WATERSHED: A FUNCTIONAL UNIT OF MANAGEMENT FOR SUSTAINABLE DEVELOPMENT

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1. Introduction

Livelihood in the rural areas of the Himalayan region primarily depend on subsistence farming. These farming systems are location and niche specific. They have developed over the centuries as a comparative advantage to other livelihood options in the hills. Such farming systems are highly dependent on surrounding natural resource base. Therefore, in the Himalaya, an upland farming is a traditional integrated land-use system which comprises of forest, agriculture, horticulture, agroforestry and animal husbandry (Sharma *et al.*, 1992). The natural settings of land-use systems and settlements in the hills have evolved following drainage pattern and availability of water resources. Hydrological and ecological linkages of land-use systems, natural resource base and farming practice suggest that a watershed could be an appropriate functional unit of management for sustainable development in hills.

There has been a growing interest among common people, planners and researchers about the importance of understanding physical, chemical and biological attributes on functioning of drainage in view of the proper management strategies for catchment areas. Integrated natural resource survey, planning and development have got momentum only recently in India (Planning Commission, 1982; Tejwani, 1984). Watersheds could form an appropriate unit of analyzing development linked resource problems, designing remedies of problems and eventually testing of the prescribed solutions in the mountains. In recent years, high growth rate of human and livestock population, has enormously increased the food demand and pressure on natural resources. Therefore, it is understood that factors leading to unsustainability in mountain system need corrective measures through identification of various resources, their utilization pattern, consequences and quantification of the extent of the problems through scientific planning and measuring the nature, extent and characteristics of resources depletion (Sharma & Dixon, 1995). Complex interdisciplinary, interregional and interinstitutional nature of the problems that are characteristics of mountain environment degradation should be studied. Management of resources following holistic approach can be one of the effective methods of reversing the pace of environmental degradation (Anonymous, 1993).

In view of limited information available on watersheds of the Himalaya in general and eastern Himalaya in particular, this work was undertaken as a multidisciplinary effort to test watershed as a functional unit of management for sustainable resource utilization. The study was designed to (a) make a conceptual framework for understanding dynamics of watershed functioning, (b) assess upland household linkages

Modern Trends in Ecology and Environment
edited by R.S. Ambasht, pp. 171–185

for resources, (c) know community perceptions and priorities for development, and (d) conclude the appropriateness of watershed as a unit of management in hills.

2. Study area

Mamlay watershed, located in the South District of Sikkim State in India was selected for this case study. It is spread in 30.14 km^2 area and characterized by an elevational range of 300 to 2650 m above msl. It comprises of most of the human habitation zone, vegetation types and cropping patterns that are common in the Sikkim Himalaya. The watershed is one of the most populated area in Sikkim providing a wide range of cultural-ethnic diversity and land-use pattern. Geologically the watershed is typified by folded structure and varied lithology with older rocks occupying the upper structural levels. Drainage is dendritic type and it merges in the Great Rangit river. Climate is monsoonic and average rainfall varies from 1400 mm at the valley to more than 2200 mm at the higher elevations, and most of this rain pours during monsoon from June to September. Average temperature ranges from 3-19°C at 1900 m and 10-27°C at 400 m elevations (Sharma *et al.*, 1992).

3. A conceptual watershed framework

A conceptual framework was developed using remote sensing and conventional methods for understanding dynamics of watershed functioning (Fig. 1). Physical characteristics such as hydrogeomorphology and climate were recorded. Status inventories were made specifically on resources such as human, land and soil, water, agriculture and livestock, and forests. Socio-economic conditions like physical infrastructure, administrative units, economic services, social services, social status, economic status and expenditure pattern of the watershed communities were surveyed. Interaction of socio-economic conditions with the natural resources were integrated to assess stresses on each of the resources. These stresses caused impacts at the watershed level, and are outlined for mitigation by evolving and implementing suitable technology pacakages.

3.1. Resources

The Mamlay watershed has 34 villages and population is unevenly distributed among different villages. Majority of the population (95%) are living at lower altitudes and just 5% of the population settled above 1500 m elevation. The growth of the population has been 17% during 1981-1991. The population density has also increased from 100 persons per km sq in 1971 to 138 in 1991.The dominating ethnic group is Nepalis with about 82% followed by 11% Bhutias and 7% Lepchas. The overall literacy was about 44% (male 48% and female 37%). About 80% of the population is engaged in primary sector (agriculture) and remaining in secondary and tertiary sectors (Fig. 1).

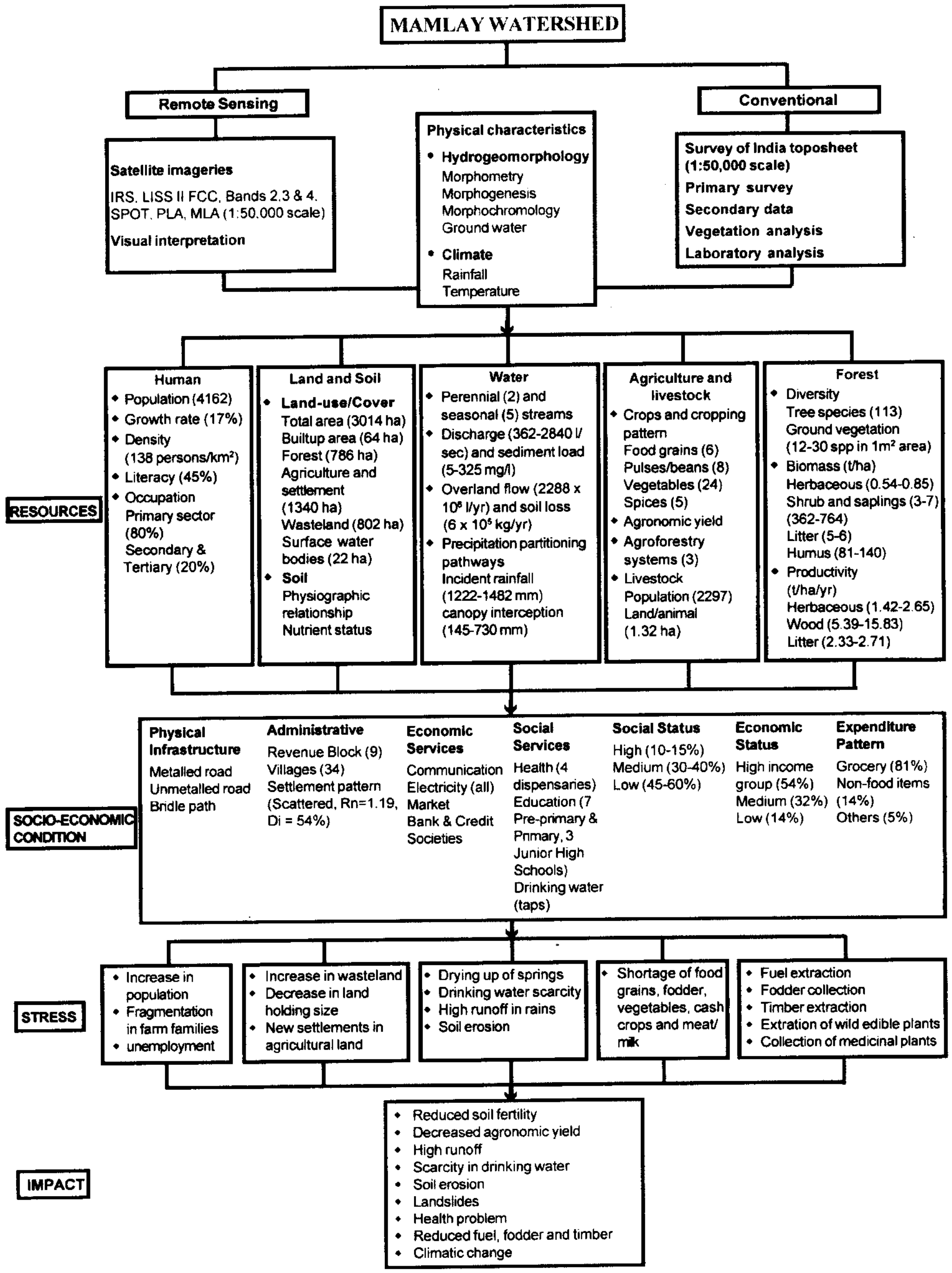

Figure 1. A conceptual framework developed as a case study in the Mamlay watershed of the Sikkim Himalaya.

The watershed has an area of about 3014 ha. Fig. 2 gives the details of different land-use/land cover of the Mamlay watershed as seen by IRS (Indian Remote Sensing Satellite)-IB, LISS (Linear Imaging and Self Scanning Sensor)-II, and FCC (False Colour Composite Bands 2, 3, 4) imageries. The land-use in the watershed is grouped in five broad categories (Krishna *et al.*, 1994; Krishna, 1996), viz., (a) forest land having dense-mixed forest, sal forest, open forest, degraded forest, scrub land and forest blanks, (b) agriculture land consisting of rainfed, irrigated, orange orchard and large cardamom agroforestry, (c) wasteland with rock out-crops and landslides, (d) built-up land, and (e) land under water bodies. Over the years there has been a constant change in the land cover under different categories (Krishna & Sharma, 1995; Rai *et al.*, 1994). The agriculture land has increased by about 13% in a span of 40 years (from 1951-52 to 1991-92) and the extent of change was much faster in the last two decades. The agricultural land under different classes shows that just 26% land is under Class I category, 39% under Class II category and remaining 35% under Class III category.

The watershed is in the catchment area of river Rangit. Drainage is dendritic type and consists of 5 seasonal and 2 perennial streams, which finally forms Rinjikhola that drains into the river Rangit. During the lean period the mid hills face immense water shortage. The discharge at the outlet of the watershed is lowest in winter (363 l/second) and highest in rainy (2840 l/second) seasons. The sediment concentration of stream water was 5 mg/l in winter and 325 mg/l in rainy season (Rai & Sharma, 1995). The annual overland flow from the entire watershed is 2288×10^6 l and soil loss 6×10^5 kg (Rai & Sharma, 1996). Precipitation partitioning pathways under different land-uses suggest that natural forests and large cardamom based agroforestry conserve significant proportion of rain water.

Farmers in the Mamlay watershed cultivate majority of crops and practice most of the cropping systems that are prevalent in Sikkim. All the four types of major cash crops such as large cardamom (*Amomum subulatum*), ginger (*Gingiber officinale*), potato (*Solanum tuberosum*) and mandarin-orange (*Citrus reticulata*) are grown in this watershed. Crop diversity is very impressive with more than 6 types of cereals, 8 varieties of pulses, over 39 vegetables, 6 spices, 14 fruits and 23 types of wild edible plants (Sundriyal *et al.*, 1994a). The four main cropping systems practiced are (a) maize-pulse combination, ginger and orange in subtropical zone, (b) maize-potato in temperate zone, (c) paddy in irrigated fields, and (d) large cardamom under tree cover in marginal lands. Maize is the cereal grown at all elevations. About 99% of the cultivated area is under rainfed condition in the watershed. Fodder trees and grasses are maintained in the farm fields and most common species are *Ficus hookeri, F. roxburghii, F. nemoralis, Saurauia nepaulensis, Listsaea polyantha* (all trees) and *Thysanolena maxima* (grass). Large cardamom is a low volume high value non-perishable cash crop, very much suitable with the mountain specificities and niche. Nitrogen-fixing *Alnus nepalensis* is extensively planted as shade/nurse tree over large cardamom crop and this combination gives higher agronomic yield of cardamom than under other canopy trees. The poor nutrient conservation and low nutrient use efficiency of *Alnus* and malleability of nutrient cycling under its influence make it an excellent association which promotes higher availability and faster cycling of nutrients (Sharma *et al.*, 1994). In the subtropical condition, orange orchards are raised alongwith traditional crops. Orange-ginger cultivation is also fol-

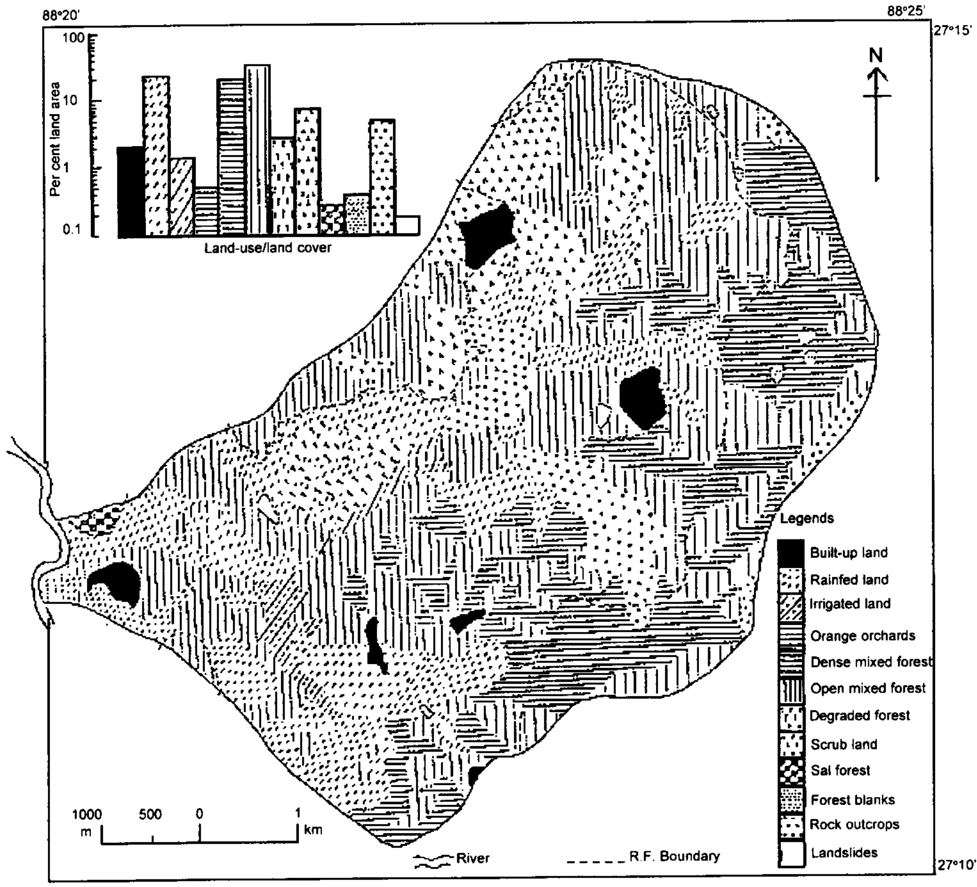

Figure 2. Land-use/land cover map of the Mamlay watershed of the Sikkim Himalaya based on visual interpretation of 1992 IRS-1B, LISS-II and FCC imageries.

lowed which is highly nutrient exhaustive causing reduced soil fertility. *Albizia stipulata* plantation in such orange orchards helps in maintaining soil nutrient levels (Sharma, 1995; Sharma *et al.*, 1995). Nutrient exhaustion through agronomic yield is 11 times higher for phosphorus and 15 times for nitrogen in orange orchards compared to large cardamom agroforestry.

The distribution of land holding size among the farmers is uneven. About 56% of the famers have small and marginal land holdings. The average size of the marginal holdings was 0.49 ha, small 1.47 ha, medium 3.87 ha and corresponding average of 14.49 ha for large holdings. Fragmentation of farm-families has caused reduction in per capita agriculture land to 0.45 ha. The population density is 1.18 persons/ha but the agricultural density is very high (up to 8 persons/ha). The farming in the watershed is a low input system that is characterized by growing food grains and cash crops. Farmers have an increasing awareness about local market "Hat" which is observed on every Sunday at the nearest town Namchi. Farmers bring their surplus produce and sell directly to the customers in this market.

Animal rearing is a common practice amongst most of the families in the watershed. Generally animals are stall fed but in recent years open grazing is becoming popular due to decrease in fodder availability. A huge amount of phytomass is collected from nearby forests. Unpalatable biomass are also collected and used for animal bedding which ultimately go to agriculture field through composts. Livestock population is increasing which is expected to replace stall feeding by open grazing as an easy means to feed cattle in near future, the trend is already visible.

People of the watershed are mainly dependent on the forests for their basic needs of fuel, timber and fodder. Besides a large number of non-timber produce are also collected. Two important forest types in the watershed are subtropical and temperate. These forests show high plant diversity comprising of dicot herbs, shrubs, trees, lianas, epiphytes, graminoides, climbers, mosses and ferns. Species richness in a small scale is high having up to 20 species in 1 m^2 area. Tree species number is also impressive with 38 and 81 (total 113) species in subtropical and temperate forests, respectively. However, just 11 and 72 tree species have reached tree stratum in respective forests (Sundriyal *et al.*, 1994c; Sundriyal & Sharma, 1996). Most of the forest sites have been subjected to human disturbance and have been degraded. Changes in different forest categories were seen in remotely sensed data over a period of 5 years from 1988 to 1992. Dense mixed forest has been reduced and converted into open mixed forest and scrub land. Similarly, forest blank area has also increased significantly. At present, just 29% of total forest is dense, 45% open mixed and the remaining 26% either degraded or blank devoid of cover (Fig. 2).

The subtropical forest is dominated by *Shorea robusta*, *Castanopsis indica*, *C. tribuloides* and *Schima wallichii*, whereas the temperate forest shows dominance of trees like *Castanopsis tribuloides*, *Quercus lamellosa*, *Rhododendron arboreum*, *Eurya acuminata*, *Symingtonia populnea*, *Nyssa sessiliflora*, *Engelhardtia spicata*, *Beilschmiedia roxburghiana* and *Symplocos theaefolia* (Sundriyal *et al.*, 1994c; Sundriyal & Sharma, 1996). Tree density, basal area and biomass of both the forests are well comparable to other Himalayan forests. The net primary productivity is higher in subtropical forest despite the lower biomass (Table 1). The temperate forest has a dominance of secondary species which can be attributed to the lower biomass accumulation in comparison to climax species. About 24% and 35% of net primary productivity is removed by villagers leaving 76% and 65% to the net ecosystem productivity in subtropical and temperate forests, respectively (Table 1). The removal of woody biomass has been highly erratic over time and space. Both the forests have fairly good plant regeneration, however, a large share is being contributed by the secondary species. A few tree species are being lopped heavily in the process of fodder collection. The forest resources in subtropical zone are under high pressure of extraction, while the symptoms of stress are also apparant in temperate forests but only in pockets close to the settlements.

Table 1. Comparative status of subtropical and temperate forests in the Mamlay watershed (after Sundriyal *et al.*, 1994c and Sundriyal & Sharma, 1996)

Parameter	Subtropical forest	Temperate forest
Number of tree species (total 113)	38	81
Tree density (per hectare)	562	715
Basal area (m^2/ha)	52	85
Tree regeneration (per hectare)		
Seedlings	5474	3437
Saplings	1776	2942
Total	7250	6379
Biomass (t/ha)		
Herbaceous plants (floor)	0.85	0.64
Shrubs and saplings	3.28	6.63
Tree (bole + branch)	362	764
Litter (leaf + branch)	5.65	5.72
Humus	81	140
Woody biomass removal (t/ha/yr, 5 year's average)	4.50	3.00
Net primary productivity (t/ha/yr)		
Herbaceous plants (floor)	2.27	1.57
Tree woody biomass		
Net primary productivity (NPP)	15.83	8.32
Net ecosystem productivity (NEP)	13.98	5.39
Removal (1992-93)	3.85	2.93
Percentage removal of NPP	24	35
Annual litterfall	2.71	2.33

3.2. Socio-economic conditions

The Mamlay watershed is one of the backward areas in Sikkim inspite of it adjoining the South District headquarters at Namchi. Socio-economic facilities are not sufficient in the watershed for a proper rural development. There was only one metalled road earlier passing through the watershed from the upper side, now another road is under construction bisecting the watershed in the low and mid hills. Administratively, there are 9 revenue blocks covering 34 villages in the watershed. The mean spacing of settlements (inter-village distance) in the watershed area is 1.01 km which is far below the national average of 2.69 km. Nearest neighbour analysis shows scattered settlement pattern (Rn = 1.19) and dispersion value of 54% also confirms it (Sharma *et al.*, 1992). There is complete electrification and drinking water supply in the villages. The nearest market for transactions, bank and credit services, government works and hospital services, is at Namchi. It takes about 3 to 4 hours of walk from some parts of the watershed to reach Namchi. Health services in the villages are provided by 4 dispensaries in the watershed. Education is the most important means to achieve rapid development, and education institutions are the most effective tools of rural transformation in such difficult terrain and backward areas. There are 7 pre-primary, 7 primary and 3 middle schools in the watershed which serve as basic educational institutions. The higher educational institutions such as intermediate and graduation are available in adjoining Namchi town. The absence of technical institutions in the area has resulted in the shortage of rural technicians and artisans.

About 10-15% of the community people are of high social status and remaining 30-40% medium and 45-60% of low social status. The economic status of about 54% of the population is high as a result of cultivation of cash crops, and the remaining 32% medium and 14% are of low status. The expenditure pattern shows that rural community spend 81% in grocery items, 14% in non-food items and 5% in other non-specified items. Therefore, most of the expenditure is on fooding and clothing. The socio-economic conditions of the watershed shows that the facilities are bare minimum and little opportunities of external market linkage. The farming has been subsistence except for large cardamom growers, and most of the basic day to day resources are collected by the villagers from the watershed itself. There has been minimum external inputs in the watershed except for rural electricity and drinking water supply.

3.3. Stress on resources

Livelihood in the watershed is primarily a natural resource dependent, and the integration of the resources with the socio-economic demands of the rural people indicate that the system was sustainable until recently. Rapid growth of human and livestock population and increasing demands on the resources have caused fast depletion and degradation of some of the resources. There is immense pressure on natural resources.

The population growth and fragmentation of farm families are the main causes of decrease on land holding size. In the process of fragmentation of farm families the pressure was laid on agricultural land for the construction of new houses, thereby decreasing the effective Class I category of cultivable land. Increase in the population has also shown signs of higher unemployment in the watershed. These unemployed people put lot more pressure on forest resources for cash incomes by collecting and selling fuelwood and non-timber products like medicinal plants and wild edibles. The heavy pressure on forest and changing pattern of land-use/cover systems caused increase in wastelands. Drying up of springs, scarcity in drinking water, high runoff in rains and high soil erosion are indication of stresses at the watershed level (Fig. 1). The fuel wood and timber extraction, collection of fodder, wild edible plants and medicinal plants have been immense from both the subtropical and temperate natural forests. These resources were available in plenty in the fringe areas of the forests earlier, but now the subtropical forest has almost vanished while most of the dense forests have been converted to open forests in temperate region (see Fig. 2).

3.4. Impact at watershed level

Ecological impacts are quite apparent in the watershed level. Utilization of natural resources and their integration with the socio-economic demands have revealed stresses on the resources as mentioned above or otherwise was in greater balance in the past. The stresses were not redressed and the resources were also not recuperated which has aggravated to cause distinct ecological impacts at the watershed level. Pronounced impacts are (a) reduced soil fertility, (b) decrease in agronomic yield of traditional crops, (c) high runoff, (d) increased soil erosion, (e) scarcity in drinking water, (f) occurrence of frequent landslides, (g) reduced availability of fuelwood, timber, fodder and other non-timber products, (h) increased health problems, and (i) climate change as observed by villagers (Fig. 1). The soil fertility has decreased for a number of reasons such as (a) transformation of forests to agricultural lands, (b) fragmentation of land holding size has left no scope of crop rotation and also forced farmers for intensive cultivation from fragile uplands, (c) practice of crop combination (orange-ginger) which are high volume and nutrient exhaustive, and (d) breakdown of traditional soil fertility maintenance practices such as addition of forest litter for mulching because these are not adequately available anymore. The consequences of reduced soil fertility have caused reduction in agronomic yield. The other impacts such as high runoff, soil erosion, landslides and scarcity in drinking water have links to the effects of conversion of the forest to agriculture land and also to farmers' not adopting the proper soil conservation methods. The resources have become limited specially in the subtropical forest as a result of over stress and crossing the carrying capacity limits of their utilization. In order to overcome some of these impacts a number of techonolgy pacakages were developed which shall be dealt in the later section of this article.

4. Linkages of upland farm household

Functioning of a household in an upland farming system depends on a number of resources which are linked to forest, agroforestry, agriculture, livestock and also to the market. A conceptual model of an upland household is provided in Fig. 3. This figure shows the linkages of different components and how an upland farm operates. An upland farm household in the Mamlay watershed has a family of 5 to 6 persons. Average agriculture land for a household is 0.87 ha with about 1.47 ha additional agroforestry land. Each farm household on an average could have access to 0.98 ha forest which is primarily a reserved one but utilized by villagers. The average livestock number per household is four (Fig. 3). Annual inputs per household in agriculture accounts to (a) about 23 days of bullock labour for ploughing per hectare, (b) human labour of 850-1250 mandays per year, (c) seed inputs of 17-438 kg/ha, (d) livestock manure to the amount of 2000 kg/yr, and (e) forest litter through animal bedding to the tune of 5000 kg/yr. The livestock rearing is supported by fodder from agriculture land (1200 to 2100 kg/ha), agroforestry system (1450 to 2500 kg/ha), and forest (5500 to 6500 kg/household/yr). The upland household depend on forest resources and gets farm returns such as (a) foodgrains in the range of 246-1957 kg/ha depending on the crops, (b) livestock products like milk (2000 l/yr), meat (40 kg/yr) and eggs (240-300 in a year), (c) fruits (5 to 10 kg/yr) and cash crops (spices like large cardamom 220 kg/ha in temperate and mandarin orange fruit 640 kg/ha in subtropical) agroforestry systems, (d) fuelwood (4000-6000 kg/yr) and timber (0.46 m^3/yr) from the forests (Fig. 3). Farmers sell their farm produce and expenditures are mainly made to meet additional food and non-food items.

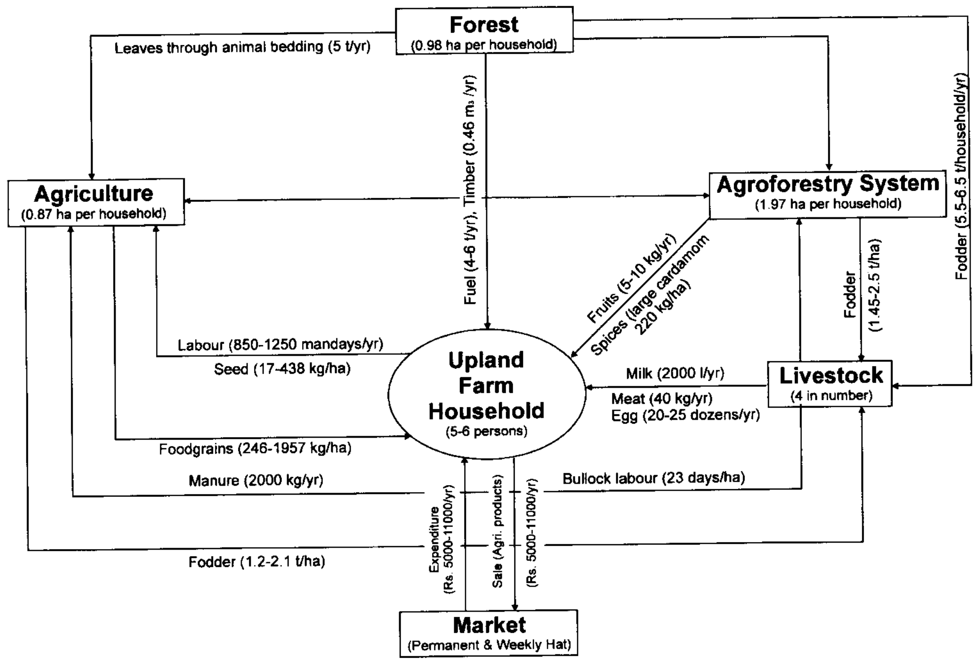

Figure 3. Linkages of an upland farm household with different resource components in the Mamlay watershed of the Sikkim Himalaya.

5. Perception and development priorities

Traditional upland farming system in the watershed has been sustainable in the past, but rapid growth of human and livestock population has put immense pressure on the natural resources. Therefore, actions on the development of the watershed on primary sector need to be channelised in such a way that traditional practices are not disrupted. The actions should strengthen the age old traditional practices by using ecologically sound technologies supported by integration of extension programmes of various departments for holistic development. One of the ways of not diverting much from the traditional practices is to consider farmers' opinion as an approach for development and their involvement in the programmes (Sundriyal *et al.*, 1994b). The other method is participatory development of a village action plan. Survey of development priorities was conducted amongst the farmers of the watershed and also with the officials of the development agencies using questionnaire method. Complete-linkage hierarchial cluster analysis for percentage similarity of priorities were developed separately for farmers and officials (Fig. 4).

Farmers revealed that agriculture, land terracing, horticulture extension, tree plantation, transportation and health facilities, water and electricity, and availability of loans can improve the living conditions in the villages. In answer to, how the farmers can contribute for the development, most of them expressed that they can assist in planting trees, making roads, terracing land and also support various develop-

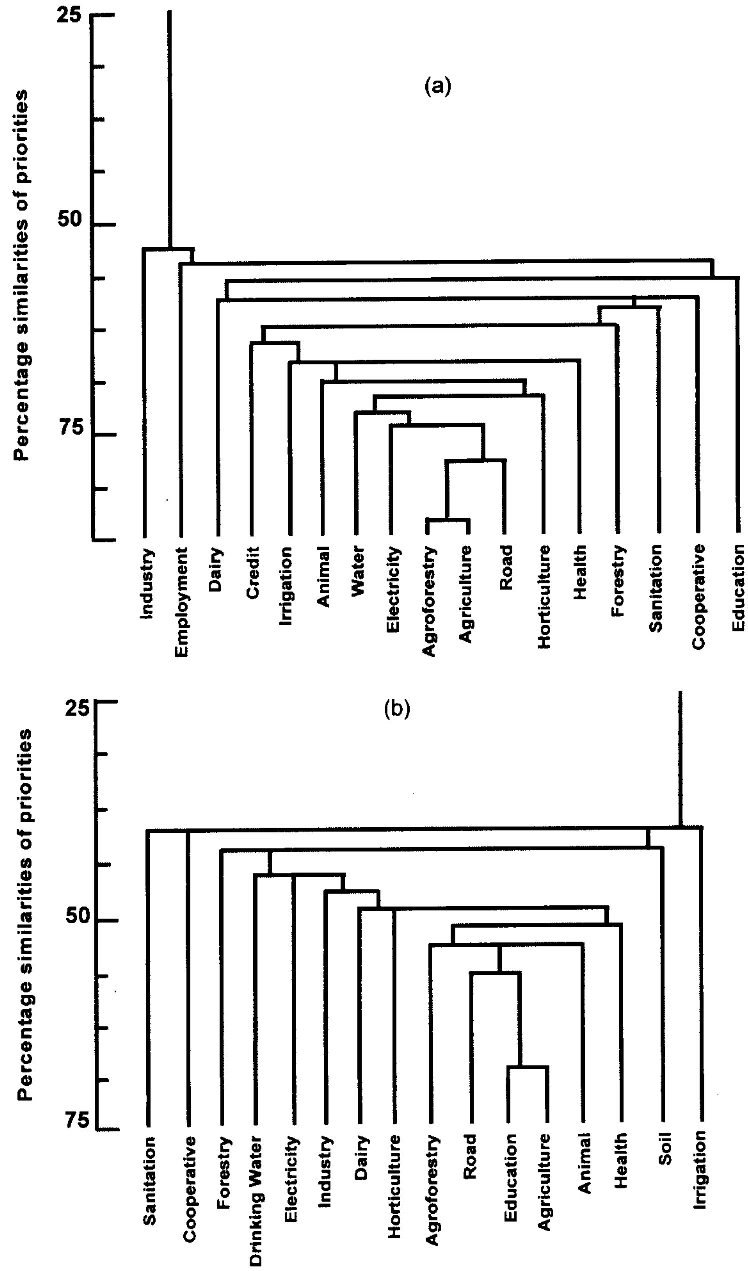

Figure 4. Complete-linkage hierarchical cluster analysis showing percentage similarity of priorities between pairs of 19 different development sectors raised by (a) farmers and (b) officials of different development institutions. The hierarchical structure shows priorities that are more similar to one another being tied together by a higher similarity percentage.

ment activities. In response to, which facilities they desire for themselves, 91% of the respondents spoke about strengthening agriculture by providing improved cereal seeds, cash crop materials, vegetable seeds, fertilizers and pesticides and extension programmes. About 82% of respondents were interested in strengthening fodder species for livestock rearing, 25% wished to terrace their land as soil conservation measure, and about 22% were interested in getting loans for purchasing better breed of animals. In response to facilities desired for their village, most of the respondents spoke to have a road connection to their villages with town at Namchi for easy access to sell their produce and procure essential items. Despite the facilities of water and electricity, villagers complain about irregular supply of both, and furthermore they want regular water supply in lean season. About 33% of the residents were interested to have basic health facilities especially maternity and child welfare centres in the villages, 6% came up for setting a cooperative milk collection centres in remote villages, 10% wanted off-season employment, and about 17% demanded support for poultry/piggery and setting of cottage industries in the villages.

Interrelationship between 17 important priorities raised by farmers were analysed through clustering and a dendrogram is constructed for showing cluster of priorities that were perceived as most similar to one another (Fig. 4). Major categories of development priorities are easily distinguished in the cluster. Priorities of agriculture (91%) and agroforestry (59%) are closely linked and they are further linked with road communication (55%), electricity (45%), drinking water supply (41%) etc. (Fig. 4). The dendrogram clearly shows the rank/order of need of different developmental priorities for addressing to make a comfortable living conditions in the villages of the Mamlay watershed.

A total of 14 departments that are engaged in the developmental activities, either in primary or secondary sectors, were interviewed for priorities. Out of 52 officials, 96% have given weightage on agriculture development through land terracing, promotion of cash crops, vegetable growing and use of improved seeds, strengthening of floriculture, horti-agriculture, agri-silviculture, farm-forestry, sericulture and piciculture. They also emphasize need for farmers training and extension programmes. About 50% feel that villagers must receive a primary level of education, 31% feel that there should be a proper network of roads, and 23% said that they must be provided with better health services. About 60% emphasized on the involvement of the villagers in development/extension programmes, while 33% felt that there should be proper technical education towards skill and talent development. Among the constraints, about 44% felt that illiteracy, mid dropouts of children from schools and least exposure of farmers, were highlighted. About 46% considered inaccessibility, topography and terrain of the hill areas as main constraint. Lack of infrastructure (21%), lack of funds (21%), lack of technical and scientific know-how (19%), high cost of input (10%), and lack of irrigation (10%) were other commonly cited constraints. Officials also observed (15%) about lack of enthusiasm among villagers, biotic pressure on forest, lack of post harvest technology and storage facilities, land tenure system and exploitation by middle man in marketing were also some of the constraints. Some of the officials (8%) felt that there is no coordination between various development agencies. The officials also suggested for a fresh, useful, farm based education/training to overcome various constraints of development in the villages. They also suggested on-farm crop improvement and ecological researches.

Interrelationship between 16 major development priorities that have been suggested by officials of government agencies are also presented by a dendrogram (Fig. 4). Priorities of agriculture development (46%) was highly ranked followed by education (26%), proper road net work (16%), agroforestry (13%) and animal husbandry (13%), etc., all of these are linked together in one cluster. Priorities and linkages among various development spheres given in the dendrogram are slightly different than those cited by the farmers.

6. Development options and conclusion

It has been observed in a watershed conceptual framework that balances between natural resources and socio-economic demands are disrupted in the Mamlay watershed. Immense pressures on resources have caused various ecological impacts at the watershed level. In order to mitigate these impacts, some scientific studies were made and technology packages were developed. We have seen that in the Mamlay watershed a household is the best level for implementing any development programmes. There is no traditions of community organization here. The upland farm communities depend on various resources as outlined earlier. These natural resources and settlement settings are governed by drainage and water availability, and the best functional unit to represent this is to follow a watershed approach. The natural resources and its dependency in the farming system shows an absolute watershed linkage. Therefore, in hills watershed should be taken as a macro unit for development and a household level for implementing and delivering inputs of development.

Development for the watershed was perceived on the basis of scientific studies on resources and farming systems, and priorities of the farmers and officials. Farm based development and recuperation of natural resources of the watershed turned out to be the core for development. Therefore agroforestry models, one each at temperate and subtropical sites, were developed for demonstration to the farmers. These agroforestry models were developed using native species for fuelwood, timber, fodder and wild edibles in marginal lands. Multipurpose plants for example *Thysanolena maxima* turned out to be an excellent species which provided cash return from infloresence by selling broom, high quality fodder in lean period and indirectly fetching income from livestock products, stem-sticks used as support to peas/beans and later used as fuel, and it worked as an excellent soil binder in the form of terrace raisers. Nitrogen fixing legume crop combination showed high promise in soil fertility maintenace. An experiment using three strains of *Azotobacter chroococcum* and two of *Azospirillum brasilense* as rhizosphere diazotrophs on local maize improvement showed enhancement of yield upto 115% over control and increased plant nitrogen and phosphorus concentrations. The association of nitrogen-fixing *Alnus nepalensis* in large cardamom agroforestry and *Albizia stipulata* in mandarin-orange agroforestry has been found to be highly beneficial in increasing the yield and nutrient balance in plant-soil systems. Cultivation of various improved varities were also tried and demonstrated. The water shortage was the main constraint of farming activities during lean period from January to May. Therefore, a perennial water source was tapped and stored in low-cost tanks. Such stored water were very useful and promoted farm activities even in dry spell. Biocomposting was tried and 26 different combinations were prepared based on the resources available in the farms. It has acted as an excellent supplement to traditional cow-dung compost. Selected forest tree species whose regeneration were almost lost in nature were raised in nursery by various techniques. In each of the agroforestry model a number of technology pacakages were made available and demonstrated. The farmers have their own specific requirements and many choices of technology pacakages were made available which may be useful to them in all or only a few as evident from their adoption. The agroforestry concept at a household was more workable. Fuelwood, fodder and timber resources dependency from the forest are reduced as a result of agroforestry strengthening. This has put much less pressure on forests allowing natural plant regeneration and regrowth. The forest has to be maintained dense with high biodiversity for hydroecological linkages that gurantees sustenance. Therefore, strong agroforestry development in upland farming system incorporating multiple resources and cash plants in terms of fruits, timber, fodder, fuel and crops will provide economic and ecological sustenance. The agroforestry, forest and other resources in an upland landscape is watershed driven.

Acknowledgement

Authors are grateful to the Director of the Insitute for providing facilities. Mr M.V.S. Manian is thanked for scanning and computer work on the manuscript.

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