits, tubers, rhizomes and vegetables, fibre plants, bamboos, and fruit beads (Rudrakshya), are widely used by the local people, but their indigenous knowledge of collecting, processing, and producing various items has yet to be adequately evaluated and promoted.

Medicinal Plants

Although over 400 plants with medicinal virtues occur in the flora of eastern Nepal (Malla and Shakya 1984-85), only about 20 of them have been exploited for commercial purposes. A number of them have been used by local people as traditional home remedies.

Overseas export figures of medicinal herbs from eastern Nepal during the years 1971/72 to 1981/82 do not exhibit any definite pattern of increase or decrease. The export items and their quantities are controlled by foreign marketing centres like Singapore, Hamburg and Tokyo. The bulk of medicinal herbs are exported to India. However, no reliable record is available to attempt any analysis. The development potential of medicinal plants remains quite high. Special items of exports from the basin are the chiraita (*Swertia* spp.), *Lycopodium* powder, cinnamon bark, and Rudrakshya beads (*Elaeocarpus ganitrus*).

There is no organized group of people for the collection of medicinal herbs. Most of the collectors are shepherds who spend their summer in the sub-alpine and alpine zones. There is no organized mechanism for the sale of medicinal herbs, nor is there any processing centre.

Medicinal herbs are regarded as a free commodity to be collected from nature. Demand for any particular item instigates mountain dwellers to collect as much as possible. Conservation measures have not yet been thought of. Thus some of the high-altitude herbs, like *Picrorrhiza* (Kutki), *Nardostachys* (Jatamansi), non-poisonous species of *Aconitum* (Nirmasi) have declined drastically. Sub-tropical and tropical herbs like *Rauwolfia,* and *Alstonia* (Chhatiwan) have already gone near to extinction in the area.

Rotational cropping of medicinal herbs from the alpine and the sub-alpine zones and the cultivation of various medicinal plants in the temperate and the sub-tropical zones should provide greater scope for cash income for the people of the Arun Basin and its vicinity.

Fibre Plants

A number of wild plants provide raw materials for making cords, clothes and paper. Paper making is a well-known cottage industry all along the Nepal Himalaya. However, the refined textile fibre from Allo plants (*Girardinia diversifolia*) is widely produced in the Arun Basin.

Hand-made paper

Bast fibres, locally known as Lokta, are obtained from three shrubs of the family Thymeliaceae (*Daphne bholua, D. papyracea* and *Edgeworthia gardneri*) which are collected extensively from oak-laurel and oak-rhododendron forests at 2,100-2,700 m altitude. The shrubs grow to about one to three m and occur as an undergrowth in shady places. The bark of mature plants are peeled from top to bottom, and thus the whole plant is destroyed. Thus rotational cropping (10-15 years) must be practiced in order to maintain a steady supply. Collection should not be done before seeding, and the roots should not be disturbed. Regeneration takes place both from seed (approx. 25 per cent) and root suckers (75 per cent) as per Jeanrenaud in Jackson (1987). Trees in the Lokta habitat should not be subjected to fuel collection. It has generally been observed that wood requirements for fuel to cook and digest, and to provide wood ash, contribute greater environmental damage than the collection of 'Lokta' itself. The ratio of one kg of paper to three kg of firewood is said to be a standard in preparing hand-made paper (Jeanrenaud 1987). The employment and income derived from hand-made paper is quite promising. However, there is a need for technological input to reduce or replace fuel material and to substitute wood ash by appropriate chemicals (Mahat 1987).

Nepali paper of Bhojpur is highly regarded in the Kathmandu market. It is not unusual to find loads of hand-made paper in the airport godown at Tumlingtar for shipment to Kathmandu. There is a growing demand for Nepali paper in the tourist industry, to produce greeting cards, calendars, letter pads, and prints, of various images depicting Nepalese art and culture. The industry is being promoted by His Majesty's Government of Nepal in co-operation with other agencies, including the UNICEF (United Nations Children's Fund). However, the risk of over-exploitation and extinction of the fibre plants and the depletion of supportive forest cover should not be overlooked. Therefore, this industry needs to be examined carefully in the context of the overall ecosystem in a watershed.

Allo as textile fibre

Fibres obtained from the inner bark of a gigantic nettle, called Allo, are widely used for making ropes, head-bands, cloth-bags, fishing nets, rough clothes, etc., by the people in the upper Arun valley. This nettle *Girardinia diversifolia* (Link) Friis occurs as an undergrowth in mixed deciduous forests of oaks, maples, and cherries at altitudes lying between 1,500-3,000 m. This plant grows profusely forming an impenetrable cover of stinging nettle with slender 1 to 3 m tall stems. The stems are cut near the base and the barks are peeled off to yield the fibre. The Allo needs lots of water for cleaning the fibres, which are considered as among the longest fibres found in plants (Canning and Green 1986). The plant seeds profusely and the root suckers also produce a lot of new stems following the harvesting. However, the forest ecosystem should not be disturbed in order to sustain a regular supply of Allo fibres. Cultivation of Allo could well be encouraged along forest edges and on rocky slopes.

The "Allo" plant (*Girardinia heterophylla*) grows on wastelands also

The Kosi Hill Area Rural Development Programme (KHARDEP) has made special efforts to develop Allo as a highly prized commodity of eastern Nepal. Studies conducted by the KHARDEP have shown that a successful cottage industry for the production of a new textile material best suited for making jackets, waistcoats, caps, and so on is entirely possible.

The Rai women of Sankhuwasabha district are skilled weavers, and their products have received wider appreciation by the urban public and overseas buyers. Technical assistance with the introduction of new types of looms, winders, warping machine, drying rollers, and subsequent training of local women have proved quite promising and a start has been made on finding marketing outlets for Allo products (Dunsmore 1987).

Bamboo

Bamboo is the most versatile plant material available to the rural people. Although it is widely cultivated, extensively collected, and intensively used by local people, its botanical identity and ecological roles are not known sufficiently. The contributions of Stapleton in Jackson (1987) provide an excellent ground for a good beginning in research and development on bamboos of Nepal.

Twenty species of bamboo have been recognized, and seven of them are still indeterminate. Based on the perception developed by local people, Nepalese bamboo may be classified into two groups - (1) large-statured bamboo and (2) small statured bamboo.

Large-Statured Bamboo ("Bans") :

There are 11 different species of large statured bamboo, which are collectively known as "Bans" (Table 16). Most of them are over ten m tall and have a diameter of over five cm in cross-section. They are used for a variety of purposes: as poles for construction of huts, sheds, houses, and small bridges, as weaving material for making mats, partition walls, and roofing materials; as pots for carrying milk and milk-products, as vegetable from young shoots; and also as fodder from leaves. Botanically bamboos of Nepal are recognized under two genera, i.e., *Bambusa* and *Dendrocalamus*. *Dendrocalamus hamiltonii*, known as Tama Bans, has a wide variety of uses and grows successfully from 2,000 m to 3,000 m altitude in the hills and valleys of Nepal. This is a "multipurpose" species preferred by most hill people.

Bamboos are principally propagated by vegetative means through rhizome cuttings, which can weigh up to 40 kg. Propagation through seeds is rather difficult, and the availability of seeds is a constraint by itself. However, judging from the wide use of bamboos in the rural economy and in maintaining the mountain ecology, it is tempting to use large-statured bamboo as the most desired plant for community forestry. Mass propagation through tissue culture techniques is entirely possible, as has been evident in the laboratories of the Royal Botanical Gardens, Godawary, Nepal. The transfer of young bamboo plants from flasks to fields involves considerable management problems, which need to be solved to attempt large-scale

Table 16 : LARGE-STATURED BAMBOO SPECIES

	Scientific Name	Local Name	Altitude (m)	Uses/remarks
1.	Bambusa nutans	Mal Bans	Terai - 1600	Construction
2.	Bambusa sp.	Tharu Bans Sate Bans	- 1500	"
3.	B. balcoa	Dhanu Bans Bhalu Bans		Scaffolding of large building
4.	B. arundinacea	Kante Bans	- 1250	Thorny
5.	B. vulgaris			planted for paper pulp, ornamental
6.	Dendrocalamus hamiltonii	Tama Bans Ban Bans Choya Bans	300 - 2000	multipurpose; fodder leaves
7.	Dendrocalamus sp.	Phusre Bans Khosre Bans Tama Bans	1500 - 2000	not good for weaving
8.	D. hookeri	Kalo Bans Bhalu Bans	1500 - 2000	cold resistant; small poles
9.	D. Sp.	Dhungre Bans	1500 - 2000	cylindrical containers, pillars for buildings, fodder, weaving
10.	D. patellaris	Nibha Bans Lyas Bans	1950 - 2600	Good quality weaving material; flutes.
11.	D. strictus	-	below 1000	Siwalik & Non-alluvial Terai.

Source : Stapleton (1987)

planting of bamboo in Nepal. The Arun Basin is one of the favourable areas for such an endeavour. Over ten species of bamboo are already in cultivation along hill slopes and valleys where the humid conditions are favourable to most bamboo species. Their cultivation may be visualized not only in terms of stabilizing fragile slopes and rehabilitating barren lands but also in terms of their economic returns through cottage industries.

Small-Statured Bamboo (Nigalo and Malingo) :

Small bamboos have a wide use as weaving material for baskets, especially "Doko", "Dalo", and as roofing mats, partition mat walls, etc. There are some nine different species under three genera -- *Drepanostachyum, Arundinaria,* and *Thamnocalamus.* Some species are most sought after for their edible shoots, while others have specific use for making writing pens or smoking pipes. Most of them are used for weaving. Cultivation of small bamboos is not infrequent, but it is customary for most high-altitude dwellers in the Arun Basin to go into forests and bring back bamboo for domestic consumption. Roy Lancaster (1981), in his travelogue, narrates as following:

"Half way through the morning and still in the dark forest, we heard a noise somewhere along the track ahead of us. .... The cracking and clattering of bamboos was unmistakable. Suddenly from out of the thicket ahead burst several men trotting in single file, each hauling a bundle of green bamboos. The canes measured 10-12 ft. in length and 0.75-1 inch thick and were packed 80-100 per bundle ..... The men ... were taking them down to Hatia where they would be used to repair roofs and fences..."

Most valued of bamboos for basket work in eastern Nepal is the "Malingo", which is known as *Arundinaria maling* in plant science. It is widespread above 2,800 m, often spreading over 80 per cent ground cover along gullies and shaded slopes where tall trees are being destroyed. In the side valley of the Arun Basin, the "Malingo" bamboo is replaced by "Ghode Nigalo" above 2,600 m (8500 feet). The "Ghode Nigalo" is a *Thamnocalamus* sp., and its swollen nodes do not weave into a waterproof roofing material as that of "Malingo". However, young shoots of both species are much relished by bears and red pandas. These bamboo clumps provide perfect shelter for mountain pheasants like the Monal (Horned pheasant), Danphe (Impeyan pheasant) and Chilime (Blood pheasant).

People of the upper Arun valley use bamboo mats as roofing material not only for temporary huts and sheds but also for permanent houses.They cannot afford wooden planks, as is more frequent in other parts of Nepal. Furer-Haimendorf quotes Stainton to confirm the dearth of conifers in the forests of the upper Arun valley as being the main cause for using more bamboo.

Mountain people are excellent weavers of bamboo materials, especially baskets, mats, winnowing trays, and grain containers. Dunsmore (1987) reports that the bamboo baskets produced by the people of the Kosi hills received a very promising response from the buyers during a small exhibition staged at Kathmandu. Bamboo-based cottage industry should be one of the important activities to promote in the Arun Basin. Large-scale plantation of bamboo for paper pulp is a feasible option provided seedlings are made available and a marketing mechanism is developed. Mahat (1987) emphasizes that the investment of government agencies in bamboo plantations and development is well justified and community forestry programmes have a potential to greatly promote cultivation and development of bamboo plantations on private as well as community-managed lands. A short description of small-statured bamboo, their habitats and uses is given in Table 17.

TABLE 17 : SMALL-STATURED BAMBOO SPECIES

	Scientific Name	Local Name	Altitude	Uses/remarks
1.	Drepanostachyum intermedium	Tite Nigalo	1200-2400 m	Baskets and Mats. Fodder. Also in cultivation.
2.	D. khasianum	Tite Nigalo		
3.	D. hookerianum	–	above 2000 m	cultivation.
4.	D. sp.	Malinge Nigalo	1800 m	also in cultivation.
5.	D. sp.	Malinge Nigalo	1800-2000 m	weaving material
6.	D. sp.	"	2500-3000 m	western sp. edible shoots
7.	Arundinaria maling	Malingo	2300-2800 m	highly valued for basket
8.	A. racemosa	–	above the Malingo	
9.	Thamnocalamus sp.	Ghode		Brushes, fodder

Source : Stapleton (1987)

Labour-based activities

Several activities, such as construction of roads, bridges, dams, etc, mountaineering expedition and trekking, quarrying semi- precious stones, employment in military service at home or abroad, and a number of other activities make use of the manpower from the Arun Basin. Of them, mountain tourism and the mining of semi-precious stones are considered here for discussion.

Table 18 : OCCURRENCE OF SEMI-PRECIOUS AND PRECIOUS MINERALS IN THE ARUN BASIN. (COURTESY : D. R. KANSAKAR)

S.No.	Name of the Locality	Altitude (m)	County rock	Type of Mineral	mineral concentration(%)	Production per day (kg)	Remarks
1.	Bhote Khola (Swachi)	1250 m	Chlorite Schist	Garnet	50	150	25-30 % Gem Quality
2.	Bhude Khani	1,350 m	"	"	30	90	30% Gem Quality
3.	Hanglung	1,570 m	"	"	20	_	_
4.	Sunamla (Paipung)	1,860 m	"	"	40	_	No Gem variety
5.	Chin khuwa	1,320 m	Mica Schist	"	_	_	Not Economic
6.	Dhami Kuwa	2,100 m	"	"	?	_	"
7.	Toribari Khotak	_	"	"	40	_	_
8.	Himmuwa	1,200 m	Garnet mica Schist	"	5	_	_
9.	Jantare Bhir	2,470 m	"	"	_	_	_
10.	Pakhuwa	1,830 m	Pegmatite in mica Schist	"	_	_	_
11.	Hyakule	2,070 m	Pegmatite in calc-silicates	"	_	_	_
12.	Tinjure	_	"	"	_	_	_

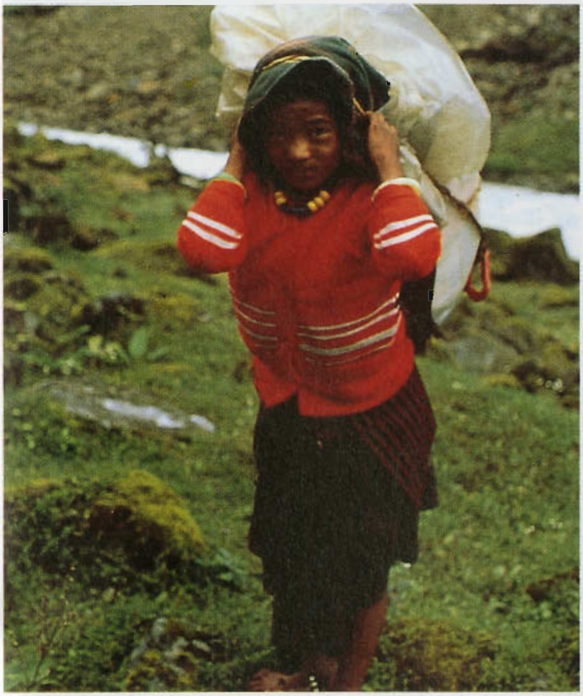
Source: Thapa 1978 : Tuladhar and Sharma 1981

Mining Activities

Chainpur area in the eastern part of the Arun Basin in Sankhuwasabha district has been well known for the occurrence of semi-precious and precious stones, like garnet, tourmaline, beryl, and aquamarine. A number of such occurrences have been reported (Table 18). As a result, six garnet mines and one tourmaline and aquamarine mine are operating under the license issued by HMG/Nepal. All of these mines are run on a small scale by private companies belonging mostly to the local people. Local people are hired by the mine owners for mining. These labourers are provided with simple excavation tools, like hammer and chisel, and in the underground shafts, they are provided with kerosene lamps or candles. No technical evaluation and documentation is done, and their excavation is guided only by visual observation of the precious mineral. As a result, mine safety, ventilation, and passageway conditions are poor, but the cost of production is low. The miners are paid according to the quantity of mineral they collect, e.g., Rs. 2.50 per kg of garnet in 1980 (Tuladhar and Sharma, 1981). The total production cost at Biratnagar is about Rs. 8.00 per kg, which includes wage to labourers and transportation on human back up to Tumlingtar and air transport from there to Biratnagar. It is then processed partly in gem industries situated at Biratnagar or Kathmandu, after which it fetches up to Rs. 300 per gm in the Kathmandu market. Thus clearly, this is a very important mineral resource of the country with a bright future. But, because of the lack of skilled gem processors in the country, this resource is far from being optimally exploited.

Mountain Tourism

Mountain tourism is a fast-growing industry in Nepal, and its role in the management of mountain ecology and economy is becoming more and more significant. The issues of protecting the environment for tourism and from tourism are often raised in the context of the eco-development of the mountains (T.V. Singh 1983).



Porterage is a source of additional income for mountain people. Even young girls take part as porters in mountaineering expeditions

Bare-footed porters on a snowy trail to Makalu base camp

Makalu (8470 m) is the fifth highest peak of the world
(Courtesy of Dan Taylor-Ide)

Table 19 : EXPEDITIONS TO MT. MAKALU I AND II

Year	No. of expeditions	Members	Countries
1983	6	34	USA, Belgium, Japan, France, Netherlands
1984	6	36	USA, Spain, Nepal, Britain, Switzerland, Italy
1985	6	46	France, Italy, Netherlands
1986	6	59	USA, Italy, Poland, France, Japan
1987	8	63	USA, Austria, Netherlands, Poland, France, Switzerland
5 Years	32	238	11 Countries

Source : Department of Tourism, HMG/Nepal.

Mount Makalu (8,475 m), the fifth highest peak in the world, is one of the popular peaks for mountaineering. The spill-over from the over-crowded Everest region is often absorbed by the Makalu area. Every year, an average of six expeditions operate in the Makalu region (Table 19).

It was observed in August-September 1986 that five expeditions operated almost simultaneously to Mt. Makalu I and II. Each of the teams had 5-15 climbing members and an equal number of Sherpa guides.They were supported by a caravan of porters, numbering to 60-120 heads. In each of the operations, the group could be classified into three categories. (i) Professional Sherpa guides and high-altitude porters above 4,500 m.(ii) Middle-altitude porters at 3,000 m to 4,500 m in altitude, and (iii) Low-altitude porters from 1,000 m to 3,000 m altitude.

Professional Sherpas and guides take full charge of the camps, camping equipment, and other belongings. They are recruited outside the region (Arun Basin) from Kathmandu and Solu-Khumbu area. The highland dwellers of the upper Arun have already gained a lot of experience and training from them. Those Bhotea people who often associate themselves with the Sherpas are indispensable for the middle altitude, i.e., 3,000-4,500 m. They replace the Rai and the Limbu porters from Tashigaon (2130m) onwards, the last village on the trail. The mid-altitude porters have special requirements for camping sites, which are largely determined by the availability of natural rock shelters along mountain slopes. Hundreds of porters get dispersed during the evening and start collecting firewood. Rhododendron leaves for bedding material, and a number of wild edible roots, rhizomes, and bamboo shoots are collected. Continued activity of this sort exerts great pressure on the natural vegetation. Above 3,600 m, the situation gets much worse due to the absence of trees. Mountaineering parties and local shepherds have been extracting wood from shrub vegetation of Juniper and Rhododendrons, after burning the leafy part of the bushes. A basketful of wood fetched about Rs. 100, which requires a clearing of about $100m^2$ of shrubland. This has resulted in bare slopes that can no longer hold winter snow for a gradual supply of water during dry months for low-lying slopes and terraces. Thus the mountain slopes in the alpine and sub-alpine zones should not be stripped of the vegetal cover if water balance of the watershed is to be maintained. The supply of firewood should be done by extracting old trees and dead logs from forests at lower elevation. It is often seen that a large amount of old trees and dead logs are left to rot in ravines and dense forests.

Thus it is tempting to suggest introduction of power saws to extract such wood and setting up of firewood sales depots for mountaineering and trekking parties. Extraction of old trees, and dead logs, by using efficient mechanical means, could well be viewed as an option to make better use of old, dying, or dead wood to save new and young trees.

Regeneration of mountain vegetation needs serious consideration in the management of watersheds. Natural regeneration of vegetation is rather poor or almost impossible when the slope is stripped of vegetation. Thus it is highly desirable to open up alternative routes to approach various base camps. After a certain period of time a particular route should be closed for a number of years, to allow regeneration.

Environmental problems arising from unmanaged disposal of litter, bottles, cans, plastics, etc., are becoming more severe in several areas of mountaineering activities. Professional guides and climbing members should be trained to dispose off garbage and a surveillance mechanism should be developed.

Mountaineering and trekking tourism offers quite a significant amount of employment to the local people. However, environmental costs and consequences are never considered. It is, therefore, important that promotion and practice of mountain tourism should be viewed in a broad context of nature conservation and environmental management.

Infrastructure Development And Ecology

The scenario of ecological processes in the Arun Basin from the disintegration of rocks at high elevations to the sedimentation of rivers at valley bottoms is not too far different from those of other mountain regions in the Himalaya. Age-old traditions of trial and error with marginal land resources have been responsible for sustaining people on mountain slopes. Rapid growth of population has become a threat to the balance of mountain ecosystems. Poor economic conditions and the even poorer educational base stand out as the most conspicuous constraints for any development strategy.

Development activities in the basin are aimed at fulfilling the basic needs of the people by improving upon the agricultural system, managing forest resources with particular reference to fuelwood needs, hygiene, and education. The Dharan-Dhankuta-Hile-Basantapur road of 86 km is a major development programme of KHARDEP, run under assistance from the United Kingdom. The programme also includes land use (crops, livestock, community forestry), roads, bridges and trails, drinking water supply schemes, irrigation projects, cottage industries, agricultural education, in-service teacher training, health, and women's development. The implementation period of five years from 1980 to 1985 in a remote mountainous area is too short to expect any appreciable effects, except in the areas of physical construction and public works. The support of the Pakhribas Agricultural Centre (PAC), also run under the co-operation of the U.K., should be regarded as an important factor that supports rural development.

The Arun river as seen from Hedangna looking South. Approximate site of the Arun-III power house lies in this sector. Num village is seen at the top left hand side corner. Sub-tropical hardwood forest (*Schima-Castanopsis*) is seen on slopes bordering the river

The Arun gorge between Num and Hedangna is the approximate site for the intake of Arun-III hydro-electric project

His Majesty's Government of Nepal is implementing a community forestry programme in the hill districts of Nepal but none of the three districts of the Arun Basin are included. The KHARDEP has a component of community forestry in its programme of rural development. In the face of the present situation where Arun III is making headway, the community forestry programme should be implemented in all the districts of the basin.

Of all the projects under consideration, Arun III Hydro-electric Scheme could well be singled out for consideration.

Arun III Hydro-electric Project

His Majesty's Government of Nepal is to undertake the Arun III Hydro-electric project and aims to complete it by the year 1995. An access road of about 170 km will be a major impetus for regional development, because its alignment falls largely along the preconceived growth axis for regional development.

The project site has a river gradient as steep as 1/30 to 1/50 in the upstream area, and the valley slopes also are quite steep with more than 40° angle. Geological, topographical, and meteorological conditions, coupled with deforested slopes, indicate that watershed management should be implemented as early as possible. The section of the valley on the upstream side, especially from the bridge below Num village, to the Chepuwa village may be considered as a "hot spot". Slash-and-burn activities should, therefore, be stopped immediately and the hill slopes should be subjected to stabilization activities, such as massive afforestation. People who are dependant on those lands should be given alternative means of livelihood by providing jobs in various construction works to begin with, and by promoting small scale industries on a long-term basis.

Priority should be given for rapid research to identify appropriate species of plants for afforestation, and to find ways and means for mass propagation of trees and shrubs. Field observations suggest that all the slopes should be barred from grazing animals or ploughing. The invasion of the *Eupatorium* and other weed species should be encouraged. Areas with stabilized soil should be identified for cultivation of *Alnus nepalensis* along wet ravines, and of bamboo on drier sites. In the sub-catchment areas agro-forestry should be encouraged, especially for cultivation of cardamom and tea. The sub-catchments 1, 2, 3, 4, 6, 7, 9, and 10 should be viewed as special areas for environmental management with a prerequisite master plan for watershed management. Structures for this project include a concrete dam 65 m high, an underground desanding basin, a 7-m diameter tunnel 11.3 km long and an underground power house. The pondage creates about 4 km of backwaters, and a maximum waterlevel rise of 50 m will inundate some of the paddy fields and a stretch of tropical forests along the gorge. An installed capacity of 201 MW is to be completed in the first phase by the year 1994. With the completion of the feasibility study, an agreement with the Federal Republic of Germany has been signed for assistance to carry out the detailed design. Major civil works are said to be on the way.

This project has generated a high degree of aspiration among the people in the Arun Basin. People have started to develop their own economic strategy by investing in lands along the proposed alignment of the road. One of the entrepreneurs has already started a distillery to produce spirits to serve the workers and labourers. Businessmen from Chainpur, Bhojpur, and Khandbari are focusing their interest on purchasing land along the road.

It is, therefore, suggested that an Action Plan for the development of Arun Basin be designed at the earliest opportunity. This would need a rapid study to elucidate and evaluate human systems in addition to physical and biological systems. Aegerter and Messerli (1985) have made a useful contribution by outlining various systems and impact areas for a systematic study. A relevance matrix for an environmental impact study for Arun III Hydro-Electric Power Development Project has been presented in the Interim Report (Nov. 1986), based on the work of the same authors. It is, however, essential that key areas for impact studies be identified. The following few areas may be identified for early consideration.

A. Non-biotic

1. Soil and Rock (Cultivated and Natural)
2. Climate (Meso-and Micro-climate)

B. Biotic

3. Terrestrial ecosystems (Forests/Agriculture)
4. Fauna (Rare and Endangered species)

5 Flora (Rare and Endangered species)

C. Social

6. Population movement
7 Structure for power and decision-making
8. Communication and Transport

D. Cultural

9. Traditions and customs
10. Cultural institutions

E. Economic

11. Infrastructures

F. Political

12. Interests of the indigenous population

Basic data on aquatic ecology is seriously lacking. However, it is obvious that the dam will interrupt the migratory fishes along the river, since no fish ladder construction is envisaged in the project.

The lake formed would provide a habitat for migratory water birds, such as duck and water fowl, and it will be a complementary waterbody to the already existing Kosi Barrage waterbody, further towards the south in Morang.

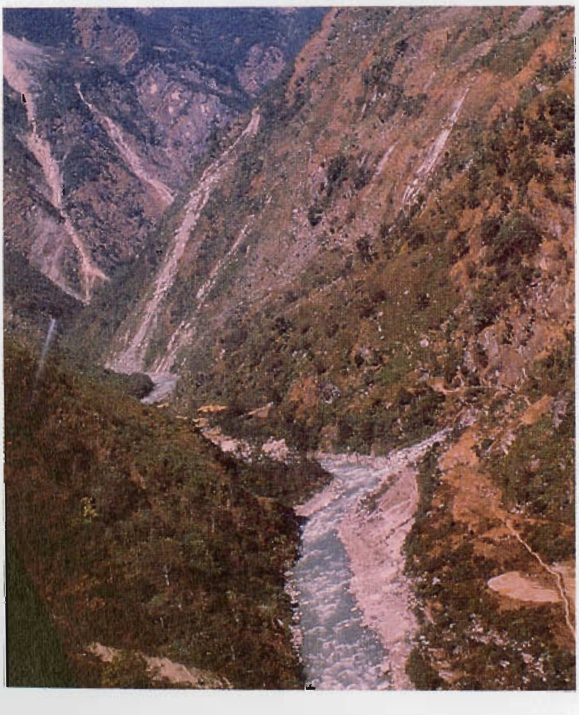
Arun Access Road

The Arun Access Road (AAR) should be visualized as a "trunk road" for eastern Nepal that links the mountainous regions with the plains of Terai. It fits well with the "growth-axis" proposed for regional development, and its socio-economic impact on the eastern development region would be very great.

The length of the road from its points of origin along Dhankuta-Basantpur Road to the intake site is estimated to fall somewhere between 110 km to 170 km. Several alternative routes have been identified (Scott Wilson Kirkpatrick and partners 1987). The programming of the Arun III demands the access road to be completed by 1990. The task ahead looks tremendous with the given schedule for road construction. Road construction on a mountain terrain is most challenging and to combat the administrative formalities, such as bidding procedures, contract award, mobilization of resources (men and machineries) within a short period of time will be still more challenging. Thus an unprecedented strategy and procedures for operating the project have to be developed.

Two options emerged for the alignment from several studies: (1) the valley route, and (2) the ridge route. Those routes lie broadly on the counter-dip alignment of the bedrock. No sector falls towards the upstream of the river to effect the watershed of the Hydel project.The "valley" route versus the "ridge" route issue needs to be analyzed on the basis of construction costs, vehicle operating costs, maintenance costs, and also environmental costs.

The valley route : It begins apparently at Hile on the ridge of Milke Danda.This ridge is unique in Nepal in terms of its northward extension to the Chinese border, almost keeping parallel to the Arun river. The valley route quickly



The sector of the Arun Valley lying between Chepuwa loop (Arun-VI site) and the Num loop (Arun-III site) is extremely degraded and needs special treatment for restoration. Slopes are steep, rainfall is high and the people are poor descends from this ridge to Pakhribas and follows the Mahamaya Khola to reach the bank of Arun. Then it keeps all along the Arun to the intake site. The air strip of Tumlingtar falls along this route, somewhere near the middle. The valley route traverses through sub-tropical and tropical zone, forested with sal trees on red latterite soil. Thus a greater risk of soil erosion and drainage problems is evident.

The Ridge route : It would be a kind of continuation of the Dharan-Dhankuta-Hile-Basantapur road, which is being constructed under the KHARDEP project. This route keeps along the Milke ridge further north of Basantapur to Mamling, Chainpur, Kharang and then descends to Tumlingtar. It will then link the district headquarters, Khandbari, and follow another ridge till it descends to the intake site.

The ridge route has finally been accepted, mainly due to its alignment along more stable terrain, and also due to strategic points for magnificent views of mountains and valleys that can be seen on either side of the ridge. Thus there is an added potential for developing tourism along the ridge.

Environmental considerations

Construction of roads in mountain terrain is a massive interference with the environment and, therefore, utmost care should be taken during planning, construction, operation, and maintenance phases. There has been a considerable degree of environmental awareness among planners and the engineers during the last five years, especially in the field of slope maintenance and vegetation conservation. However, studies and subsequent norms and strategies for mountain roads have yet to be developed. The Arun Access Road almost sounds like a crash programme. Thus an integrated team of engineers, environmental scientists, and social scientists should work together on the operation site to minimize adverse effects leading to environmental degradation.

The Milke Danda offers unique habitats for a wide variety of Nepalese rhododendron, magnolia, and the orchids. Faunal wealth is equally rich. A conservation programme should be implemented in order to safeguard these trees, which are presently exploited for cooking meals, providing temporary shelter for over 6,000 workers along the alignment of the road and, for preparing tons of bitumen for surface coating of the road. The forests of Milke danda are heavily subjected to intense

A sector of the Dharan-Dhankuta road showing heavy engineering work in road construction

exploitation during the works on the Hile-Basantapur sector. A hill called 'Guranse Danda', i.e., the Rhododendron Ridge in literal Nepali, has turned into a bare slope without a single tree even before the road reached there. After the road arrived, forested slopes on either side of the ridge have been more extensively deforested. Thus a conservation plan for the management of forests and forest resources has become imperative.

A flow-chart of environmental impacts due to construction of roads has been outlined by Joshi and Dhungel (1986). The lessons of experience from the task of building the Lamosangu-Jiri 110 km road are highlighted by Shaffner (1987).

The flow chart (Fig 11) indicates that the construction of a road begins with forest clearance and acquisition of land. The activity culminates with the generation of employment, which mean drawing more people to the work site and increasing fuel needs and timber demand. Shaffner's experiences confirm that the area served by the Lamosangu-Jiri road is increasingly threatened by deforestation and land degradation, a fact which not only has negative influence on road construction, but also on road maintenance. Thus forest management stands out as one of the key is-

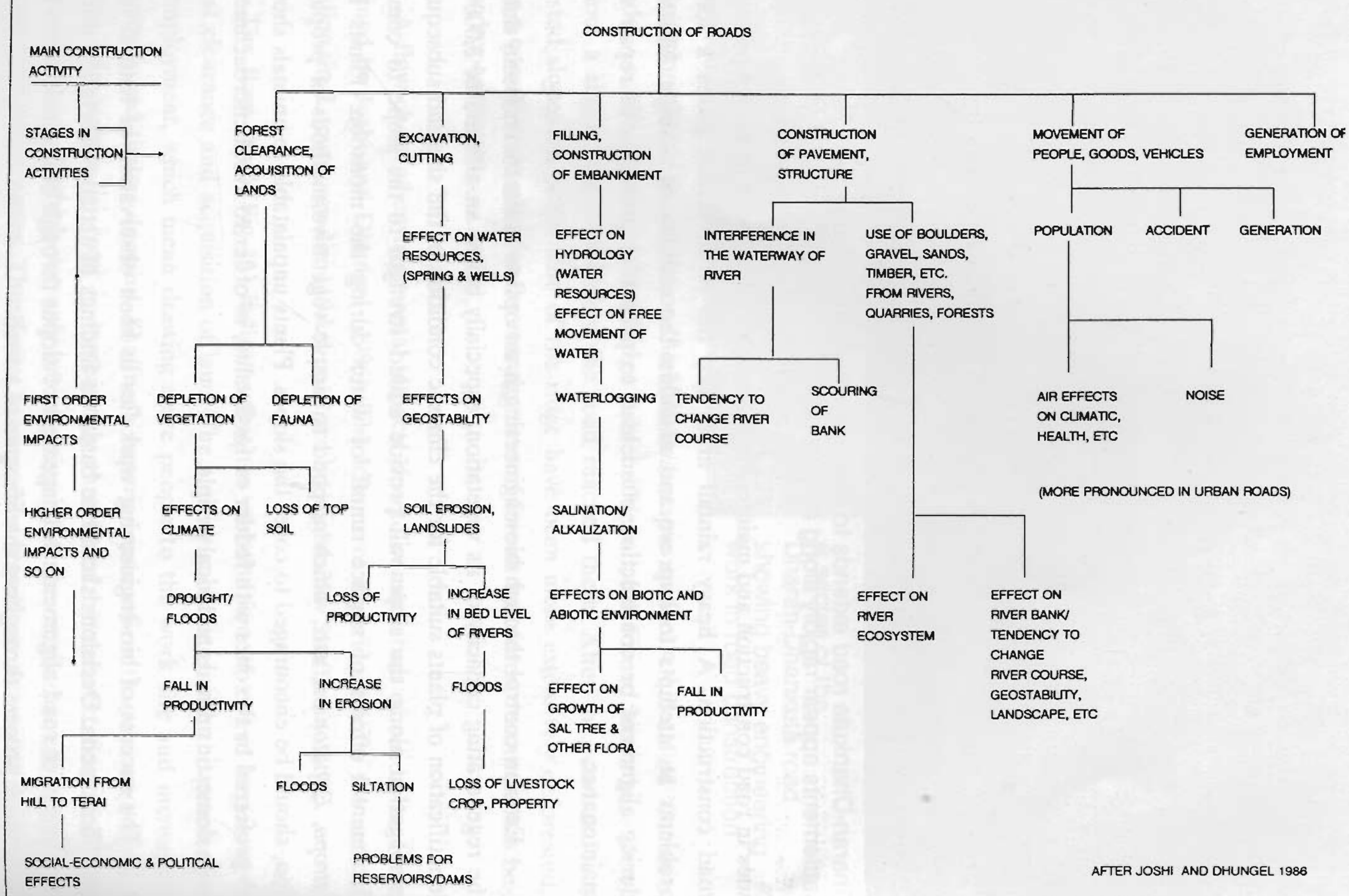
Dharan-Dhankuta road extends to Basantapur along the ridge top. New settlements appear rapidly along new roads

sues in road construction and maintenance. Slope stabilization is fundamental to any road construction. A heavy rainfall area, like the Arun Basin, poses a lot of problems at attempts to improve and maintain the stability of a slope. Mistakes during alignment or construction often lead to perpetual problems of repair and maintenance.

Erosion control through bio-engineering is an option in the Arun Basin due to the regenerating capacity of its vegetation, especially below an altitude of 3,000 m. Identification of plants suitable for the climatic condition of the site and subsequent propagation along the slope will provide added strength to the slope to combat detrimental effects of surface runoff of water during the monsoon. Plants like *Jatropa, Eupatorium,* etc., which respond to simple vegetative methods of propagation, should be encouraged to cover the slopes. Plants unpalatable to animals should be preferred to the ones with fodder or food value, in order to avoid encroachments from domestic animals and local people.

The success of bio-engineering work lies in keen observation of natural facts and phenomena. Decisions should be based on findings of actual observation during the surveys of road alignment. Management of slopes through biological means is a continuous process throughout the life span of a road.

FIG 11 : A COMPREHENSIVE FLOW CHART OF ENVIRONMENTAL IMPACTS DUE TO CONSTRUCTION OF ROADS



Economic Aspects

Road construction has an enormous impact on the socio-economic structures of the region. The Dharan-Dhankuta-Hile-Basantapur road has already indicated what sort of impact is likely to be expected in the region. Hile, for example, was nothing but a tiny village of some Tibetan people who came down form Wollanchung Gola after the trade with Tibet (China) was reduced to a small fraction. The decision to make it a road head was soon followed by a rapid growth of the township and, in less than 15 years, it has become an active marketing centre of eastern Nepal. This resulted in the reduction of commercial activities at Dhankuta. In the same fashion, Sidhuwa and Basantapur are growing rapidly, and the resources of mountain people are being used up in investments for fixed assets, like houses and lodges. A general impression from the area suggests that unless tourism is developed as a strong component, those investments are unlikely to bring good returns on a long-term basis. The road construction activities will generate a substantial amount of income for the local people, and their easy access to consumer goods should bring about considerable changes not only in the life style of the people but also in their spending habits. It is still to be seen how much the road would facilitate the increase in productivity of the area through modern inputs like fertilizers, improved seeds, improved livestock, pesticides, and so on.

The Arun Basin, like any other mountainous region in Nepal, has a subsistence farming economy. How this system can be converted into a market economy through production of cash crops and development of forest resources should be a priority area of planning for the development of the Arun Basin.

Conclusions And Recommendations

1. The Arun River Basin is a convenient natural unit for examining the complexity of mountain environments in the Himalaya. The basin may be divided into two distinct zones for developing management strategies, i.e., the northern zone and the southern zone.

   The northern zone consists of the great Himalaya and the fore Himalaya. The valley is narrow and steep, with slopes exceeding 40^{o} angle: rainfall is very high, exceeding 3000 mm per year. The population is sparse, and ekes out a precarious living on marginal lands. This region should be managed as a protection zone not only for the conservation of its rich biological diversity and challenging mountain peaks but also as ecological support to the hydropower along the Arun River.

   The southern zone consists of midlands and Mahabharata, with wider valleys formed under a matured topography with moderate slopes. This region is heavily terraced and functions as a typical mountain farming system, where agriculture, forestry, and livestock are closely interlinked to maintain a subsistence system. Present trends of declining productivity against a growing population need to be examined vis-a-vis depletion of natural resources. Any attempt to provide management guidelines on environmental issues would need a focus on increasing the productivity of land without encroaching into vegetated areas.

2. Any environment poses a unique problem within the context of a specific area. In a mountainous ecosystem, identification of homogenous or homologous areas become a problem in the absence of adequate data on biological as well as physical factors. However, it should be possible to identify "isopotential" areas on the basis of plants, animals and vegetation distribution. For example, potential areas for cardamom cultivation are indicated by the occurrence of aldar trees; for pineapple and banana, Sal trees are the indicators. Farmers of the Arun Basin are actually following such indicators to introduce fruits and cash crops in their field. Similarly, a climax forest indicates a matured and stable slope while deformed, bent, or curled trees indicate soil creeps and similar other phenomena operative on a slope.

3. The functioning of rural societies and their farming systems has acquired an equilibrium through ages of trial and error. To externalize decision in order to exert influence or to intervene in their system one would need careful thought based on the following key questions :

   (a) How, where, and when the peasant works in his field, forest, and grassland ?

   (b) What factors determine his choice of technology, preference of sites, and adoption of crops ?

   (c) What is his calendar of activities and how is his pattern of movements and migration, within and outside the basin fixed ?

4. Water resource development in the basin is dominated by a large power plan of 400 MW, the Arun III Hydro-electric Project, which is going to be the most significant element to be added in the ecosystem. Its impact on the biophysical as well as socio-economical environment has to be considered adequately, in order to maintain a balance between water discharge and sediment transportation. This would need certain slopes along the river to be repaired and restored, especially in the Num-Chepua sector. This sector receives the heaviest downpour of monsoon and any unattended or abandoned slopes give way to rapid erosion and slope failures. Productivity of the area should be enhanced rapidly by supplying high-yielding varieties of potatoes, maize, and millet, with necessary agronomic support.

The approach road of about 170 km will exert unprecedented pressure on forest produce of economic importance, such as medicinal herbs, fibre plants, orchids, and animal produce such as bear bile, musk pods, and animal skins. Township development along the road is drawing more people into the ecosystem. This is surely going to exert more pressure on the resource base of the basin. The development of water resources along the Arun Valley should have as a component a recycling mechanism, where the output of the project from its seat of production reaches directly to the site of origin for its maintenance and development.

5. Our knowledge on mountain ecology is still very incomplete. Therefore, a programme has to be developed to generate minimum essential data on some key factors, such as weather systems and climate, hydrological regime, geomorphological features and soil characteristics, forest ecosystem, agricultural system, and the human response to those factors.

6. A diagnostic study on the present state of ecology could be based on the assessment of quality and quantity of climax forests and natural vegetation as against transformed ecosystems, such as cultivated land, grazing land, and abandoned slopes. Such studies should be tied up with modern methods of remote sensing for monitoring and evaluating environmental conditions.

7. In such an area, where massive interference on the environment due to hydropower development, road construction, mountain tourism and mountaineering is anticipated, it becomes necessary to formulate an Action Plan for the development of the basin in harmony with its environment.

8. A legal framework, administrative procedures, economic sanctions, etc., are some of the important tools in implementing management plans. However, the remoteness of mountain districts weakens implementation and accelerates the misuse of legislations and sanctions. Thus the need for a Management Authority emerges. Such an authority should not only co- ordinate development activities with environmental issues but should also be able to locate responsibilities of various implementing bodies.

Appendix I: Commercially important medicinal plants occuring in the Arun Basin

Botanical Name	Local Name
Achyranthus aspera	Datiwan
Aegle marmelos	Bel
Aconitum spicatum	Bikh
A. heterophyllum	Atis
Berberis sps.	Chutro
Cinnamomum tamala	Tej-pat, Dalchini
Dioscorea deltoidea	Vyakur
Elaeocarpus sphaericus	Rudrakshya
Holarrhena antidysenterica	Indra Jau
Lichens	Jhyau
Mesua ferra	Nag Keshar
Nardostachys jatamansi	Jatamasi
Orchis incarnata	Panch Aunle
Lycopodium clavatum	Nagbeli Pitho
Picrorhiza scrophulariiflora	Kutki
Rubia manjith	Majitha
Rheum emodi	Padamchal, chulthi
Swertia sps.	Chiraita
Valeriana wallichii	Sugandhawal
Zanthoxylum armatum	Timur

Appendix II : Birds spotted in the Arun Basin during 1986 August/September (Courtesy H.S. Nepali)

Ciconiidae

01. White-necked Stork

Accipitridae

02. Honey Kite
03. Dark Kite
04. Sparrow Hawk
05. Upland Buteo
06. Crested Serpent Eagle
07. Changeable Hawk Eagle
08. Black Eagle
09. Cinereous Vulture
10. Bearded Vulture
11. King Vulture
12. White-backed Vulture

Falcoidae

13. Red thighed Falconet
14. Peregrine Falcon
15. Oriental Hobby
16. Lesser Kestrel
17. Eurasian Kestrel

Phasianidae

18. Tibetan Snow Cock
19. Common Hill Partridge
20. Blood Pheasant
21. Impeyan Pheasant
22. Kalij Pheasant

Charadriidae

23. Green-Shank
24. Common Sandpiper
25. Pin-tail Snipe
26. Solitary Snipe

Laridae

27. Great Black headed Gull

Columbidae

28. Wedge-tailed green Pigeon
29. Bengal Green Pigeon
30. Snow Pigeon
31. Black Rock Pigeon
32. Long tailed Cuckoo Dove
33. Rufous Turtle Dove
34. Spotted Dove

Psittacidae

35. Blossom-headed Parakeet

Cuculidae

36. Banded-Bay Cuckoo
37. Plantive Cuckoo
38. Large green-billed Malkoha
39. Koel Cuckoo
40. Sirkeer Cuckoo

Strigidae

41. Spotted Scops Owl
42. Barred Owlet

Trogonidae

43. Red-headed Trogon

Coraciidae

44. Indian Roller

Upupidae

45. Hoopoe

Alcedinidae

46. Eurasian Kingfisher
47. White-breasted Kingfisher

Meropidae

48. Small Green Bee-eater

Caspitonidae

49. Great Himalayan Barbet
50. Golden-throated Barbet
51. Blue-throated Barbet
52. Crimson-breasted Barbet

Picidae

53. L. yellow-naped Woodpecker
54. S. yellow-naped Woodpecker
55. Himalayan pied Woodpecker
56. Darjeeling pied Woodpecker
57. Fulvous-breasted. p. Woodpecker

Apodidae

58. White-rumped Needle tail
59. House Swift
60. Edible Nest Swiftlet

Hirundinidae

61. Sand Martin
62. Crag Martin
63. Barn Swallow
64. Striated Swallow
65. Nepal house Martin

Linidae

66. Black-headed Shrike
67. Gray-backed Shrike

Dicruridae

68. S. Racquet-railed Drongo
69. Ashy Drongo
70. Black Drongo

Sturnidae

71. Brahminy Myna
72. Gray-headed Myna
73. Commom Myna

Corvidae

74. Yellow-billed Blue Magpie
75. Red-billed Blue Magpie
76. Himalayan Tree Pie
77. Nut Cracker
78. Red-billed Chough
79. House Crow
80. Jungle Crow
81. Raven

Campepnagidae

82. Large-cuckoo Shrike
83. Dark-cuckoo Shrike
84. Long-tailed Minivet
85. Scarlet Minivet

Irenidae

86. Iora
87. Orange-bellied Leaf Bird

Pycononotidae

88. White-cheeked Bulbul
89. Striated Bulbul
90. Red-vented Bulbul
91. Rufous-bellied Bulbul
92. Brown-eared Bulbul

Timilliidae

93. Slaty-headed Scimitar Babbler
94. Rufous-necked Scimitar Babbler
95. Rusty-cheeked Scimitar Babbler
96. Scaly-breasted Wren Babbler
97. Red-headed Babbler
98. Black-chinned Babbler
99. Jungle Babbler
100. Spiny Babbler
101. Spotted Babbler
102. Striated Laughing Thrush
103. White-crested Laughing Thrush
104. White-spotted Laughing-Thrush
105. Rufous-chinned LaughingThrush
106. Gray-sided Laughing-Thrush
107. Red-headed Laughing-Thrush
108. Black-faced Laughin-Thrush
109. Red-billed Leiothrix
110. Chestnut-throated Shrike
111. Spectacled Barwing

112. Bar-throated Minla
113. Blue-winged Minla
114. Yellow-napped Yuhina
115. Stripe-throated Yuhina
116. White-bellied Yuhina
117. Chestnut-headed Tit Babbler
118. White-browned Tit Babbler
119. Black-capped Sibia

Muscipidae

120. Sooty Flycatcher
121. Verditer Flycatcher
122. Paradise Flycatcher
123. Rufous-breasted Blue Flycatcher
124. Gray-headed Flycatcher
125. White-throated Fan-tailed Flycatcher
126. Pale-Blue Flycatcher
127. Ferrunginous Flycatcher
128. Orange-gorgetted Flycatcher

Sylviidae

129. Olive Ground Warbler
130. Chestnut-headed Ground-Warbler
131. Blanford's Bush Warbler
132. Rufous-capped Bush Warbler
133. Hodgson's Prinia
134. Brown-hill Prinia
135. Tailor Bird
136. Tickell's Leaf Warbler
137. Plain-Leaf Warbler
138. Orange-barred Leaf Warbler
139. Dull-Green Leaf Warbler
140. Yellow-rumped Leaf Warbler
141. Yellow-eyed Leaf Warbler
142. Gray-headed Warbler
143. Goldcrest
144. Broad-billed Flycatcher Warbler
145. Smoky Leaf Warbler

Turdidae

146. Blue Chat
147. White-browed Bush Robin
148. Orange-flanked Bush Robin
149. Golden Bush Robin
150. Rufous-bellied Bush Robin
151. Magpie Robin
152. Blue-fronted Redsart
153. White-capped River Chat
154. Little Forktail
155. Slaty-backed Forktail
156. Collared Bush Chat
157. Dark-gray Bush Chat
158. Pied Bush Chat
159. Blue-head rock Thrush
160. Chestnut-bellied Rock Thrush
161. Pied Ground Thrush
162. Orange-headed Ground Thrush
163. Whistling Thrush
164. Tickell's Thrush

Troglodytidae

165. Wren

Cinclidae

166. Brown Dipper

Prunellidae

167. Altai Accentor
168. Alpine Accentor

Paridae

169. Gray Tit
170. Green-backed Tit
171. Yellow-cheeked tit
172. Coal Tit
173. Sikkim Black Tit
174. Crested Brown Tit
175. Red-headed Tit
176. Rufous-fronted Tit

Sittidae

177. Chestnut-bellied Nuthatch
178. White-tailed Nuthatch

Certhiidae

179. Sikkim Tree Creeper

Motacillidae

180. Hodgson's Tree Pipit
181. Paddyfield Pipit
182. Richard's Pipit
183. Rose-breasted Pipit
184. Gray Wagtail
185. Pied Wagtail
186. Large-pied Wagtail

Dicaeidae

187. Thick-billed Flower-pecker
188. Plain-colored Flower-pecker
189. Fire-breasted Flower-pecker

Nectariniidae

190. Fire-tailed Sunbird
191. Nepal Sunbird
192. Black-breasted Sunbird
193. Scarled-breasted Sunbird
194. Streaded Spiderhunter

Zosteropidae

195. White-Eye

Ploceidae

196. Tree Sparrow
197. House Sparrow
198. Sharp-tailed Muniya
199. Spotted Muniya

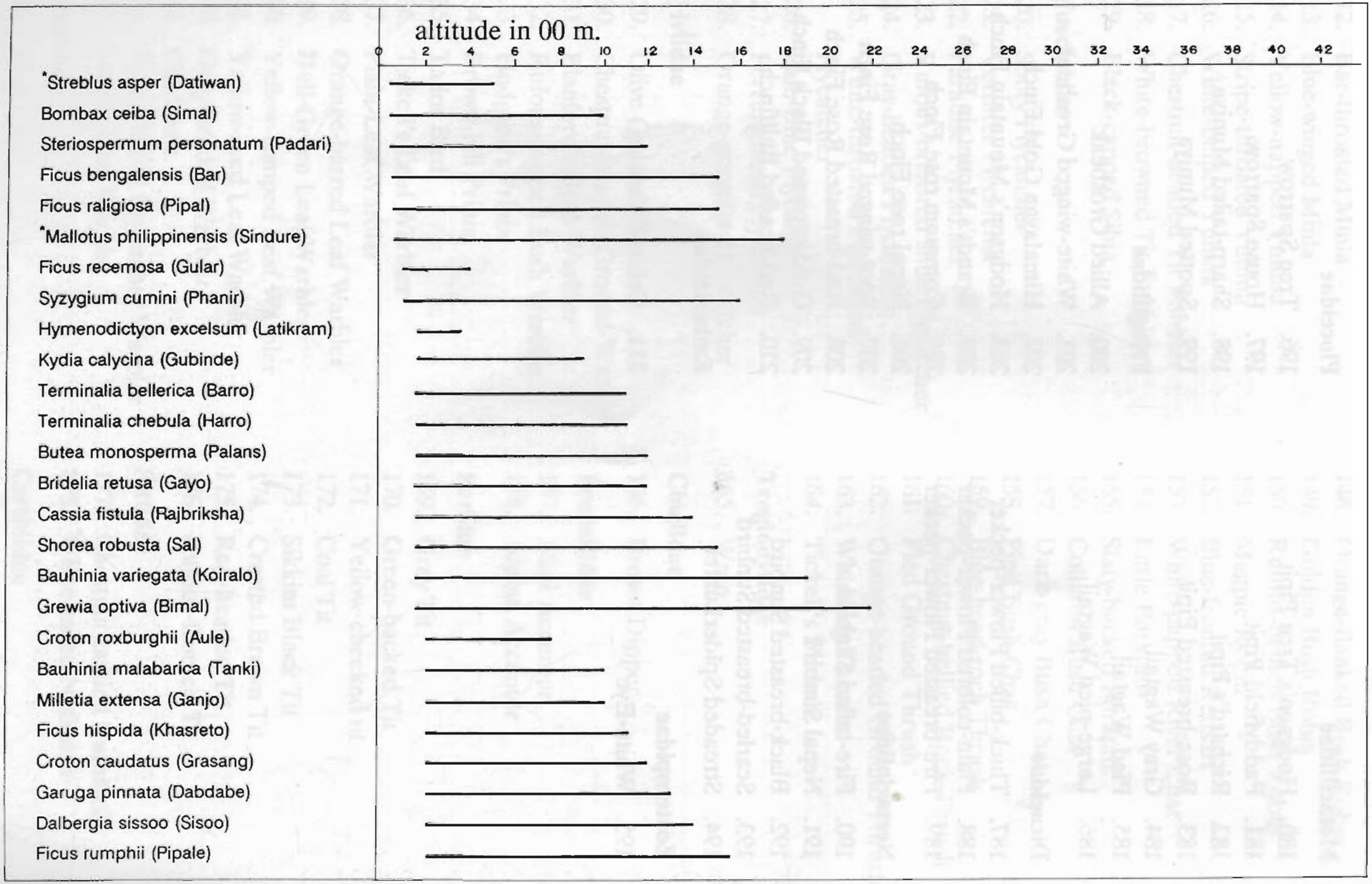
Fringillidae

200. Allied Grosbeak
201. White-winged Grosbeak
202. Himalayan Gold Finch
203. Hodgson's Mountain Finch
204. Brandt's Mountain Finch
205. Commom rose Finch
206. Nepal rose Finch
207. Spot-winged Rose Finch
208. Red-breasted Rose Finch
209. Gold-crowned Black Finch
210. Red-headed Bullfinch

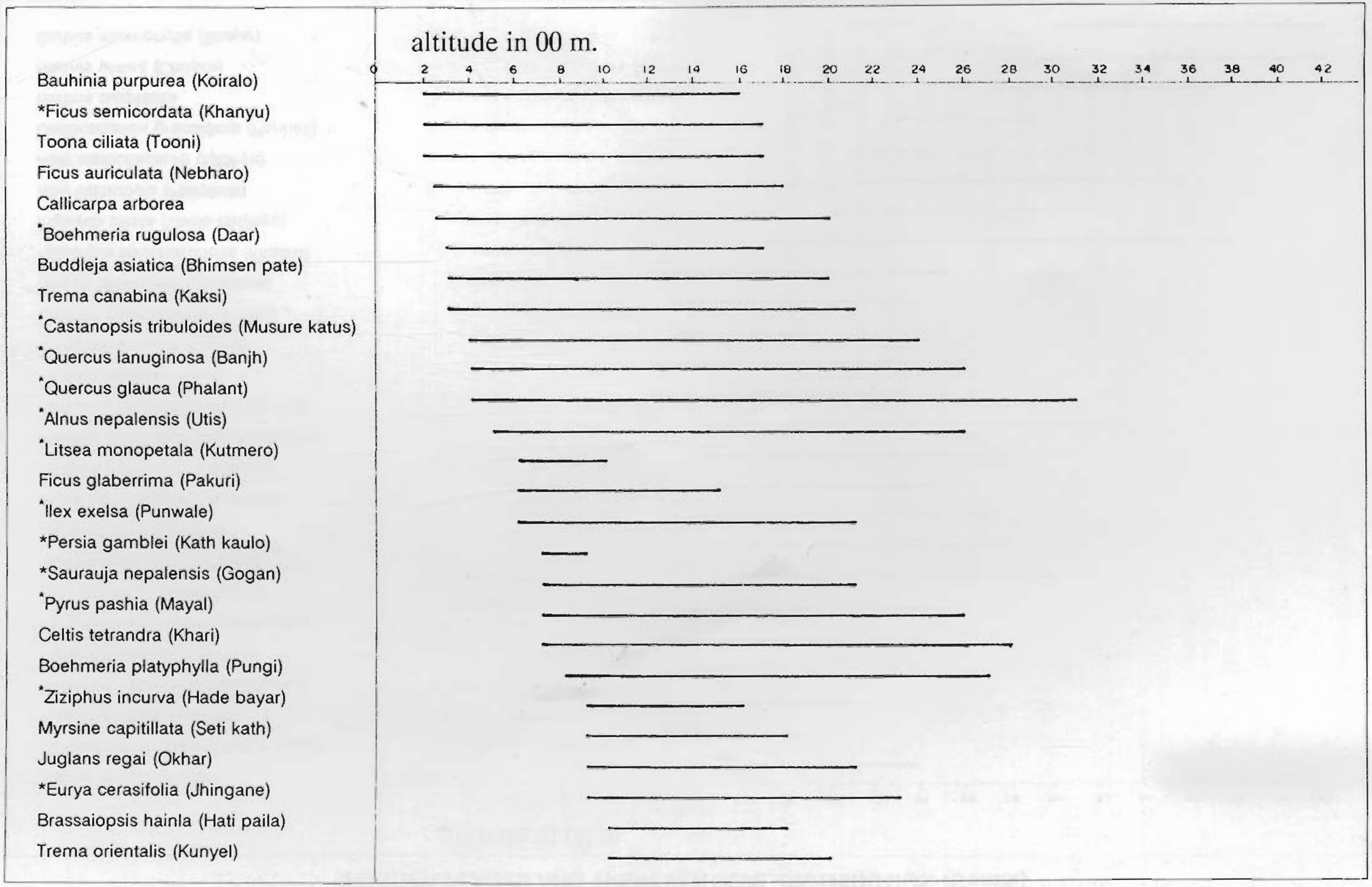
Emberizidae

211. Crested Bunting

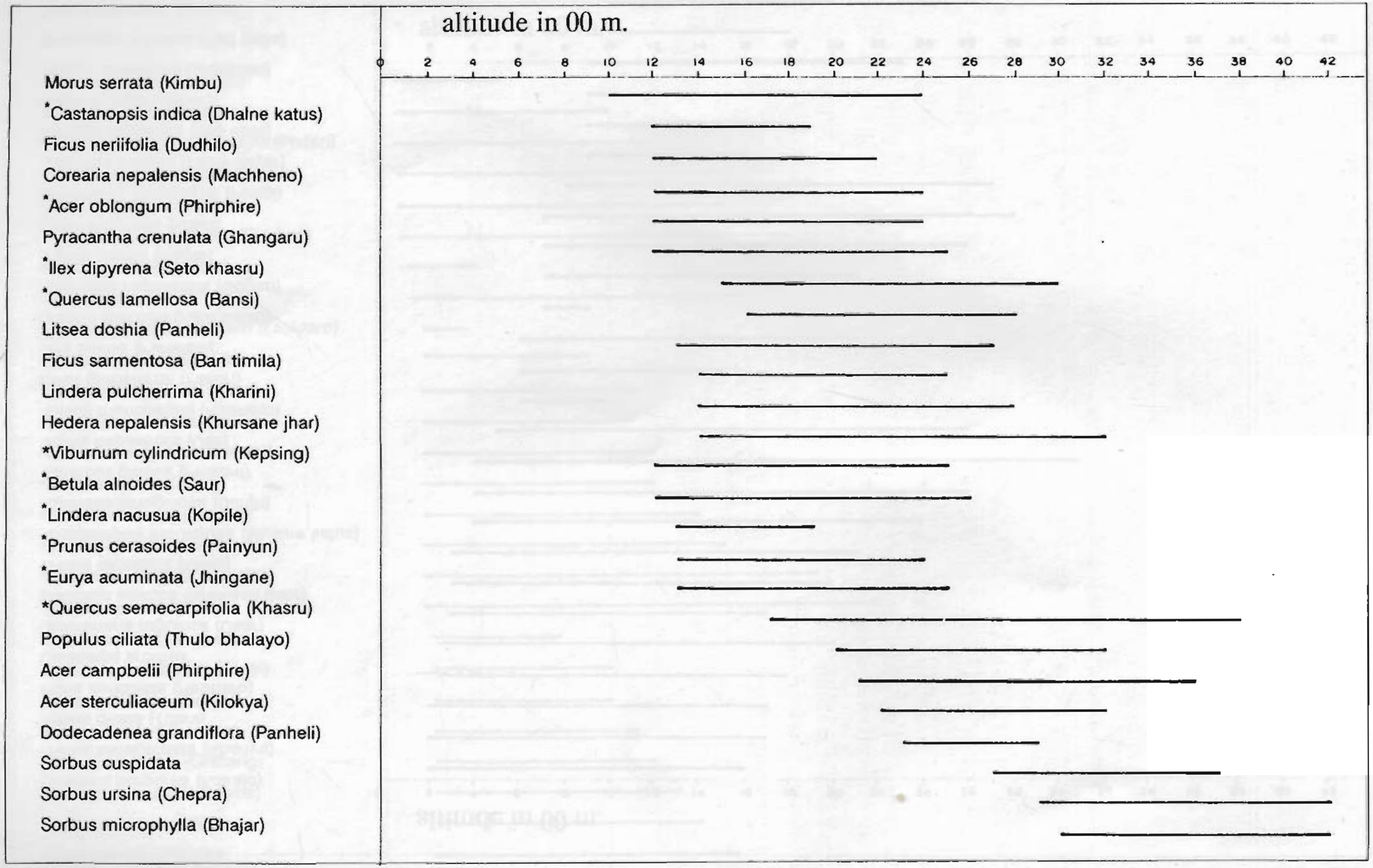
APPENDIX III : FODDER PLANTS AND THEIR VERTICAL DISTRIBUTION



FODDER PLANTS AND THEIR VERTICAL DISTRIBUTION (Contd.)



FODDER PLANTS AND THEIR VERTICAL DISTRIBUTION (Contd.)



*First grade species having more than 30% dry matter and less than 10% total ash. (D. Bajracharya et. al. (1985)

Appendix IV : Fish which is special to Kosi System
(Courtesy K.G. Rajbansi)

1. Chela gora (Ham)
2. Barilius jalkapoori (Shrestha)
3. Danio acquipinnatus (McClelland)
4. Putius clavalus (McClelland)
5. Garra annadalai (Hora)
6. G. goiyla (Gray)
7. Labio angora (Ham)
8. L. Boga (Ham)
9. L. bata (Ham)
10. Psilorhynchys pseudocheneis (Menon & Dutta)
11. Pseudocheneis sulcatus (McClelland)
12. Sciaena coiter (Ham)
13. Tetradon cutcutia (Ham)

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Tirtha Bahadur Shrestha is a plant ecologist who has spent over 25 years in plant collection and botanical research in the Nepal Himalaya. He has a doctorate degree in applied ecology from the Grenoble Univeristy in France where he presented a thesis on the ecology, biogeography and cartography of North-West Nepal (Jumla-Saipal region). Prior to that he spent well over one year at the British Museum (Natural Histroy) and at the Kew Herbarium in London studying Himalayan plants.

Dr. Shrestha is a member of the Royal Nepal Academy where he is responsible for promoting the growth of science in Nepal and for integrating scientific knowledge with Nepali language, literature, arts, culture and various other branches of knowledge and learning. His working base in botany and ecology is in the Department of Forestry and Plant Research (previously Department of Medicinal Plants), Ministry of Forests and Soil Conservation, His Majesty's Government of Nepal.

Dr. Shrestha is the first recepient of the Senior Research Fellowship of ICIMOD and he has been keenly interested in ecological problems and developmental prospects of the Arun River Basin in eastern Nepal. Besides, he has been actively engaged in various endeavours of nature conservation in Nepal.

Founding of ICIMOD

ICIMOD is the first International Centre in the field of mountain area development. It was founded out of widespread recognition of the alarming environmental degradation of mountain habitats and consequent increasing impoverishment of mountain communities. A co-ordinated and systematic effort on an international scale was deemed essential to design and implement more effective development responses in each of the countries concerned.

The establishment of the Centre is based upon an agreement between His Majesty's Government of Nepal and the United Nations Educational Scientific and Cultural Organisation (UNESCO) signed in 1981. The Centre was inaugurated by the Prime Minister of Nepal in December 1983, and began its professional activities in September 1984.

The Centre, located in Kathmandu, the capital of the Kingdom of Nepal, enjoys the status of an autonomous international organisation.

Participating Countries of the Hindu Kush-Himalaya Region

o Nepal	o China
o India	o Pakistan
o Bhutan	o Burma
o Bangladesh	o Afghanistan

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