

Micro-watershed-based farming systems for sustainable livelihood in eastern Himalayan hill ecosystem

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The hilly mountains of eastern Himalayan region of India are endowed with bountiful natural resources of land, water and vegetation which in turn provide a great scope for growing a wide variety of agricultural and horticultural crops besides, animal husbandry and fishery. Agriculture in the hills especially in Eastern Himalaya Region (HER) of India traditionally has been Jhum (shifting) in nature. Over the past decades, due to increasing human population, the Jhuming cycle which extended to 20-30 years in older days, has now been reduced to 3-6 years. This has resulted in reduced farm output, loss of biodiversity and ecosystem services and increased land denudation. Moreover, the impact of climate changes like increase in extreme events (heavy rain, frost, cold wave, drought etc.) is further contributing to challenges of sustaining hill agriculture. In this regard, micro-watershed based farming system, viz. Integrated farming system (IFS) or Integrated Organic Farming System (IOFS) under farmers participatory mode is a viable option to enhance the production, employment and income through scientific integration of several components like crops, vegetables, fish, live stocks and others. A judicious mix of agricultural enterprises like dairy, poultry, piggyery, fishery, sericulture etc. suited to the given agro-climatic conditions and socio-economic status of the farmers would bring prosperity in the farming.

Keywords: Hill ecosystem, Integrated farming system, IOFS, Organic farming, Productivity

MOST of the hill ecosystems of Eastern Himalayan including North Eastern Himalayan Region (NEHR) of India receive good amount of precipitation in rainy season but receive very less or no rain in winter months. Growing crops as well as rearing livestock in this winter season without sufficient availability of water is very difficult in hills. The hills and mountain regions of India especially NEHR varies in slopes, tree species, livestock, land holdings etc. In NEHR of India, 'Slash and Burn' form of agriculture known as 'jhuming' is prevalent in an area of about 0.36 million hectares (m ha). Other predominant indigenous farming systems of the region are *Zaboo* farming in Nagaland, pond-based farming system in Tripura, Assam and Manipur, *Apatani* rice-based farming system in Arunachal Pradesh and terrace rice cultivation or wet rice cultivation in Sikkim and Nagaland. All these farming practices are organic by default and farmers use farmyard manure, green manure, composts and indigenous means of pest control

for crop and vegetable production. The concept of IFS/IOFS should be promoted with due care of livestock and water harvesting structures for year-round crop cultivation and nutrient supply.

IFS models developed by ICAR research complex, Umiam

Different farming system models (Table 1) comprising cereals, pulses, oilseeds, vegetables crops, fruits, livestock unit, fodder crops, farm pond and vermicomposting units have been developed at ICAR Research Complex for NEHR, Umiam for NEHR of India has been developed based on the different mountain ecosystems to meet the diverse requirement of the farm household while preserving the resource base and maintaining the environment. Researchers conducted a detailed survey of land uses to characterize different farming systems in order to develop the Farming System Models. Slopes were transformed into terraced fields, and the risers of terraced fields were



Farming systems in hills of North East India

planted with guinea and broom grasses along with other plants for stability and to provide green fodder. The agronomical crops were assigned in the slopes below 50% towards foot hills, whereas horticultural crops rose in the slope between 50-100%. Slopes over 100% are used for forestry/silvi-pastoral crop. In addition to food security, integration of livestock in the farming systems was considered for enhancing the income and employment of farmers. Integration of different cropping system and livestock unit were planned for economic viability of the respective farming system. In all the models, natural forests were maintained on the hill top with high slope for contributions to natural resource conservation, reducing rainfall erosivity and increasing infiltration etc. Vermicomposting, crop residue recycling, intercropping etc. were integrated for sustaining soil and crop productivity. Gauging stations were installed at appropriate places in each model for generating data on runoff, soil and nutrient loss. Micro

watersheds comprising of dairy based land use, mixed forestry, silvi-pastoral land use, agro-pastoral system, agri-horti-silvi-pastoral, silvi-horticultural system etc. is being evaluated on long term basis at ICAR Research Complex for NEH Region, Umiam, Meghalaya.

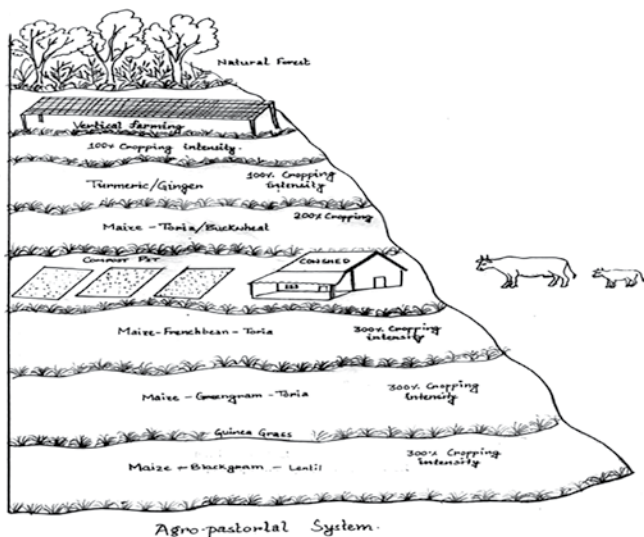
Case study from some IFS models developed

Agro-pastoral system farming system

Agro-pastoral system established in 0.64 ha area is having an average slope of 32.4%. The hill slopes are having forest land of 0.06 ha and a planned land used area of 0.58 ha. The crop planning was done in such a way that the top portion of water shed was utilized for single crop, middle portion for double cropping and bottom portion for triple cropping. Vertical farming was also included in this watershed for proper utilization of the land and maximum yield and income from the same piece of land. The results revealed that the

Table 1. Various micro watersheds-based farming systems developed for Eastern Himalayas of India

Name of the model	State	Components	B:C ratio
Banana – tuber crop- pineapple based system	Arunachal Pradesh	Banana + tuber crops + pine apple	3.68
Horti-livestock-fishery-composting system	Manipur	Horti + livestock + fishery + compost+ others	4.85
Dairy based farming system	Meghalaya	Dairy + green fodder (annual & perennial) + tree bean etc.	2.21
Agro-Pastoral system	Meghalaya	Agri crops (cereals, pulses, oilseeds, spice) + dairy + pasture crops	1.75
Agro-Horti-Silvi-Pastoral system	Meghalaya	Vegetables + fruits + silvi-pasture (tree sp. fodder grass) + piggery	1.95
Silvi-Horticultural system	Meghalaya	Horticultural crop (Assam lemon, pineapple) + tree species + spices + bamboo + Alnus + fodder crops	1.90
Intensive integrated farming system (IIFS)	Meghalaya	Agricultural crops + vegetables + fruits + fish + poultry + pig etc.	2.32
Integrated organic farming system (IOFS)	Meghalaya	Agri + Horti + Cattle + Duck + Fishery	2.41
Agri-hort-livestock integration	Mizoram	Horticulture (fruits + vegetables) + pigs + others	2.84
Agri-horti-fishery-poultry-azolla – mushroom-vermicompost system	Nagaland	Agri + horti + poultry + fish + mushroom + vermicompost + others	3.15
Integrated organic farming system (IOFS)	Sikkim	Agri + horti + livestock + composting + others	2.67
Agri-hort-duckery-fish based system	Tripura	Agri + horti + duck + fish + others	3.57



Agro-pastoral based IFS in Meghalaya



cultivation of single commodity in the watershed is not profitable, hence integration of various enterprises is advocated. An integrated approach with crops and livestock showed that maximum income was obtained from the sale of cow milk and calves (₹2,36,838). This system could generate 247 man-days employment excluding family labour amounting to ₹74,840 adding to the cost of other inputs and amounting to ₹2,02,912. The gross and net income of ₹3,82,078 and ₹1,69,166 was obtained, respectively giving an input-output ratio of 1.63. Production of guinea grass on terrace risers in the lower and middle part of the watershed and broom on the top portion of the watershed provided green fodder sufficient for 8 months for the dairy unit without any extra input/management cost.

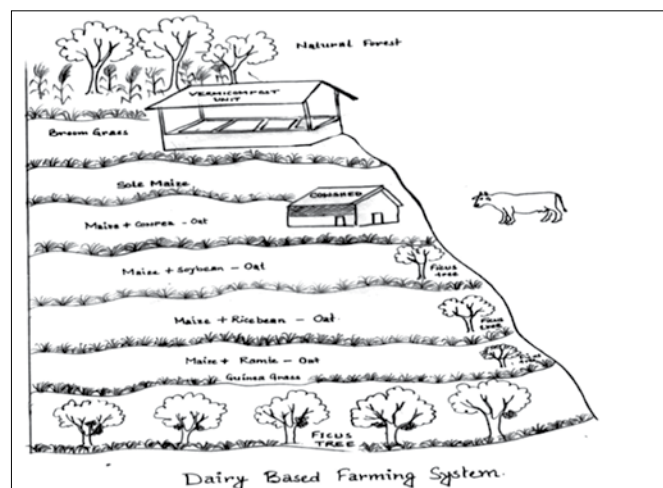
Dairy based farming system

Dairy based farming system was evaluated on a micro watershed of 1.39 ha area including 0.45 ha of forest land. Land up to 100% slope with minimum 0.5 m soil depth may be utilized for dairy based system. Conversion of hill slopes to bench terraces was found to retain 80-90% of the annual rainfall and the soil loss was restricted within 2 t/ha/yr. The area under planned land use was 0.94 ha of which 0.45 ha terrace area falls

under annual fodder crops and the remaining under broom and guinea grass production. Three milch cows along with their calves were maintained. An analysis of fodder production and requirement revealed that total green fodder from forage crops and slopping land was 35.12 t, while the requirement for dairy animals was 31.6 t, showing a surplus of (+) 3.52 t/annum. The feed concentrate, paddy straw and medicine were arranged from nearby market costing to ₹1,23,764.00. The milk yield obtained from the system was 4,680 litres amounting to ₹2,30,56. The net annual income from the system was calculated as ₹1,56,796.

Silvi-pastoral based land use model

Sometimes, the hill slopes are not suitable for cultivation of crops and farmers have no option to leave the field and search for new options of his livelihood. Keeping in view the livelihood of the farmers, silvi-pastoral system was established at such hills where average slope is 32.18%. The top portion of the micro-watershed was utilized for broom grass to fulfill the requirement of fodder for the animal during lean period and fuel woods in the form of stick. The area is having 75 plants of *Symingtonia populnea* of about 25 years age. The entire area was planted with guinea and broom grass



Dairy based IFS in hills



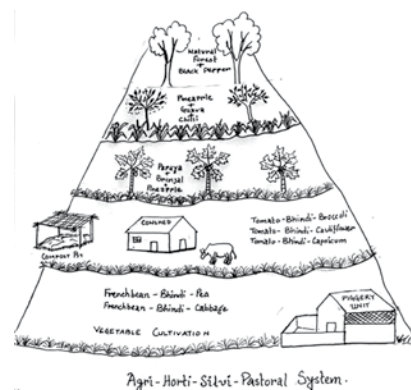
which recorded green fodder of 154.93 q. *Symingtonia populnea* plants produced 21.60 q of green leaves during lean period. This fodder was consumed by 50 goats (Black Bangal) maintained on the farm. The goats were allowed to graze for 3 hours per day and green fodder @ 3 kg per adult along with 100 - 150 gms of concentrates per adult/day were given. To increase the income of the system, water harvesting pond of $45 \times 25 \times 3 \text{ m}^3$ was dugged out and lined with polythene. This pond was utilized to capture runoff water and rearing of fish. In this pond, 500 fingerlings were released during April and harvested in the month of December. The fish were provided with excreta of 600 broiler poultry reared in rotation of 50 birds at an interval of 15-20 days and sold at 35-40 days of age stage. At this stage the average weight of the poultry was 2.45 kg/bird. The bird's excreta were directly shifted to fish pond at 2-3 days interval, which acted as food for fish and plankton. The total broiler weight was 1470.00 kg. The gross income generated was ₹3,04,843.00 with net income of ₹1,21,650.00, having input: output ratio of 1:2.50.

Agri-horti-silvi-pastoral based land use system (cattle + pig with agri-horti crops)

Agri-horti-silvi-pastoral based land use system was developed for mid hill altitude areas in which lower reaches were utilized for agriculture crops, mid terraces for vegetable and fruits crops, while upper hill slopes were kept for silvi-pastoral system. This system was standardized for 0.50 ha area for small and marginal farmers of the region, in which the area for agricultural crops, vegetables, fruits and silvi-pasture was 1,300, 1,500, 1,200, and 1,000 m^2 . The alder (*Alnus nepalensis*) tree in silvi-pasture while 20 years old fruit plants, were used in the study. In between the Alder trees, guinea grass was grown on 1,000 m^2 area which registered 15 t green fodders for the animal kept in the system. The remaining fodder requirement was met from the tree leaves of *Ficus* sp. and *Symingtonia populnea* grown in silvi-pastoral system. Besides 18 q paddy straw was procured from the market for the dairy animal. These trees provided additional energy in the form of biomass, i.e. fuel wood @ 18 kg/tree/year. To make the system remunerative 03 pigs were reared with external input of concentrate while the remains of vegetables were provided to pig for economizing the system and best use of resources. The fruit plants were growing in half-moon terraces and chiefly contain Assam lemon, oranges and guava.

Integrated organic farming system (IOFs) model for livelihood and nutritional security

It is necessary to utilize all the resources available on- and off the farm effectively in organic farming. The IOFS model is comprised of different enterprises such as cereals (rice and maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetable crops (French bean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chili, coriander, etc.), fruits (Assam lemon, papaya, peach), dairy unit (a milch cow + calf), fodder crops, central farm pond, duckery (18 ducks) farmyard



manure pits and vermicomposting unit. A farm pond of 460 m^2 area with average depth of 1.5 m was part of the IOFS model for life saving irrigation, duckery and aquaculture. Climbing vegetables such as bottle gourd, chow-chow, cucumber, ridge gourd etc., were grown on a structure created above water bodies in one side of the pond dyke for vertical intensification. The solid waste from cow shed was used for FYM making and vermicomposting. The total cost of cultivation was recorded at ₹ 60,835 per year under the IOFS model with an area of 0.43 ha. A total net return of ₹ 82,903 per year was achieved under the IOFS model which is about ₹ 192,798/ha and higher than the region's farmer common practices of rice monocropping or improved practice of rice-vegetables cropping system. Aprox. 94.4% of the total N requirement, 85.1% of the total P_2O_5 requirement and total of 98.2% K_2O requirement could be met within the model itself and only 4.6% of the total N requirement, 17.9% of the total P_2O_5 requirement and 1.8% of K_2O is required to be met from the external source to sustain the model. The nutrient requirement of the model from external source would be reduced substantially with the efficient recycling of pond silt, intercropping with legume, use of bio-fertilisers, etc.

SUMMARY

Farming system plays a very important role in sustainable development of hill and mountain agro-ecosystem by promoting efficient use of resources, environmental protection and enhancing the productivity and income. Farming system makes efficient use of resources by using waste product or by product of one enterprise as input for the others and reduce the risk of total failure significantly. Not only the farmers' year-round food and nutritional security is ensured in the IFS/IOFS, but their employment and income also enhanced substantially. However, identification and quantification of specific enterprises in hills is needed for developing sustainable location specific IFS/IOFS models for enhancement of livelihood of farmers. There is also need for large scale demonstration and policy intervention for support to the farming community for adoption of IFS/IOFS models in hill and mountain agro-ecosystem for sustaining environment, improvement of soil health and enhancing the income.

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