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Article *in* The Indian Journal of Agricultural Sciences · August 2019

DOI: 10.56093/ijas.v89i8.92843

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Indian Journal of Agricultural Sciences **89** (8): 1267–72, August 2019/Article

Integrated Organic Farming System: an innovative approach for enhancing productivity and income of farmers in north eastern hill region of India

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Received: 25 December; Accepted: 11 February 2019

ABSTRACT

About 85% farmers of the north eastern hill region (NEHR) of India are small and marginal. Hence, there is need for establishing package of practices in an integrated manner to enhance on-farm resource recycling, employment, income and sustain soil health. An integrated organic farming system (IOFS) model (0. 43 ha) was assessed during 2005- 2017 at ICAR Research Complex for NEH Region, Umiam, Meghalaya (960 m ASL) with diversified farming components like field crops, horticultural crops, livestock (one cow + calf) along with perennial fodder crops, central water harvesting pond for composite fish culture and as a source for irrigation during lean season and provision for nutrient recycling. The productivity and income from the on farm IOFS model was compared with the ruling farmers practice-I (Monocropping, i.e. rice-fallow system) and farmers practice-II (cultivating about 30% farm area for second crop like vegetables after rice). The average results indicated that the rice equivalent yield (REY) from the IOFS model was 19. 8 t/ha as against 4 t/ha and 6.72 t/ha from the farmers practice-I and II, respectively. The enhancement in net income due to IOFS was 355 and 191% relative to farmers practice -I and II, respectively. The IOFS model could meet 92, 82 and 96% (N, P_2O_5 and K_2O) of its nutrient demand within the system. The IOFS model was also replicated in farmers' field through participatory approach in three villages covering about 110 ha area and 317 households during 2013 to 2017. After 4 years, on an average farmers productivity of various crops (tomato, potato, chili, carrot, French bean, ginger and turmeric) enhanced by 15 to 45% and annual income enhanced by about ₹ 15500 per house hold. Thus, IOFS could be a viable option for organic food production and sustainable agricultural development in the hill ecosystem of north east India.

Key words: Cluster approach, Hill agriculture, Organic food production, Resource recycling, Technology dissemination

The North Eastern Region (NER) of India has multiple advantages to go for organic food production due to minimum use of fertilizer, availability of plant- and livestock-excreta-based organic manure (about 46 million tonnes) and pesticides, and favourable climatic conditions for growing a wide range of crop species (Bujarbaruah 2004). Considering the cultivated area of the NER at little above 4 million ha, this quantity of manure and biomass is a good amount for going organic farming (Das *et al.* 2014). Organic farming is considered as one of the best options for protecting/sustaining soil health and produce healthy foods (Das *et al.* 2017). The soil fertility is maintained by returning all the residues to it through composts and residue recycling, thereby, minimizing the gap between nutrient addition and removal from the soil. To sustain and satisfy as many as their needs, the farmers include crop production, livestock, poultry, fisheries, beekeeping etc. in their farms. When farming components are identified considering the agro-climatic conditions, farmers need and market demand, organic farming can provide much higher income than conventional practice. To make the organic agriculture sustainable, it is necessary to utilize all the resources available on- and off the farm effectively by integrating complementary and supplementary enterprises. Thus, an IOFS model comprising different modules of cereals, pulses, oilseeds, vegetables crops, fruits, dairy unit, fodder crops, water harvesting and nutrient recycling components have been visualized at ICAR Research Complex for NEH Region, Umiam, Meghalaya to meet the diverse requirement of the farm household while preserving the resource base

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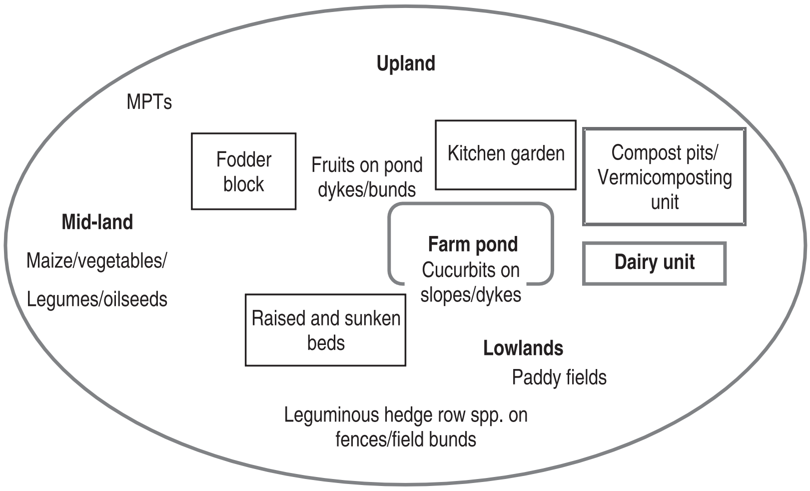

Fig 1 Schematic diagram of IOFS model.

and maintaining the environment.

MATERIALS AND METHODS

An IOFS model for valley land was established at ICAR Research Complex for NEH Region, Umiam, Meghalaya (21.5°N - 29.5°N latitude, 85.5°E -97.3°E longitude and 950 m above mean sea level) during 2005 in an area of 0.43 ha. The model comprised different enterprises such as cereals (rice and maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetable crops (Frenchbean, tomato, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chili and coriander), fruits (Assam lemon, papaya, peach), dairy unit (one cow + calf), fodder crops, central farm pond, leguminous hedge row plants, FYM pits and VC unit (Table 1). For technology dissemination, participatory demonstration in cluster approach was initiated since 2013 in farmers' field. Farm designing is an important aspect for optimizing the utilization of resources within the farm (Fig 1). Topography of the land and varieties of crops to be cultivated are the two basic factors in farm design.

Evaluation of IOFS model in Institute farm: 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 and aquaculture. Composite fish culture involving surface feeder (Catla, silver carp and puntius/java punti), column feeder (Grass carp and rohu), and bottom feeder (mrigal, common carp and gonius) constituting 40, 30 and 30%, respectively were adapted. The stocking density adapted was 1 fingerling/ m^2.

Table 1 Nutrient concentrations in different biomass recycled on-farm

Particular	N	P_2O_5	K_2O
FYM	0.75-0.81	0.22-0.27	0.88-0.95
Vermicompost	1.29-1.53	0.47-0.55	1.05-1.18
Tephrosia spp. green leaf	2.48-2.66	0.45-0.57	1.08-1.21
Rice-maize residues	0.41-0.56	0.15-0.19	0.95-1.18
Vegetable residues	0.89-0.92	0.19-0.25	0.98-1.56
Weed biomass	1.48-1.76	0.21-0.39	1.11-1.22
Soybean pruning	2.58-2.66	0.23-0.27	1.55-1.68
Pulses residues	1.50-2.92	0.45-0.56	0.95-1.10

A dairy unit (one improved crossbred Jersey cow with a calf) was maintained in the model to serve the dual purpose of milk production and supplying manure for fish pond and crops. The cowshed on the embankment of the water harvesting pond in community land has been designed in such a way that the washings of the cow unit is diverted to the fish pond thorough a channel that helped in growth of phytoplankton and zooplankton which serve as feed for the fish. Perennial fodder grasses like Broom grass (*Thysanolaena maxima*), Congo signal grass (*Brachieria rosenesis*), Hybrid Napier (*Pennisetum typhoides* × *P. purpureum*) and Guinea grass (*Panicum maximum*) were raised in the system for organic green fodder production for dairy animals. The solid waste from the cow shed was used for FYM and VC making.

Maize + soybean - vegetable (carrot, tomato, frenchbean, potato cropping systems) were adopted on uplands near farm pond. Need based irrigation was given to vegetables especially during dry season using a 0.5 HP *tulu* pump to vegetables. Soybean (variety JS-335) was detopped (about 25 cm height) at 45 days after sowing (DAS) when the crop was at the maximum vegetative growth and generated the highest biomass for green leaf manure. The soybean crop was then left to grow for seed purpose. A nutritional kitchen garden was also established in the model with various seasonal vegetables. Small beds of 1.25 m width and about 5 m length were established for growing vegetables throughout the year. The crop calendar adopted in kitchen garden was: carrot, tomato, potato, French bean, cucumber in summer/pre-*kharif*; okra, brinjal in rainy season and broccoli, cabbage, lettuce, coriander, beet root, radish, chili, French bean etc. in winter/post rainy season. In low-lying areas of the farm, some area was converted to raised and sunken beds of about 1.25 m width, 8 m length and 25-30 cm height where vegetables (tomato/potato/carrot/French bean-okra) were grown on raised beds and rice-pea/lentil on sunken beds. Rice varieties (Shahsarang 1, Lampnah and Vivekdhan 82) were grown with organic manure generated within the model. The left-over residues in the field were recycled through mulching and mixed with the soil while field preparation. Leguminous hedgerow species like *Tephrosia candida*, *Crotalaria tetragonoloba* were raised on the field bunds for generating N rich green leaf manure. Every year 2 cuttings were given and leafs were used for green manuring or as mulch materials. All the leftover, crops and weed residues were used for vermicomposting using the cow dung and earthworm (*Eisenia foetida*). Climbing vegetables such as bottle gourd, chow-chow, cucumber and ridge gourd, were grown on a raised structure (*Machan*) created above water bodies in one side of the pond dyke for vertical intensification. Bottle gourds were also grown in embankments of FYM pit and allowed to climb over the bamboo *Machan* constructed above the pits. Pumpkin was raised in another side of the pond and allowed to crawl on the ground/pond dyke slopes. Fruits like Asom lemon, peach, and papaya were raised on pond dykes and farm fences. For growing all the crops, FYM and VC from the model were used after proper decomposition. Nutrients were applied through organic sources on the basis of N-equivalent and phosphorus (P) requirement compensated through rock-phosphate. Crop residues were used as mulch materials during winter for vegetables crops. Pest and diseases were managed through organic means. Resistant varieties (like DA 61 of maize, Naga local of French bean, Mega tomato 2 and 3), crop rotation, manual weeding and mulching was practiced for managing pest and diseases including weeds. Since, the soil of the northeast India and study site is acidic in nature, application of rock phosphate (100-150 kg/ha) and liming (500 kg/ha in furrow in alternate years) was done for phosphorus nutrition as application of organic manure alone is not enough to meet the crop requirement.

The produce from different components were harvested and converted into monetary terms as per farm price. Nutrient concentrations in different biomass are given in Table 1. Nutrient balance was obtained by using following formula:

Nutrient balance = Farm nutrient demand - Nutrient recycled.

Technology up scaling in cluster approach: A village in Ri-Bhoi district of Meghalaya namely Mynsain (132 households, 60 ha cultivated area) was adopted for disseminating organic production technology developed in the ICAR Research Complex for NEH Region, Umiam through a model village concept under Network Project on Organic Farming-Tribal Sub Plan (NPOF-TSP) with financial assistance from ICAR-Institute of Farming Systems Research, Modipuram, Uttar Pradesh in 2013. During 2016, another two villages, i.e. Pynthor (125 households, 30 ha) and Umden Umbathiang (60 households, 20 ha) were adopted under the programme for technology dissemination.

A sensitization meeting with the villagers including village head (Headman), member of the self-help groups (SHGs), Department of Agriculture (Gram Sabha) as well as Participatory Rural Appraisal (PRA) was conducted to collect basic information about the villages. A formal memorandum of understanding (MOU) between ICAR, Umiam and the village was made for continuing organic farming. The survey (PRA) and farmers training were conducted to initiate the programme. The programme in the village had diverse components for sustaining productivity and soil health (Table 2).

Farmers were advocated to grow cucurbits like bottle gourd, pumpkin, cucumbers and chow-chow (*Sechium edule*) above the water bodies of *jalkund* and on pond dykes for intensification and effective land utilization. A community vermicomposting unit (size 6 m × 8 m × 2.6 m) consisting of eight tanks (2 m × 1.5 m × 0.75 m) was constructed in

Table 2 Components of organic farming system in the village under cluster approach

Particular	Component
Food crops	Cereals, pulses, oilseeds, vegetables and fruits
Food-feed crops	Food crops for human consumption as well as feed for livestock like sweet potato, colocasia, maize etc.
Livestock and poultry	Piggery and dairying and backyard poultry farming
Community and individual vermicomposting unit	Biomass recycling and quality manure production
Green manuring and green leaf manuring	Generation of organic manure in system
Hedge row intercropping (leguminous shrubs)	*Tephrosia*, *Crotalaria*, *Indigofera* spp. as fencing, conserve soils and water and produce nutrient rich green leaf manure
Planting of multipurpose tree species (MPTS)	Bamboos, *Michaelia champaca*, *Alnus* sp. etc. for conserving soil, generating additional income as well as for environmental security
Cultivation of fodder crops in degraded lands	Cultivation of perennial grasses like Hybrid Napier, Congo signal etc. for ensuring supply of green fodder and rehabilitation of degraded lands
Soil conservation measures	Terracing, half-moon terracing, vegetative barriers etc.
Water harvesting for multiple use	Five new ponds (about 500 m^2 area and 1. 5 m depth each pond) were constructed and seven existed ponds were renovated
Micro-rain water harvesting structures for diversified activities in hills	A total of 37 small rain water harvesting structure - jalkund having 30,000 liters capacity each were developed for growing vegetables and for rearing of animals such as pig and poultry specially during dry season.
Development of water harvesting structure	Farm ponds and jalkunds
Capacity building	Training and field visits were organized to enhance the capacity of the farmers in organic farming technologies
Organic outlet	Near highway for marketing organic produce.

the village with an objective to produce vermi-compost by recycling farm biomass. Another two vermicomposting units were established in Pynthor village of two tanks each in individual farmer's households. 15 vermibeds (2 m × 1.5 m × 1 m) were also installed in all three villages for quality compost production. For improved handling of FYM, a low cost shed with locally available materials were advocated above the FYM pits. Raised (1 m) and sunken beds (1 m) with 1:1 dimension (0. 2 to 0.3 m height) was developed in about 2 ha area after rice harvest in lowland for cultivation of vegetables like tomato (var. Avinash, Rocky), French bean (var. Naga local), potato (var. Kufri Megha), carrot (var. New Kuroda) and lettuce. Four varieties of guava were planted in the field namely Allahabad Safeda, RCGH-1 and RCGH-7, RCGH-4. Pineapple planted under the programme now started giving harvest and farmers are selling the fruit at ₹ 15-20/piece. Multipurpose trees (*Michaela champaca, Alnus* spp.) along with perennial fodder (Broom grass, Congo signal, Napier) were also grown for rehabilitation of degraded land and supply of fodder to cattle in lean period. Farmers were provided with improved pig breed Lumsniang and poultry (Vanaraja, Gramapriya) for higher productivity, nutritional security and income.

RESULTS AND DISCUSSION

Assessment of IOFS at Institutional farm

Productivity and economics: The production assessed in terms of rice equivalent yield (REY) was the highest from crops followed by dairy and fishery components. The model as a whole resulted in a REY production of 7.89 t from 0.43 ha (about 18.4 t/ha). Whereas, the production from equivalent farm size under farmers practices were 1.72 and 2.90 t (4.0 and 6.5 t/ha) under farmers practice –I and farmers practice-II, respectively. Thus, the IOFS model resulted 395 and 193% increase in productivity over farmers practice –I and farmers practice-II, respectively. The enhancement in equivalent yield was mainly due to higher market price of vegetables, milk and fish than field crops like maize and rice. Due to efficient recycling of on-farm resources, and year-round production of crops, fruits and fish enhanced the system productivity and substantially of IOFS than the farmers practice. The adoption of diversified farming (crop, fruit, livestock and fishery) has been reported to enhance system productivity by 190 to 352% higher than the farmers' practice (without integration) in mid-altitude of Meghalaya (Das *et al.* 2013).

The total annual cost of production was ₹ 56654 for the IOFS model with an area of 0. 43 ha. Maximum expenditure was incurred in crop component of the model with 46.6% of the total cost of cultivation. Dairy unit with one adult cow and one calf registered 37.8% of the total cost of production, while fishery component recorded 8.6% of the total cost (Table 3). For maintaining vermicomposting unit of 72 m^2 area and other important operations like hedgerow planting, residue recycling, rock phosphate application and liming, the expenditure incurred was ₹3700 which account to 7% of the total cost.

A total net return of ₹71442 per annum was achieved under the IOFS model which is much higher than the farmer common practices of rice monocropping or improved practice of rice-vegetables cropping system (Table 3). The highest contribution towards the total net return was given by crop component of the model (66.5%) followed by dairy (24%) and fishery components (15.2%). The fish production was ~136 kg from the model. The net return from dairy component was calculated only in terms of milk production since the cow dung produced was recycled back into the model which was used as manure for crop production. The production of vermicompost from model was 1500 kg annually and it was used in the farm itself for nutrient supplementation to crops. The net returns obtained from the IOFS model was 355 and 191% higher relative to farmers practice I (₹15700.) and II (₹24518), respectively. The higher net returns from the IOFS compared to farmers practice –I and II was mainly due to higher system productivity owing to efficient nutrient recycling, farm intensification and higher productivity. Higher net

Table 3 Economics of the IOFS model (area=0.43 ha) (after seven year of stabilization)

Component		Area (ha)	Rice equivalent production (tonnes)	Annual cost of production/(₹)	Net return/year (₹)	Employment (man-days)
Crops	Cereals, pulses, oilseeds, vegetables, fruits and fodder crops	0.373	4.93	26429 (46.6%)	47487 (66.5%)	98
Dairy	1 milch cow + 1 calf	0.004	2.56	21365 (37.8%)	17065 (24%)	121
Fishery	Composite fish culture	0.05	1.05	4910 (8.6%)	10840 (15.2%)	8
Nutrient cycling	Vermicompost/FYM/ Hedgerow planting/ Residue recycling/Rock phosphate application/Liming	0.01	-	3950 (7%)	-3950	28
Total		0.43	8.54	56,654	71442	255
Farmers' practice-I (Rice-Fallow)			1.72	10100	15700	87
Farmers' practice-II (Rice-vegetables in small scale)			2.90	18975	24518	125

REY of 19.8 t/ha was recorded under the IOFS model compared to 4.0 t and 6.75 t/ha under farmers' practice-I & II, respectively.

returns of 176 to 284% under integrated farming system than the farmers' practice (without integration) have been also reported by Das *et al.* (2013). IOFS also generated 193 and 104% higher man-days (1 man day = 8 hours) relative to farmers practice I and II, respectively (Table 3). Increase in the employment was attributed to the year round diversified farming activities under IOFS in relation to few activities in conventional farming practices (Das *et al.* 2013)

Livelihood assessment: Considering the benefits from the IOFS model with a net return of ₹71442/year from 0.43 ha area, a net income of ₹5954 per month or ₹196/day was achieved which is a modest amount for living by a four-member family (2 adults and 2 children). Assuming food requirement and other expenditure per day (as per ICMR recommendations with some modification for NER) for a four-member family (2 adults and 2 children) for rice (1300 g, ₹33), dal (150 g, ₹15), oil (300 g, ₹15), vegetables (1000 g, ₹25), fruits (400 g, ₹ 20), fish (110 g, ₹17), meat (100g, ₹15), others (milk, egg etc. ₹15), a total of ₹155 is required per day (₹56575/annum) towards food and nutrition (Panwar *et al.* 2018). In almost all the food commodities, there is deficit in the per capita consumption (kg/annum) in NER as against the recommendations by ICMR except for milk.

Nutrient balance: The total nutrient requirement of 0. 43 ha area IOFS farm has been estimated as 64. 7, 23.1 and 53.8 kg of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O), respectively. On efficient farm nutrient recycling, the IFOS could produce an amount of 59.7, 18.9 and 51.9 N, P_2O_5 and K_2O, respectively within the system itself. Hence, 92% of the total N, 82% of the total P_2O_5 and 96% of the total K_2O requirement could be met within the model itself and only 8, 18 and 4% of N, P_2O_5 and K_2O requirement is to be met from the external sources to sustain the model, respectively (Table 4). 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 biofertilizers such as *Azotobacter*, *Rhizobium*, phosphorus solubilizing microorganism etc.

Impact IOFS in farmers' field: Through five new farm ponds and seven existing ponds (about 500 m^2 area and 1.5 m depth) about 9000 m^3 water was harvested. Similarly, through 37 *jalkunds* (30000 l capacity) 1110 m^3 rain water harvested. Thus, a total of 10110 m^3 (1 m^3= 1000 l water) rain water was harvested, which was used for composite fish culture, integrated farming and irrigation during lean season in addition to serving domestic purposes. The IOFS started giving very good returns with very less quantity of external inputs. As the villagers were not using any synthetic fertilizers or pesticides earlier, the possibility of reduction in yield due to adoption of organic farming does not arise. Rather due to adoption of improved organic production technology, the yield of rice, maize, French bean, ginger, tomato, carrot and chilly had been enhanced by about 15, 22, 40, 33, 45, 37 and 27%, respectively over conventional practice. The average fish productivity was 1.9 t/ha as against less than a tonne per ha in conventional practice. The litter size in pigs also ranged from 6 to 9 as against 4 to 6 in local breed. Nutri-seed pack containing seeds of leafy vegetables, cucumbers, bottle gourd, chili, etc. were provided to farmers specially to women for cultivation in kitchen gardens. Interaction with the farmers revealed that they are now able to meet their daily vegetable requirement from their kitchen gardens which also is improving their nutrition. Rising of cucurbits like bottle gourd, pumpkin, cucumbers and chow-chow above the water bodies of *jalkund* and on pond dykes for vertical intensification gave very good results. Farmers harvested 15-20 pumpkins or bottle gourds (40-50 kg) from the raised structure (*Machan*) over the *jalkunds*. The villagers are selling their improved piglet at 3500/piglet to the market. Similarly, the fish are sold at ~150/kg. Produced vermicompost are either used in their own farm or sold at 10-15/kg. Villagers are currently selling their produce in local market and along the highway side outlet constructed under the programme as uncertified organic produce with 15-20% higher market price as compared to conventional produce. Hammer mill unit established in the village through the community is helping farmers in enhancing their income. Interaction with the farmers revealed that on an average, the incomes of the farmers are increased by about ₹15500/annum due to adoption of IOFS practices over their earlier income in three-years. It is expected that, with the certification of organic products, the income of the farmers will be further improved over the years. Increase in productivity and farm income due to integration of various farming components along with efficient recycling of on-farm resources have been reported by Das *et al.* (2013).

Table 4 On-farm nutrient supply balance sheet under IOFS model (area=0. 43 ha)

Component	Nutrient requirement (kg)			On-farm nutrient recycled (kg)			Nutrient balance (kg)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Cereals (Rice, maize)	21.1	7.5	17.5	6.6	2.3	12.2	-14.5	-5.3	-5.3
Horticultural crops (Vegetables, fruits)	31.4	11.2	26.2	11.8	2.6	9.0	-19.6	-8.6	-17.2
Dairy component	0.0	0.0	0.0	13.1	4.9	6.6	13.1	4.9	6.6
Others (Oilseeds, pulses, green manuring crop, fodder, etc.)	12.2	4.4	10.1	28.2	9.1	24.1	16.0	4.8	14.0
Total	64.7	23.1	53.8	59.7	18.9	51.9	-4.9	-4.2	-1.9

The study revealed that adoption of IOFS will not only promote organic food production but also reduce dependence on external resources through efficient recycling of on-farm biomass and other resources. It is possible to earn about ₹ 14500/ha (₹ 12000/month) through adoption of IOFS practice. Application of lime, biofertilizer, liquid manure can meet the nutrient requirement of the IOFS farm when on-farm resources are efficiently recycled. There is urgent need for locations specific IOFS models for upscaling in NEH region of India.

ACKNOWLEDGEMENTS

The authors are thankful to ICAR-Indian Institute of Farming systems Research, Modipuram and ICAR Research Complex for NEH Region, Umiam, Meghalaya (TSP component) for providing financial support to undertake the study in Institute and farmers' fields.

REFERENCES

Bujarbaruah K M. 2004. Organic Farming: Opportunities and Challenges in North Eastern Region. ICAR Research Complex for NEH Region, Umiam, Meghalaya.

Das A, Choudhury B U, Ramkrushna G I, Tripathi A K, Singh R K, Ngachan S V, Patel D P, Layek J and Munda G C. 2013. Multiple use of pond water for enhancing water productivity and livelihood of small and marginal farmers**.** *Indian Journal of Hill Farming* **26**(1): 29–36.

Das A, Patel D P, Kumar M, Ramkrushna GI, Mukherjee A, Layek J, Ngachan S V and Buragohain J. 2017. Impact of seven years of organic farming on soil and produce quality and crop yields in eastern Himalayas, India. *Agriculture Ecosystem and Environment* **236**: 142–53.

Das A, Patel D P. Kumar M, Ramkrushna G I, Ngachan S V. Layek, J and Lyngdoh M. 2014. Influence of cropping systems and organic amendments on productivity and soil health at mid altitude of North East India. *Indian Journal of Agricultural Sciences* **84**(12): 1525–30.

Panwar A S, Syiemlieh H, Kalita L, Tahashildar M and Layek J. 2018. Food and nutritional security through farming system approach. *Conservation Agriculture for Advancing Food Security in Changing Climate, Volume I (Crop Production, Farming System and Soil Health).* Das A, Mohapatra K P, Ngachan S V, Panwar A S, Rajkhowa D J, Ramkrushna G I and Layek J (Eds). Today & Tomorrow's Printers and Publishers, New Delhi, pp 223–44.