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Hill agroforestry systems in south Sikkim, India

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Abstract. In the Mamlay watershed of south Sikkim, India, about 80% of the population depend on land for their livelihood. The agricultural land-use activity includes agroforestry, horticulture and animal husbandry besides growing crops in irrigated or unirrigated fields. Trees are maintained in the farms mainly for fodder and rarely for fuel purposes. Cropping system is characterised by cultivation of cereals and cash crops to ensure supply of food grains and returns for daily needs. This paper presents data on crop production and farm management aspects including the linkages among tree–crop–animal components of a hill agriculture system. Crop diversity is high and crop combinations are fixed and well tested. Unpalatable grasses are used for composting by mixing with cow dung to meet high demand for manure and thus exhibit efficient recycling of plant material. The system is at low input level, and is therefore adopted by even the poorest section of society. Limited infrastructure facilities, sloping terrain, inaccessibility to most agricultural zone, depletion of natural resources from forests, water scarcity during lean period and heavy rainfall during monsoon, and erosion are the main constraints which need to be improved through research using scientific means.

1. Introduction

Land-use systems in the Himalayan region of India comprise forest, agriculture, horticulture, agroforestry and animal husbandry. These components are interdependent and play a vital role in maintaining the economy of the region. Most of the farming systems are at the subsistence level [Fonzen and Oberholzer, 1984; Misra and Ramakrishnan, 1982; Nair, 1985; Ralhan et al., 1991; Shah, 1982; Sharma, 1991; Singh et al., 1984; Singh et al., 1989; Toky and Ramakrishnam, 1981] and have evolved over the years from trial and error by the farmers to meet the demands for food, fodder, fuelwood and timber. There are a number of little known crops which have good production potential but have received little attention [Gangwar and Ramakrishnan, 1989]. The upland farming systems differ from one area to another, and need to be extensively studied for developing management strategies for sustainable development. This paper is based on a detailed study of existing agroforestry systems in a watershed of the south district where the majority of population (80%) is engaged in agriculture. Aims of the study were to (i) prepare an inventory of the crops, trees and wild edible plants used and are growing in the watershed; (ii) analyse the range of inputs in the production of different kinds of crops; (iii) record fuel and fodder utilization; (iv) carry out chemical

analysis of some important fodder tree species; (v) analyse the production potential of different crops; (vi) study the annual income and expenditure, capital and marketing behaviour of the people in the watershed, and (vii) assess the system for its potential and research needs, based on the above findings.

2. Study area and methods

2.1. *Environmental setting of the study area*

Sikkim state has an area of 7096 km^2 (0.22% of the total country) and a population of 405505 (0.047% of total population of India) with a density of 57 persons/km^2. The State earns about 47% of its GDP from agriculture [Agriculture Census, 1980–1981]. Although a few reports on the agriculture systems of Sikhim are available [Awasthi and Prasad, 1987; Singh et al., 1989; Subba, 1984], quantitative information on the tree component and details on the structure and functioning of agricultural systems are lacking at a watershed level. Sikkim comes under zone II (viz. eastern Himalayan agro-climatic region) with Darjeeling, Arunachal Pradesh, Meghalaya, Nagaland and North Assam [Planning Commission, 1989]. The state is very rich with respect to its genetic diversity in both forest vegetation and agricultural crops; the state comprises more than 4000 species of flowering plants [Agriculture Census, 1980–1981]. Lower and middle hills are dominated with mixed broad-leaved evergreen-deciduous forests, whereas, at higher elevations conifer-rhododendron forests are present. Alpine meadows are common between 4000–5000 m above mean sea level (m.s.l.), beyond which is permanent snow. The prevalent land-use also varies with altitude (Table 1).

The study area (Mamlay watershed) is located in the south district of Sikkim (between 27°10′8″ to 27°14′16″ N and 88°19′53″ to 88°24′43″ E) having an area of 30.09 sq km. It has an elevational range from 300–2640 m above m.s.l. The watershed comprises 9 blocks covering 34 villages. The climate is monsoonic, and average rainfall varies from 1494 mm at 400 m to 2200 mm at 1900 m elevation, most of which occur during monsoon from June to September. The average maximum temperature during this season varies from 19–27 °C and the average minimum temperature from 14–20 °C. The humidity remains very high during this period (75%). Winter is cold particularly at higher elevations with occasional showers, extending from November to February, with a mean temperature varying from 3 °C at higher ridges to 10 °C at lower elevations. During December–January, frost is very common particularly at higher ridges. Summer, which is generally dry and warm, extends from March to May. The terrain is hilly with very steep slopes, the average angle being 30–40°. Two major forest types occur in the watershed [Sundriyal et al., 1994]; (i) sub-tropical, dominated by *Shorea robusta*, *Castanopsis indica*, *Castanopsis tribuloides* and *Schima wallichii*, and (ii)

Table 1. Vegetation zones, dominant species and landuse practice in the Sikkim Himalaya.

Elevation (m)	Climatic zone	Climax species	Shrub species	Grasses	Land-use
4500	Alpine	*Rhododendron, Pedicularis, Geum, Primula, Sorosis, Saussurea, Anemone, Corydalis, Silene, Potentilla, Androsace, Rheum, Geranium, Saxifraga, Meconopsis, Podophyllum*	*Rhododendron, Juniper, Meconopsis, Rubus, Rosa, Arundinaria*	Yak grass, Poa, *Agrostis, Calamogrostis, Festuca, Kobressia,* Irish grass	Timberline – upper limit of tree growth
3800	Sub-alpine	*Abies webbiana, Larix griffithii, Tsuga brunoniana, Picea smithiana, Rhododendron arboreum, R. hodgsonii, R. cinnabarium, Acer, Betula, Juniperus*	*Meconopsis, Astragalus, Cotoneaster, Arundinaria*	*Carex, Trisetum, Arundinella, Eragrostis*	Upper limit of successful potato growing
3000	Cool-temperate	*Quercus pachyphylla, Magnolia cambellii, Tsuga, Betula, Acer pectinatum, Michelia, Rhododendron, Arundineria*	*Rosa sericea, Princepia utilis*	*Eragrostis, Juncus, Setaria, Elusine, Chrysopogon, Pogonanthum*	Upper limit of successful maize growing
2700	Temperate	*Quercus lamellosa, Castanopsis tribuloides, Machilus lanuginosa, Symingtonia, Betula, Acer, Alcimandra, Alnus nepalensis, Macranga, Juglens*	*Leucosceptrum, Rubus, Smilex, Cephalostichium Berberis*	*Imperata, Arundinella, Chrysopogon, Avena, Elusine, Setaria, Echinocloa, Triopogon, Panicum, Paspalidium*	Upper limit of successful large cardamom growing
2000	Warm-temperate	*Machilus, Quercus lamellosa, Engalhardtia, Toona ciliata, Semecarpus, Eurya, Prunus, Castanopsis, Jambosa formosa, Pheobe attenuata, Symplocos theifolia, Symingtonia*	*Eurya, Rubus, Leucosceptrum, Oxyspora, Maesa, Osbekia, Datura, Cephalostacutum*		Upper limit of successful rice cultivation
1000	Sub-tropical	*Shorea robusta, Terminalia, Castanopsis indica, Schima wallichii, Duabanga, Callicarpa, Dendrocalamus hamiltonii, Microstegium, Clerodendron, Ailanthes, Tetrameles*	*Alstonia, Maesa, Bauhinia, Lagerstromoea, Spatholobus*	*Eragrostis, Setaria, Dichanthium, Cynodon Pogonatherum, Cyperus Digitaria, Saccharum, Arundinella*	Double cropping system

temperate forest, dominated by *Quercus lamellosa*, *Castanopsis tribuloides*, *Symingtonia populnea*, *Alnus nepalensis*, *Juglans regia*, *Eurya acuminata*, *Symplocos theifolia*, *Quercus lineata*, *Beilschemiedia roxburghiana* and *Leucosceptrum canum*. A total of 113 tree species have been recorded from both forests [Sharma et al., 1992].

The agricultural zone ranges between 400 m to 1900 m with a few patches of forests in between. The soils are loamy in texture with varying amounts of coarse fractions and are therefore susceptible to erosion. Soil depths vary from area to area but a depth of 60–90 cm is common. Geologically the watershed is a part of the Rangit tectonic window within the central crystalline zone of Sikkim Himalaya. The upper elevations (above 1500 m) shows a dominance of green purple slates, phyllite and quartzites, the mid elevation (500–1500 m) which forms the major agricultural zone, is dominated with dolomite, coal, slate, phyllite and quartzite, and the lower hills are composed of sandstones, shales and conglomerates [Sharma et al., 1992].

The total population of the watershed is 4162 with an annual growth rate of 10%. The density is 1.18 person/ha but the agricultural density is very high (up to 8 persons/ha). Average size of a family is 6, made up of 2 adults and 4 children. About 62% of the total area of watershed are for agriculture, 12% forest, 18% cultivable waste-land, 5% pasture and 3% barren land. There was an increase in agricultural land by about 13% in 1991–92 over 1951–52. Forest area although reduced by just 1.4%, the density of the trees decreased significantly within this period [Sharma et al., 1992]. About 31% of the land holdings are marginal (land < 1 ha), 25% small (land 1–2 ha), 41% medium (land 2–10 ha) and 3% large holdings (land > 10 ha). The houses are commonly made of bamboos, timber and thatching grass (*Imperata cylindrica*). Unlike to the central Himalaya [Shah, 1982; Singh et al., 1984], the settlements are of dispersed type and lack a community organization. The watershed represents the majority of human habitation zones of the Sikkim Himalaya.

2.2. *Methods*

All the 34 villages of the watershed were surveyed for records on crops cultivated and cropping patterns. A complete inventory was made for recording all inputs and outputs in the upland farming systems [Nair, 1987]. The inputs included (i) labour in terms of bullock-days and man-days (ii) fertilizers in terms of quantities of manure and chemicals (if any) and (iii) seeds. The outputs included (i) yield of edible crop products and (ii) yield of crop by-products. The amount of seed/rhizome sown in the field, as well as economic yields were based on 12–17 observations for different crops at different locations in the watershed taking into account the wide range of elevation. Estimation of the actual amount of food and fuel wood consumed was carried out on the basis of regular observations in the villages. The source and supply of fodder for animals was quantified as contribution of agricultural by-products, forest and tree fodder from agroforestry by estimation in the villages and by measuring the daily ration of food concentrates given to the animals by each household. About 20 head loads, each of fodder, bedding leaves and compost were weighed in different villages in different months and average values are presented. Tree fodder and grasses were brought to the laboratory and oven dried for measurement of constant weight. Nutrient analyses of matured leaves of some important fodder trees were made [Allen, 1989; Piper, 1950] as cattle are mostly fed with such leaves. Use of firewood by human population was also quantified under different categories viz. firewood for cooking, water heating, house warming, local wine/beer preparation, animal food preparation and festivals. Villagers were asked to burn a known weight of fire wood and observations were taken for time and quantity of fire wood consumed for the aforementioned categories. Villagers reported average agronomic yield, fodder and firewood weights on back load basis ('bhari') each being 40, 25–30 and 35–40 kg, respectively.

3. Structure of the system

3.1. *Cropping system*

In south district, 11.6% of the cropped area is under irrigation although it is only 1% in the Mamlay watershed. The cropping system in the Mamlay watershed can be categorized into four major groups such as: (a) maize-pulse combination, and ginger in sub-tropics, (b) maize-potato in temperate, (c) rice in irrigated fields, and (d) large cardamom under tree cover (Fig. 1). All cropping systems except that of rice are a mixture of trees, shrubs and herbs. The intensity of cropping varies from farm to farm and from household to household due to differences in socioeconomic conditions, particularly inputs and products, dependence on land and tenurial system etc. Despite a great diversity in crops, selection of crop combinations is fixed and the crop rotation is same as adopted by farmers from the experiences of their past generations with the main criterion being to meet the demand of food, fodder, cash, fuel and timber. Cattle rearing is a common practice.

The cropping systems are different in irrigated ('khet') and unirrigated ('bari') fields. Rice is grown on irrigated fields as a mono crop, sometimes the bunds of rice fields carry soybean and pulses. After harvest of the rice, fields are left fallow. Maize is most common crop, grown at all altitudes and in rainfed conditions. Generally pulses are grown in a mixed or relay cropping sequence with maize. Crop combination, sowing and harvesting time vary from sub-tropics to temperate conditions of the watershed (Fig. 1).

3.2. *Crop and tree components*

Maize and rice are the main cereals grown in the watershed, and large cardamom, ginger, orange and potato are important cash crops (Table 2).

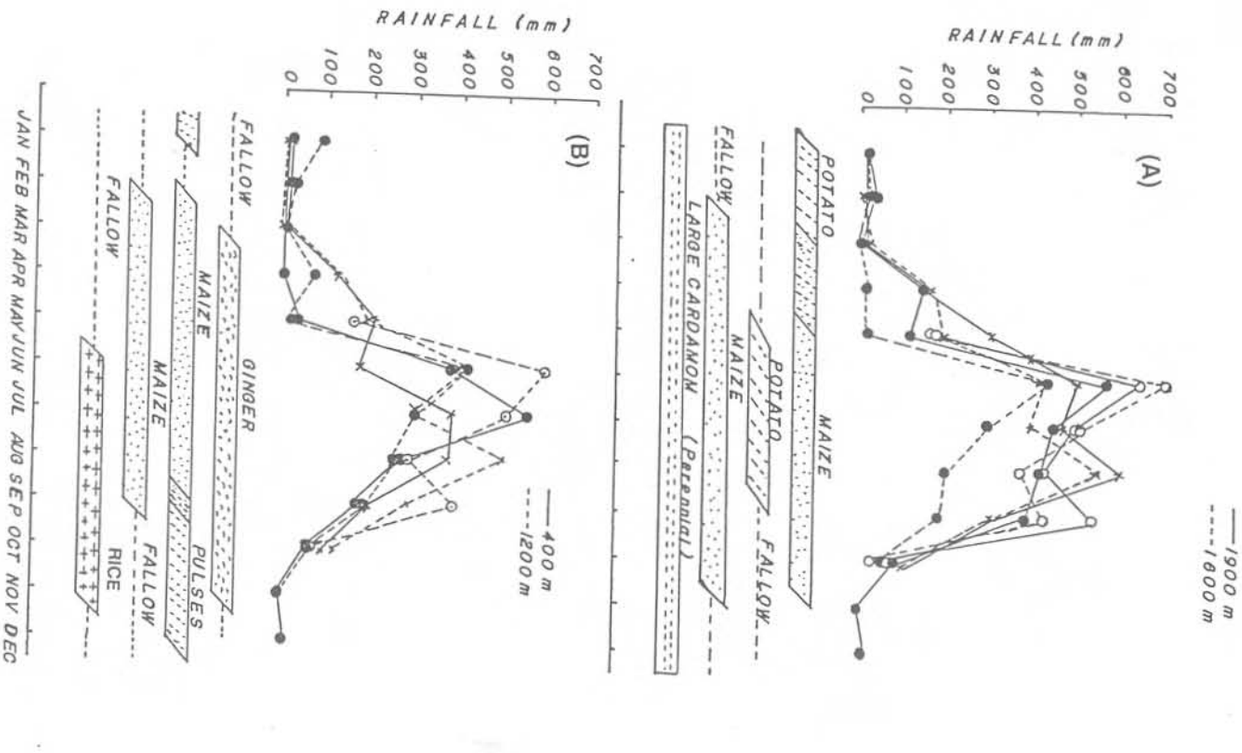

Fig. 1. Cropping pattern, and rainfall at different elevations in the year 1991 (–○–), 1992 (–●–) and 1993 (–×–) at temperate (A) and sub-tropical (B) zones of the Mamlay watershed.

Table 2. Inventory of important crops and fruit trees in the agroforestry systems in the Mamlay watershed of south Sikkim.

Crops (local names)	Botanical name	Growing elevation range (m)	Sowing-harvesting time	Agronomic yield (kg/ha)	Average market price (Rs/kg)
Food grains:					
Maize (*Makai*)	*Zea mays*	300–1900	Feb/Mar–Sep/Oct	1957	4.50
Rice (*Dhan*)	*Oryza sativa*	< 800	Jun/Aug–Oct/Nov	815	8.50
Fingermillet (*Kodo*)	*Eleusine coracana*	1000–1300	May/Jul–Oct/Dec	780	4.00
Wheat (*Ghau*)	*Triticum aestivum*	1000–1500	Nov–Apr	1025	5.00
Barley (*Jau*)	*Hordeum vulgare*	1200–1900	Oct–May	1413	3.25
Buckwheat (*Phaphar*)	*Fagopyrum esculentum*	900–1900	Oct–May	690	3.60
Food crops other than food grain:					
Pulses and Beans:					
Blackgram (*Kalodal*)	*Phaseolus mungo*	700–1300	Oct–Jan/Feb	562	8.00
Horsegram (*Gahat*)	*Dolichos biflorus*	500–1000	Oct–Jan/Feb	430	5.00
Field peas (*Matar*)	*Pisum sativum* var. *hartense*	300–1900	a) Sep/Oct–Feb b) Feb/Mar–May/Jun	611	5.00
Soyabean (*Bhatmas*)	*Glycine soja*	600–1200	May/Jun–Oct/Nov	960	8.00
Bean (*Gheu simi*)	*Phaseolus* sp.	800–1400	Apr/May–Jul/Sep	246	Pod – 4.75 Grain – 9.00
Bean (*Singtame simi*)	*Phaseolus* sp.	800–1200	Apr/May–Jul/Sep	435	14.00
Bean (*Masyam dal*)	*Phaseolus* sp.	600–1100	Jul/Aug–Jan/Feb	518	7.00
Bean (*Mantola simi*)	*Phaseolus* sp.	700–1150	Jul/Aug–Jan/Feb	579	12.00
Vegetables:					
Potato (*Alu*)	*Solanum tuberosum*	> 1200	a) Apr/Mar–Aug/Sep b) Oct/Nov–Mar c) Dec/Jan–Apr/May	5190	4.50
Sweet potato (*Sakarkanda*)	*Ipomaea batatus*	800–1200	Aug–Dec	3–6[a]	4.50
Cassava (*Simaltarul*)	*Manihot esculenta*	< 1200	Feb–Dec/Jan	5–9[a]	4.75
Taro (*Pindalu*)	*Colocasia antiquorum*	500–1900	Feb/Mar–Sep/Oct	6–12[a]	3.00
Chayote (*Iskus*)	*Sechium edule*	500–1900	Jan/Feb–Jun/Oct	Fruit – 50[a] Tuber – 7[a]	1.50 3.50
Dioscorea (*Ghartarul*)	*Dioscorea* sp.	900–1300	–Dec/Jan	Fruit – 15[a] Tuber – 8[a]	2.50 4.50

Table 2. Continued.

Crops (local names)	Botanical name	Growing elevation range (m)	Sowing-harvesting time	Agronomic yield (kg/ha)	Average market price (Rs/kg)
Tomato (*Rambera*)	*Lycopersicum esculentum*	300–1900	Feb/Mar–Jul/Sep	2–4[a]	7.50
Radish (*Mula*)	*Raphanus sativus*	> 1400	a) Sep/Oct–Jan b) Nov/Dec–Feb/Mar	965	3.50
Pumpkin (*Pharsee*)	*Cucurbita moschata*	500–1900	Mar/Apr–Jul/Nov	2152	3.00
Mustard leaves (*Rayosag*)	*Brassica gentia* var. *rugosa*	800–1900	Oct/Nov–Dec/Mar	210	2.00[#]
Cauliflower (*Phulkopi*)	*Brassica oleracea* var. *botrytis*	300–1900	Aug/Sep–Nov/Jan	5529	9.00
Cabbage (*Bandakopi*)	*Brassica oleracea* var. capitata	300–1900	Aug/Sep–Nov/Jan	6356	6.00
Jack fruit (*Kattar*)	*Artocarpus heterophyllus*	300–1900	–Apr/Jun	40–100[a]	7.00
Lady's finger (*Bhindi*)	*Avilmoschus esculentus*	300–1900	Feb/Mar–Oct/Dec	3240	6.00
Gourd (*Lauka*)	*Lagenaria esculentum*	300–1900	Apr–Jul/Aug	20–30[a]	3.00
Gourd (*Ghiraula*)	*Luffa cylindrica*	300–1900	Feb/Apr–Aug/Oct	10–20[a]	5.00
Carrot (*Gazar*)	*Daucus carrota*	300–1900	Aug/Oct–Feb/Mar	665	10.00
Bittergourd (*Karela*)	*Momordica charantia*	500–1900	Apr/May–Sep/Oct	6–10[a]	5.00
Wild bittergourd (*Bankarela*)	*Momordica cochinchinensis*	> 1000	–Jul/Oct	5–10[a]	4.00
(*Simrayo*)	*Nasturtium officinale*	300–1900	–Jul/Aug	220	4.00
Cucumber (*Kankra*)	*Cucumis sativa*	800–1900	Apr–Jul/Oct	8–12[a]	7.00
Bringal (*Baigun*)	*Solanum lycopersicum*	300–1900	Feb/Jun–Oct/Dec	215	5.00
Siyuchana (*Majhibora*)	*Vigna sinensis*	< 1500	Jul–Sep/Oct	415	6.00
Turnip	*Raphanus repa*	< 900	–Sep/Oct	805	6.00
Onion (*Piyaj*)	*Allium cepa*	300–1900	Jan/Feb–May/Jun	6425	Shoot – 2.00[#] Bulbs – 4.00
Spices:					
Ginger (*Aduwa*)	*Zingiber officinale*	< 1250	Mar/Apr–Nov/Dec	3745	5.00
Large cardamom (*Elainchi*)	*Amomum subulatum*	> 1200	–Aug/Nov	220	67.50
Turmeric (*Hardi*)	*Curcuma longa*	< 1000	Feb/Mar–Nov/Dec	510	11.50
Garlic (*Lahsun*)	*Allium sativum*	300–1900	Aug/Sep–May/Jun	840	20.00
Capsicum (*Khorsani*)	*Capsicum* sp.	300–1900	Mar/May–Jun/Oct	215	20.00

Table 2. Continued.

Crops (local names)	Botanical name	Growing elevation range (m)	Sowing-harvesting time	Agronomic yield (kg/ha)	Average market price (Rs/kg)
Fruit:					
Orange (*Suntala*)	*Citrus reticulata*	800–1300	–Oct/Jan	20–25[a]	6.00*
Guava (*Ambak*)	*Psidium guajava*	< 1200	–Oct/Jan	5–7[a]	5.50
Banana (*Kela*)	*Musa* sp.	300–1900	–Throughout the year	9–18[a]	6.00*
Papaya (*Mewa*)	*Carica papaya*	< 800	–Apr/Jun	32[a]	6.00
Limes & Lemon (*Kagji Nimboo*)	*Citrus* sp.	< 900	–Throughout the year	10–30[a]	11.00
Peach (*Aru*)	*Prunus persica*	1000–1900	–Aug/Sep	20[a]	8.00
Pear (*Nashpati*)	*Pyrus pashia*	700–1500	–Aug/Sep	26[a]	4.75
Mango (*Chuche Anp*)	*Mangifera sylvatica*	< 1200	–May/Jul	400[a]	8.00
Pomegranate (*Darim*)	*Punica granatum*	< 1400	–Oct/Nov	10–15[a]	2.00[#]
Plum	*Prunus domestica*	< 1500	–Oct/Nov	15–25[a]	6.00
Trees:[b]					
Siris	*Albizia odoratissima*	< 1200			
Utish	*Alnus nepalensis*	> 1100			
Koirala	*Bauhinia variegata*	< 800			
Chuletro	*Brassaiopsis mitis*	800–1900			
Barkunlay	*Casearia glomerata*	< 1000			
Amala	*Emblica officinalis*	< 1000			
Phaledo	*Erythrina stricta*	< 1000			
Nebara	*Ficus roxburghii*	> 500			
Syalphusray	*Grewia vestita*	< 800			
Malata	*Macaranga pustulata*	800–1700			
Gineri	*Premna bengalensis*	< 800			
Chilaunay	*Schima wallichii*	< 1300			
Lapsi	*Spondias axillaris*	< 1200			
Pipli	*Symingtonia populnea*	> 1700			

[a] kg/plant; * per dozen; [#] per bundle (of about 200 g) or per fruit.
[b] Tree species mentioned in Table 3 are not included in this list to avoid repetition.

Farmers grow at least one of these cash crops in addition to the cultivation of cereals and pulses. Every farm has a good number of trees especially for fodder and some for timber purposes. Leguminous nitrogen-fixing *Albizia* is planted in sub-tropical condition, while another nitrogen-fixing actinorhizal species *Alnus nepalensis* is extensively planted as a shade tree over large cardamom plantation. *Alnus* is known to fix 29 to 117 kg nitrogen/ha [Sharma and Ambasht, 1988]. Generally each farm family consists at least 18–25 trees (Fig. 2). *Litsaea polyantha* and *Ficus hookerii* are the most common fodder trees. *Ficus roxburghii, Ficus nemoralis, Saurauia napaulensis, Ficus benjamina* (all trees) and *Thysanolaena maxima* (broom grass) are other common fodder species. *Celtis tetrandra, Grewia vestita, Bridelia retusa, Vitex heterophylla, Ficus hirta, Bauhinia purpurea* and *Ficus saemocarpa* are also used as fodder trees but their density is very low.

At least eight varieties of pulses and 40 types of vegetables are grown in the Mamlay watershed (Table 2). Large cardamom shows good production (200–400 kg/ha) at all slopes except south facing slopes. Cultivation of potato at higher elevations and ginger at middle and lower altitudes is becoming popular. Erosion is the main problem of the watershed and a few families use *Thysanolaena maxima* and rarely bamboos on the margins of sloping land to check soil erosion.

Oranges, bananas and guavas are common fruit sold in the market. Orange orchards are common in between the 800–1300 m elevation range. These orchards are established for commercial purposes. The orange orchards are also used for cultivation of maize, pulses and ginger. Peaches, pears, walnut, mango (*Mangifera sylvatica*), chiuri (*Bassia butyracea*) fruit are mainly used

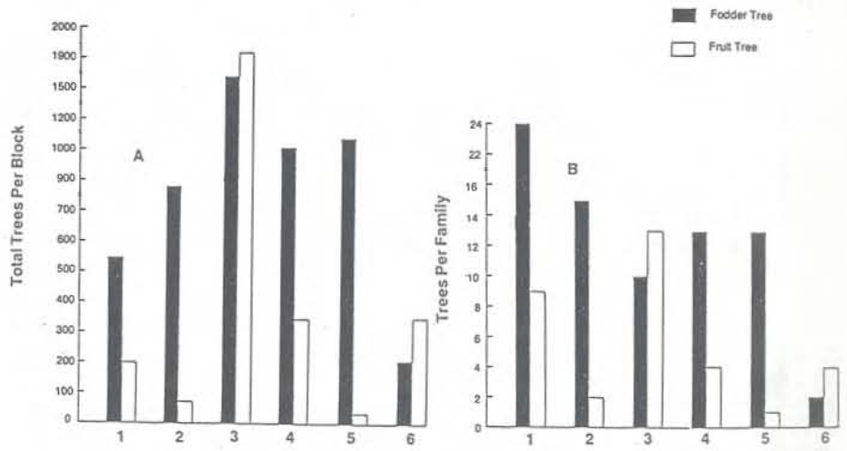

Fig. 2. Total number of trees per block and trees per household in the Mamlay watershed of south Sikkim (symbols: Blocks – (1) Pazer, (2) Chimchey, (3) Mamlay, (4) Jaubari, (5) Damthang, (6) Pabong.

for family consumption, although the surplus is marketed (Table 2). A study revealed that productivity of crops is in general independent of elevation (or different climatic conditions) and it depends mainly on the range of inputs as well as land type, which vary from farm to farm.

3.3. *Mixed farming and income*

Almost all families possess a few livestock in their households. Livestock distribution per household is 4 consisting of cattle, pig, and goat. A few poultry birds are also maintained by each family. Villagers usually own a cow for milk, oxen for ploughing, pig and goat for meat and chicken for egg and meat. The majority of livestock are of local breed.

Fodder is collected mainly from the forest land, margin of the fields and cultivable wasteland. Besides, crop residues are also used to meet daily requirement of fodder. Stall feeding, usually twice in a day, is a mixture of green grasses, green leafy materials, grains and straw. In addition, concentrated mixture of roughage/oil cakes ('peena') is given to the milking animals, and the mixture is cooked with grains (mainly maize), salt and water. Oxen are given 'peena' during ploughing season only. Generally one head of cattle is fed by about half kg of 'peena' per day, which is purchased @ Rs 5.00 per kg. One adult animal consumes about 40 kg of salt annually. It takes 3–4 hours per day on an average for a person to collect fodder from forests and the quantity of collection depends on the numbers of cattle per farm-family. About 60–75% of the fodder requirement are met from forests and the rest from agricultural lands. One head load consists of about 25–30 kg fresh weight (7–10 kg dry weight) of fodder. Generally one animal head (cattle) is given one head load in a day. Most of the fodder trees on agricultural fields kept as fodder banks to feed cattle during lean period (December to February). Rice straw is also stored for lean periods. Stall feeding of animals is the common practice but due to fragmentation of farm-families and increase in cattle population, grazing is being adopted by some families.

Data on the annual income in the 6 blocks of the same watershed revealed that about 54% of the households are earning above Rs 1500 per annum, 32% between Rs 500–1500 and 14% below Rs 500 per annum. There are some households, particularly in the Jaubari block, earning an income of Rs 10000 to 100000 per annum. Such families have large cardamom farms. Study on household annual expenditure on different items showed that 77 to 86% of the expenditure is on food items and the rest 14 to 23% is on non-food items such as clothing, religious functions etc. Expenditure on food items such as rice and cereals is the highest followed by oil, sugar, spices and tea. Besides, expenses on tobacco, cigarette and local wine ('ruksi') are quite significant. A few poor families also collect wild edible plant parts from forest and other areas and sell them in weekly market at different times of the year (Table 3).

Table 3. Some important wild edible plants available in the weekly market 'hat' at Namchi, south Sikkim.

S. no.	Plant species	Local name	Plant part used	Time of availabilty	Market price (Rs.)	Remarks
1.	*Agaricus* sp.	*Chyau*	Fruiting body	Jun–Sep	10–20.00*	a
2.	*Bassia butyracea*	*Chiuri*	Fruit	Jun–Jul	3.00*	b, c
3.	*Castanopsis tribuloides*	*Katus*	Fruit (nut)	Feb–Apr	40.00*	b, d
4.	*Cinnamomum* sp.	*Sinkauli*	Stem bark	Year round	30.00*	e
5.	*Dendrocalamus hamiltonii*	*Bamboo*	New shoots	Jun–Oct	12.00*	f
6.	*Dioscorea* sp.	*Bantarul*	Rootstock	Jan–Feb	5.00*	g
7.	*Diplazium* sp.	*Ningro*	Tender shoot	Jul–Aug	15–20.00*	h
8.	*Elaeocarpus lancaefolius*	*Bhadrasay*	Fruit	Apr–Jun	10–20.00*	b
9.	*Emblica officinalis*	*Amala*	Fruit	Oct–Jan	4.00*	b, i
10.	*Ficus benjamina*	*Kabra*	Tender shoot	Feb–Mar	8–10.00*	j
11.	*Heracleum wallichii*	*Chimfing*	Fruit	Jul–Aug	10.00'	i
12.	*Juglans regia*	*Okhar*	Fruit	Sep–Nov	20.00#	b
13.	*Machilus edulis*	*Pomsee*	Fruit	Jan–Feb	10.00*	b
14.	*Nasturtium officinale*	*Simrayo*	Vegetative shoot	Nov–Jan	4.00''	h
15.	*Rumex nepalensis*	*Halhale*	Shoot tip	Year round	10.00*	k, l
16.	*Spondias axillaris*	*Lapsi*	Fruit	Oct–Nov	4.00*	b, i
17.	*Swertia chirata*	*Chireta*	Vegetative	May–Oct	10.00*	k, l
18.	*Tamarindus indica*	*Tittri*	Fruits	Feb–Mar	5.00*	i, k, l
19.	*Terminalia belerica*	*Barra*	Fruits	Year round	20.00*	k, l
20.	*Terminalia chebula*	*Harra*	Fruit	Feb–Mar	10.00*	k, l
21.	*Urtica dioica*	*Sisnoo*	Shoot tip	Feb–Mar	5.00''	h
22.	*Verginia* sp.	*Pakhanbet*	Shoot/root	Year round	35.00*	k, l
23.	*Viscum album*	*Harchur*	Vegetative part	Year round	5.00*	k, l

* per kg, # per 100 units, ' per 50 g, '' per 100 g.
a – Fruiting body eaten as vegetable; b – fruit are eaten; c – seeds made into butter; d – fruit are roasted and eaten; e – spices, sold dried; f – vegetable (boiled, raw or fermented); g – rootstock (sold raw or boiled); h – tender shoots as vegetables; i – made into pickles; j – shoot bud used for pickles; k – sold dried; l – medicinal.

3.4. *Nutrient composition of fodder trees*

Eighteen important fodder trees present in the watershed were selected for nutrient analysis. *Saurauia napaulensis* contained the highest chlorophyll content. *Ficus* spp., *Bauhinia purpurea* and *Litsea polyantha* showed lower amount of cellulose and lignin content in their leaves and were therefore preferred. These species also had a high protein content. In contrast, *Antidesma diandrum, Acer pectinata, Stereospermum suaveolens* and *Bassia butyracea* contained higher cellulose and lignin and were therefore least preferred for fodder (Table 4).

4. Interaction between components

The close association between the components of system results in interaction. There is direct interaction between tree crop and field crop for soil conservation, particularly on steep farms. Besides, incidence of direct interaction is also evident between the trees (for fodder), animals (farm manure) and crops. At certain locations a variety of agricultural and horticultural crops presents a multi-tier canopy configuration. In orange orchards the major portion of the upper canopy goes for orange followed by maize in the middle storey and ginger, beans, vegetables and other herbaceous crops in the lower storey. Maize cobs are harvested and their stems are left as such and used as props for beans and pulses. After the harvest of the beans and pulses, all crop residues are burnt in the fields for immediate release of nutrients/ash. In large cardamom fields, *Alnus nepalensis* and other trees are used as shade trees. Trees protect large cardamom from direct sunlight, check evapotranspiration and protect from the direct downpour of rain on cardamom. Bamboos, besides its various uses in daily chores, are used for house construction and thatching purposes by poor farmers.

Generally unpalatable grasses are cut and used for cattle bedding (litter) in rainy periods (June–September) while in winter (October–February) dry leaves are used as bedding material. One head load of 15–20 kg is used for 2 cattle for 3 days. Such litter is composted to meet high demand for manure in the agricultural fields. Farmers demand better varieties of cash crops. For example, potato growers preferred red instead of white variety of potato due to the former's high production, better taste and greater market value.

5. System functioning

5.1. *Labour utilization and inputs*

Yearly labour input per household varied from 850 to 1200 man-days. This includes man-days for agriculture (350–500), animal (210–300), fuel wood

Table 4. Leaf characteristics and nutrient composition of some common agroforestry tree species of the Mamlay watershed in south Sikkim (all calculations are based on dry weight basis) (after Sharma et al., 1992).

Species	Local name	Leaf moisture (%)	Mean per leaf area (cm^2)	Total chlorophyll (mg g^{-1})	Ash	Cellulose	Lignin	Phosphorus	Nitrogen	Protein*
					%					
Acer pectinata	*Kapase*	56.66	209.90	1.48	0.376	40.15	47.30	0.104	2.30	14.37
Antidesma diandrum	*Archal*	61.90	68.50	0.69	0.396	51.92	38.36	0.059	1.30	8.12
Bassia butyracea	*Chiuri*	47.05	266.80	0.43	0.352	39.72	34.86	0.050	1.46	9.12
Bauhinia purpurea	*Tanki*	62.65	204.44	0.43	0.273	7.69	28.54	0.109	2.80	17.50
Celtis tetrandra	*Khari*	20.00	40.75	0.39	0.344	18.65	23.84	0.026	2.26	14.12
Engelhardtia spicata	*Mahwa*	50.00	81.60	1.16	0.249	22.82	16.01	0.028	1.80	11.25
Ficus clavata	*Khaneu lutey*	60.00	73.66	1.19	0.285	11.85	22.88	0.028	1.48	9.25
Ficus hirta	*Khasrey*	76.36	858.75	1.62	0.230	14.88	12.11	0.034	2.52	15.75
Ficus hookerii	*Nebaro*	58.33	70.80*	0.84	0.226	11.82	11.38	0.224	3.24	20.25
Ficus nemoralis	*Khaneu*	42.85	67.60	0.98	0.205	22.82	12.98	0.205	2.18	13.62
Ficus saemocarpa	*Bar*	57.89	75.00	1.74	0.157	8.65	9.00	0.080	0.46	2.87
Ficus sp.	*Kathebar*	65.11	123.70	1.40	0.136	8.57	4.61	0.126	1.89	11.81
Litseea polyantha	*Kutmero*	56.00	109.10	0.79	0.185	12.57	7.14	0.016	2.41	15.06
Ostodes peniculatus	*Baipari*	60.00	165.90	0.83	0.240	9.00	15.22	0.191	1.48	9.25
Psidium guajava	*Ambak*	47.82	54.66	0.61	0.248	10.47	19.35	0.067	2.00	12.50
Saurauia nepaulensis	*Gugun*	64.28	247.20	1.92	0.187	28.68	10.06	0.040	1.52	9.50
Stereospermum suaveolans	*Parari*	55.21	54.25	1.50	0.335	40.72	34.36	0.056	1.79	11.18
Vitex heterophylla	*Panchpate*	44.11	40.64	0.92	0.203	13.83	7.27	0.166	1.16	7.25

* Protein % = Nitrogen (%) × 6.25. This is based on the assumption that plant proteins contain 16% nitrogen.
* Showed great variation in leaf sizes, therefore inspite of large odd leaves the average value is low.

collection (245–300) and other works (45–100). In comparison to mono-cropping in paddy fields (225 man-days/ha), mixed and other croppings imply high labour (up to 500 man-days/ha). Besides human labour, various other inputs are also required in the farms (Table 5). A common practice of cooperative (mutually sharing of labour) farming is visualized among the neighbouring families. Generally all hard labour works including ploughing of the fields and fuel collection are done by men. However, labour on fodder collection and harvesting of crops is equally shared by women and men. Due to out migration of some land owners for services and business in the towns of the state, a tenancy status of the land holding is also seen which is observed mostly in marginal group of farmers as well as labourers from Nepal. There are several terms of tenancy but the common practice is to pay the owner in case or kind or both. This is sometimes fixed and sometimes a proportionate share (one-fourth) of the produce is agreed upon. During winter when work in the farms is least available, some men look for off-farm jobs in the market, road side or in house construction. About 4% of the households earn money from other services (tailoring or carpentry, etc.).

Farmers generally store seeds of cereals and vegetables. Propagating rhizomes, tubers of ginger, potato etc. are stored as well as purchased from the market. Sometimes government agencies also provide seeds, pesticides, insecticides, etc. Chemical fertilizers are applied by a small fraction of the farmers who can afford to buy them from the market. Application of pesticides/insecticides is negligible though sometimes state government distribute them free of charge.

Table 5. Various inputs to some important crops in the Mamlay watershed.

Crops	Botanical name	Inputs				
		Human labour (Man-days per ha)	Bullock labour (Bullock-days per ha)	Seed (kg/ha)	Farm manure (kg/ha)	Fertilizer (kg/ha)
Maize	*Zea mays*	120	18	30	5500	80
Ginger	*Zingiber officinale*	450	34	3500*	19000	–
Rice	*Oryza sativa*	225	52	45	–	–
Potato	*Solanum tuberosum*	164	35	1000*	14000	–
Butter bean	*Phaseolus* sp.	60	–	17	–	–
Singtame simi	*Phaseolus* sp.	52	–	26	–	–
Nepali simi	*Phaseolus* sp.	50	–	25	–	–
Masium dal	*Phaseolus* sp.	20	–	35	–	–
Kalodal	*Phaseolus mungo*	43	4	26	–	–

* Presented on fresh weight basis.

5.2. *Capital and marketing*

A major portion of the income for the livelihood of the farmers comes from the sale of the agricultural products like vegetables, cash crops, fruits, etc. The yield of most of the crops is nearly equal to that of the state average. About 90% of farmers in the remote areas (i.e. Pabong Block) give their orange orchards on contracts. In contrast, 80% of farmers close to town (i.e. Singithang and Kamrang blocks) sell the produce themselves. Thus villages close to town have shown better income as compared to those in remote areas (except those having large cardamom farms) due to easy accessibility to the market for regular supply of milk and other farm produce.

During lean period farmers sell their animals such as goat and poultry birds to meet their cash requirement. However, rich farmers sell a portion of their produce during off season to fetch higher returns. Namchi town is the headquarter of the south district. In this town, besides the availability of general items throughout the year, the local farm and forest products are displayed in a weekly market ('hat') which takes place on Fridays. Mainly children and women from all walks of life participate in this market and sell their items to fetch money for weekly expenditure. Most of the farm products brought to the weekly market are surplus. Large quantities of commercial crops are directly handed over to the retailers or wholesalers, and middlemen exploit all terms and conditions of the sale. Sometimes the retailers and wholesalers give loan to the farmers with an amount ranging from Rs 500 to 5000, depending upon the farmer's production capability. Therefore, the farmers are bound to sell their produce to the retailers/wholesalers at a prefixed price. In most cases retailers become active and act as middlemen as well as 'pseudo-wholesalers' during production of the cash crops. A diagrammatic representation of the inflow and outflow of the agricultural produces from the 9 blocks of the Mamlay watershed is presented in Fig. 3.

5.3. *Fuel wood*

The use of fuel wood is the only form of energy for cooking. Cardamom growers use a huge amount of firewood (70–80 kg of firewood for 100 kg of cardamom curing). Average firewood consumption per household per day is as much as 21 kg excluding cardamom curing. A family of 6 persons, on an average is using 4000 kg of dry wood in a year, out of which 69% are used for cooking, 9% for animal food preparation, 7% for water heating, 7% for house warming during winter, 6% for local wine/beer preparation and rest for festival and other uses. Firewood is collected by men, women and children from nearby forested areas. At higher elevations, people collect firewood during winter months only and store it in heaps ('peel') for the whole year, whereas, at lower elevations collection is made throughout the year. Due to collection of huge amount of firewood, forests near to the villages are subjected to rapid degradation and over exploitation. A very small fraction of firewood (1–3%) also comes from the agriculture fields.

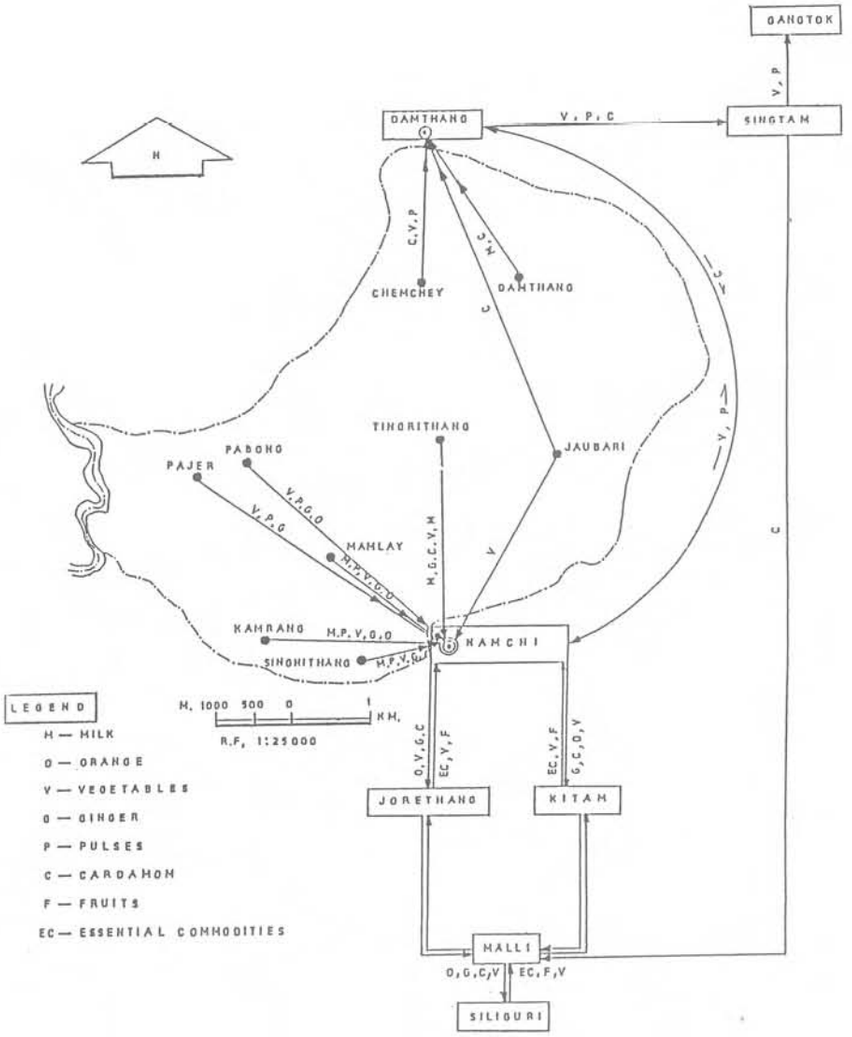

Fig. 3. Location of different blocks, marketing linkages and inflow/outflow of commodities in the nine blocks of the Mamlay watershed of south Sikkim.

6. System dynamics

It is evident from the livelihood status of the people of the watershed that this agriculture system is mostly at subsistence level. Population is increasing at a fast rate and within next few decades, there will be practically no scope

for increasing the area under agriculture. Fragmentation of land holdings, construction of new houses in agricultural fields, sloping terrain and forest clearing are mainly responsible for low production and declining soil fertility.

The weekly market system, 'hat', is well established in Sikkim, and is very popular among the masses. The farmers remain aware of market prices and demands. They cultivate at least one of the cash crops in addition to the cereals, pulses and vegetables. However, due to lack of proper storage and transport facilities, the farmers are exploited by middlemen and brokers. The sale of these cash crops is practiced through negotiation, bargaining or on commission basis. This problem is more severe with the farmers in remote areas.

Large cardamom gives good return and its production is a stable system but the number of families having cardamom farms is very few. Orange orchards are used for mixed farming and sometimes the failure of one crop is compensated by another. There is a promising system of agroforestry by growing fodder trees/grasses on the margins of the agricultural fields. Generally stall feeding is popular (at least in some parts) and therefore forests show good regeneration.

7. Assessment

7.1. *Merits*

All the components of the agriculture system in the Mamlay watershed of south Sikkim seem to satisfy the basic needs of the villagers for food, fodder, fertilizer, and timber as well as cash return. Although the system is at low production level, it is a low input system which can be utilized even by the poorest section of the people. Although crop combinations are very few, they are well tested. Trees are grown mainly for fodder, fruit or fuel/timber needs at the bunds of the farms and thus help in reducing soil erosion. Mixed farming, mainly using legumes in maize and rice fields brings about substantial improvement in the physical and biological characteristics of the soil. The use of *Albizia* and *Alnus* in agricultural and large cardamom farms, respectively, is beneficial for improving fertility status of the soil by N_2 fixation. The use of unpalatable grasses for composting and agricultural waste for cattle feed results in an efficient recycling of the materials. Farmers have increasing awareness of cash crops and they are grown in equal balance with cereals. Agricultural surplus brought to the weekly market fetches immediate monetary returns. Stall feeding of animals reduces grazing hazards in the forest areas. Although road network is poor between villages, farmers have accessibility to all other types of infrastructure/institutions at nearby Namchi town.

7.2. *Constraints*

Despite many positive aspects of this hill agriculture, so far no extension work has been done in this watershed due to lack of information on agriculture systems as well as technical and research know-how. The limited area under cultivation, very steep slopes, small and marginal farms, lack of money for investment, chemical fertilizers and irrigation facilities are the major constraints for crop production. Further, increase in population at an exponential rate is also supposed to put a high burden on the system in the near future. Fragmentation of the families leads to the use of well-terraced agricultural fields for new house construction which ultimately affects soil health and reduction of cultivable land. Rainfall distribution is so erratic that we recorded a difference of 400 mm in different altitudes of the Mamlay watershed itself and 80% of this rainfall come in the rainy season (June–September). The large amount of the rainfall in such a short time leads to increased erosion hazards. There is sufficient moisture in the soil during the rain, however, once this moisture is exhausted in post-monsoon season, nothing is left for next crop. At higher elevations sometimes crops are damaged due to hail storm, frost etc. Due to exploitation by middleman, farmers get small returns for their cash crops. Lack of storage facilities as well as money needed for home utilization are other major constraints which lead the villagers to sell their cash crops at lower prefixed prices. In need of cash, most of the wild edible species are exploited senselessly which may pose a threat to their survival in the near future.

8. Potential and research need

State government has recently started working on agriculture development by providing improved seeds, fertilizers and pesticides, and terracing the agricultural fields in some areas of the south district. There are veterinary and agricultural services at district level. However, these efforts are not adequate. Personal interview with the residents of the watershed revealed that agriculture sector should receive top priority for the development. Most of the researches are limited to double-cropping of rice, a crop which is grown on irrigated fields [Awasthi and Prasad, 1987]. In hills irrigated area is limited and most of the farmers rely on unirrigated and mixed farming system. Since most of the agriculture systems are at subsistence level, multiple cropping system should be a thrust area of research and may be strengthened by planting fruit, fodder, fuel and timber trees. Crop productivity vary from farm to farms because of changing inputs in the form of labour, seeds and manure. Basic researches leading to evaluate minimum requirements of various inputs in different crops are lacking. Most of the farms do not receive any chemical fertilizer input and also have high slates and phyllites due to sloping land and erosion of soil. For such farms suitable bund/hedgerow species should

be sorted out. Furthermore management of farmland using organic compost should receive immediate attention. Traditional cow-dung-plant compost application is excellent but is not adequate. This should be supplemented by weed compost, and composting technique of weeds which takes 6 week time has been already developed by our Institute. Weed compost increases the nutrient conservation as opposed to the traditional practice of dried weed burning in winter. Both traditional cow-dung-plant compost and weed compost not only increase soil fertility but also help to increase soil porosity, thus reducing runoff and erosion by enhancing infiltration. Fragmentation of farm-families has reduced land-man and land-cattle ratios. Therefore more important task is to use marginal and small farms intensively. Such farms cannot meet farmers' food demand and therefore researches should be carried out to keep them either under tree cover or other species of economic value or fast growing species after a careful screening. Use of improved varieties of cash crops and vegetables can increase the existing level of income. Rainwater-harvesting technology can help take the advantages of irrigation. Furthermore, there is a need to take extension researches directly to the farmers' fields. Livestock is another integral part of hill farming system. Animal population is growing continuously in the recent past, therefore grazing may cause a threat to forest regeneration in the near future. Livestock management with sound research support should also receive due attention.

The migration from rural to urban areas is not as severe in Sikkim as it is in the central Himalaya [Singh et al., 1984]. This is due to lower literacy rate of the people. With the increase in education status of the people, it is expected that more people will move out in search of better employment opportunities in towns and cities. Therefore, better land-use strategies should be adopted to increase the productivity in the area under cultivation through recent scientific inputs and best utilization of available resources, so that educated people can also take farming as a profession.

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