Multiple Use of Pond Water for Enhancing Water Productivity and Livelihood of Small and Marginal Farmers

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ABSTRACT

Multiple use of pond water (MUW), an integrated approach for rain water management for enhancing water productivity was demonstrated during 2010-12 in a participatory mode in 18 farmers' field covering 15 villages across Ri-Bhoi District, Meghalaya. The programme was sponsored by the Ministry of Water Resources, Government of India under the scheme Farmers' Participatory Action Research Programme (FPARP) Phase-II. Interventions of crop-fish-pig (pig based) and crop-fish-duck based MUW in farmers' field resulted significant improvement in water productivity, employment generation, income and livelihood of farmers over the farmers' practice. The pig and duck based MUW through diversified farming (crop, fruit, livestock and fishery) enhanced system productivity by 352 % and 190 % and generated a net return of Rs. 28,250 and 20,350 from an area of 1500 m^2, which were 284% and 176 % higher than the farmers' practice (without integration), respectively. The MUW for harnessing complementary interaction of crop-fish-livestock also substantially improved employment generation to 67 and 52 man days annually under a pig and duck based MUW system from an area of 1500 m^2 compared to 24 man-days under farmers' practice, respectively. The water productivity recorded with these MUW systems were 0.70 kg fish/m^3 (equivalent to 4.7 kg rice/m^3) and 0.45 kg fish/m^3 (equivalent to 3 kg rice/m^3) water compared to 0.23 kg fish/m^3 under farmers' practice, respectively. Thus, the efficacy in MUW through farm diversification of small and marginal farmers in the north-eastern hilly region with colossal disparity in water balance frontage (surfeit in rainy seasons and scarce in winter) can bring a sea change (positively) in socio-economy, food and livelihood security. Hence, integrated water resource management through farm diversification offers the opportunity for efficient use of scarce water resources for better livelihood security as well as "no regrets" measures in making resilience of small hill farming to the impacts of climate change.

Keywords: Water productivity, Farm diversification, Integrated water resource management, Life-saving irrigation, Livelihood security, Multiple water use.

INTRODUCTION

The farmers of the North Eastern Region (NER) of India are mostly small and marginal in land holdings and depend mainly on agriculture for their livelihood. The agricultural productivity in the region is very low and the region is in severe deficit of food grains (13%), fish (48 %), meat (57 %) and eggs (80%) (Vision 2050) and the requirement are met through supply from neighboring states, West Bengal, Andhra Pradesh, etc. The region is very rich in water resources (42 million ha m), receives high rainfall (the long-term average rainfall of the NER is about 2000 mm and Ri-Bhoi; the study site is 2450 mm), but most of it goes waste as runoff along the steep slopes. Further, erratic distribution of rainfall (both in spatial and temporal dimensions) often leads NER to suffer from extreme water scarcity during pre- and post- monsoon months. It is projected that by 2021, 15 million population will be added to the current 45 million in the region (Choudhury et al. 2012). Consequently, the already low per-capita per year total utilizable water availability (1404 m^3) will further reduce to < 1000 m^3 and the region will be pushed from already water stressed to water scarce zone. Trend analysis of long term rainfall data (1983-2010) for mid altitude Meghalaya (Umiam, 25° 41′ N latitude, 91°55′E

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longitude, 1010m msl) using non-parametric Mann Kendall test further revealed that contributions of monsoon months to total annual rainfall are declining marginally at the rate of 1.70 mm. Probability analysis also showed a high frequency of anomalies (*p*>0.6) of either deficit or excess in occurrence of normal monsoon rainfall (Choudhury et al. 2012). Therefore, water harvesting and their efficient utilization is the major approach for providing security to the livelihood in the hills of NER of India. The harvested water should be efficiently utilized for enhancing water productivity (Das et al. 2013). There are many existing small and large water bodies, farm ponds and wet lands, which are mostly underutilized. The fish productivity is very low (500 kg/ha) mainly due to non-adoption of improved species and husbandry practices. The water productivity in the region is very low, mainly due to the conspicuous absence of scientific integration among different enterprises involving agriculture, livestock, horticulture and fishery (Das et al. 2012; Das et al. 2013). Farming system approach for promoting a multiple use of pond water (MUW) allows efficient use of water, recycling of farm wastes and less dependency on supply of external inputs to a great extent. It is believed that rain water harvesting and its recycling in farming system mode will improve resource use efficiency, farm productivity, net income and employment generation round the year from bio-resource flow of one or other components and thereby, promoting food and nutritional security at the house hold level. Keeping these in view, in the present paper, result demonstrations on adoption of such multiple uses of water through farming system approach at several farmers' fields across Ri-bhoi district, Meghalaya has been discussed at length.

MATERIALS AND METHODS

Climate of study area

The study area experiences a tropical monsoon climate. Analysis of long-term climate data (30 years) reveals that seventy percent of the total rainfall is received during July to September, with average annual rainfall of 2450 mm. April is the hottest month, with average minimum and maximum temperatures of 17.3 ºC and 29.4 ºC, respectively. The coldest month is December where the average minimum and maximum temperatures are 7.6 ºC and 20.4 ºC, respectively. The average relative humidity is highest in the month of June (89.4 %) while January records the lowest relative humidity of 72 %. Daily pan evaporation rate varies from 2.04 mm day^{-1}(during December) to 4.60 mm day^{-1} (during April) with a mean value of 2.89 mm day^{-1}. Daily wind speed varies from 2.58 to 4.39 km hr^{-1}, with a mean value of 3.36 km hr^{-1}. Average sunshine hours are 5.42 hr day^{-1}.

The average amount of annual rainfall received during 2010-12 was 2351 mm, about 79 % of which was received during May to September. December to March was the extreme dry period during which crop suffers from water scarcity. The average maximum and minimum temperature were 25.33ºC and 13.68 ºC, respectively. The average monthly weather parameters of 2010-12 are presented in Fig 1.

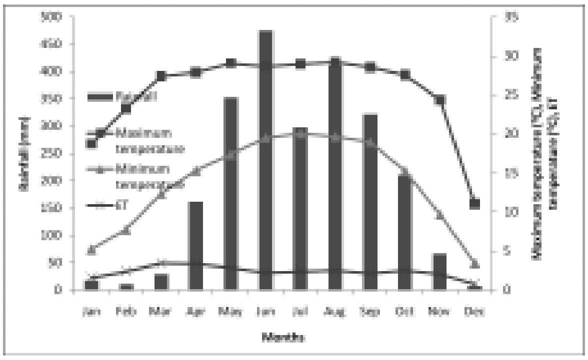

Fig 1: Average monthly weather parameter of Umiam during 2010-12

Field survey and farmers' selection

Field surveys were conducted to select beneficiaries among the farmers from different villages of Ri-Bhoi district, Meghalaya for implementing the demonstration units. Beneficiary farmers having existing ponds were given preference in selection while special care was taken in covering more villages representing small and marginal farmers. Two MUW models demonstrated were crop-fish-pig (pig based) and crop-fish-duck based integrated farming systems. Meetings were conducted with farmers along with village leaders such as headman, secretaries as well as members of youth clubs, NGOs, etc. The objectives, goal and importance of MUW were highlighted during the meetings. The name of farmers, villages and geographical locations of the demonstration sites have been provided in Table 1.

Table 1: List of beneficiary and their geographical location of the demonstration site

Name of beneficiary	Village name	Area of pond (m^2)	Latitude (N)	Longitude (E)	Elevation above mean sea level (m)
Ms. Aitihunsuting	Ladsyat	180	25.738500	91.885933	765
Ms. S. Sohshang	Mawbri	350	25.736017	92.054800	889
Mr. K. Lyngdoh	MawleinMawkhan	770	25.705267	91.895833	940
Mr. N. Kharpan	Umtrew	450	25.722567	91.890583	805
Ms. JrisLyngdoh	Road iew	1150	25.719233	91.984533	900
Mr. Shining Rynghang	Mawbri	360	25.724350	92.040183	903
Mr. P. Nongrum	Byrwa	870	25.692633	91.890467	872
Ms. SyndamonKhyriem	Nongpyrdet	1560	25.676733	92.064400	888
Ms. IohkyntiKharumnuid	Umtung	1110	25.688683	92.027600	883
Ms. RibhaShylla	Sawnumber	210	25.693100	91.890750	863
Mr. R. R. Makdoh	Mawtnum	560	25.870033	91.888000	584
Ms. PhidalisMakdoh	Iewmawlong	880	25.893250	91.886367	550
Ms. PhotinaNongrum	Umeit	490	25.706833	91.952917	900
Ms. MilianMarsharing	Kyrdem	170	25.692817	92.074750	881
Ms. Philinda Sumer	Liarkhla	520	25.745550	92.075283	898
Mr. PhringstarUmdor	Larsyat	450	25.738533	91.886100	775
Ms. SyrpailinRymbai	Kdonghulu	1060	25.741400	92.067283	883
Mr. R. Mukhim	Nongpyrdet	530	25.676517	92.065833	876

The performance of crops, fish and livestock under demonstration were compared with the farmers' practice (no integration) in term of productivity, income and employment.

Soil and plant sample analysis

Composite soil samples were collected at 0-20 cm depth from all the demonstration sites to determine soil chemical properties. The soil pH was determined in a 1:2.5 soil:water suspension (Jackson 1973), soil organic carbon (SOC) by Walkley and Black method (1934), available N by alkaline potassium permanganate method (Subbiah and Asija 1956), available P_2O_5 by Bray's method (Bray and Kurtz 1945) and available K_2O by Ammonium Acetate Extraction method (Jackson 1973).The soils were mostly high in organic carbon (SOC), available N, K_2O and low to medium in P_2O_5 status. The soils were acidic in reaction (pH: 5-6) but the water collected from ponds were neutral in reaction (pH:7) mainly due to periodical liming and was found favourable for fish culture. Important soil chemical and fertility status of the demonstration sites are given in Table 2.

Farm layout/design and implementation

To promote MUW, integrated crop-fish-livestock systems were demonstrated in farmers' field. Field crops, fruits and vegetables were grown in association with the livestock such as pigs, ducks, etc. This system involves recycling of wastes or by-products of one farming component as an input to another component, with a view to optimize the production while maximizing the marginal return per unit input use from a unit area, with due environmental considerations. Early bearing fruits such as banana, lemon, guava, papaya and vegetables like carrot, tomato, and cabbage were cultivated close to the pond/livestock shed to generate additional income and to minimize the operational expenses on feed, fertilizers and maintained a balanced ecosystem with no waste in the system. Wherever possible high-value crops like broccoli, capsicum, etc. were cultivated for higher income and water productivity.

Training cum awareness programme

Training, practical demonstrations and awareness programmes were conducted in the Institute as well in farmers' field on various aspects of water harvesting, multiple use of water through farming system and improved crop and livestock husbandry practices. First sensitization-cum-training program on "Rain water management" was organized on 25th October, 2011. Another training-cum-demonstration programme on "Enhancing soil and water productivity" was held on the 22nd March, 2012 at ICAR Research Complex for NEH Region,

Table 2: Soil fertility status of the demonstration sites

Name of farmers	Village name	Available nutrients (kg/ha)			SOC (%)	Soil pH	Water pH
		N	P_2O_5	K_2O			
Ms. Aitihunsuting	Ladsyat	188.2	34.4	239.8	2.64	5.13	7.98
Ms. S. Sohshang	Mawbri	213.2	31.6	196.2	2.51	5.81	7.88
Mr. K. Lyngdoh	MawleinMawkhan	225.8	35.1	336.1	2.15	5.65	7.6
Mr. N. Kharpan	Umtrew	250.9	18.4	167.3	2.65	5.66	6.41
Ms. JrisLyngdoh	Road Iew	150.5	26.7	110.4	2.12	5.09	8.2
Mr. Shining Rynghang	Mawtneng	213.2	28.1	240.8	2.53	5.82	7.88
Mr. P. Nongrum	Byrwa	200.7	30.9	172.4	1.69	5.00	7.9
Ms. SyndamonKhyriem	Nongpyrdet	225.8	34.4	289.6	2.3	5.19	6.88
Ms. Iohkyntikharumnuid	Umtung	188.2	31.6	209.6	2.09	5.66	7.6
Ms. RibhaShylla	Sawnumber	225.8	18.4	46.4	1.69	5.31	7.04
Mr. R. R. Makdoh	Mawtnum	150.5	28.1	342.4	1.92	5.9	7.48
Ms. PhidalisMakdoh	Iewmawlong	138.0	40.9	649.1	2.07	5.91	7.58
Ms. PhotinaNongrum	Umeit	225.8	30.2	214.8	2.12	5.91	7.44
Ms. MilianMarsharing	Kyrdem	163.1	27.4	181.7	2.05	5.12	7.40
Ms. Philinda Sumer	Liarkhla	188.2	29.5	198.3	2.1	5.15	7.75
Mr. PhringstarUmdor	Larsyat	200.7	38.8	110.4	2.6	5.13	7.47
Ms. SyrpailinRymbai	Kdonghulu	225.8	36.5	277.8	2.1	5.1	7.84
Mr. R. Mukhim	Nongpyrdet	213.3	37.4	240.8	2.09	5.2	7.5

Umiam, Meghalaya. In both the programmes, beneficiaries and village *Panchayat* "*DorbarShnong*" members attended in a large number with active participation of woman members. During the awareness-cum-training programme, the objectives and activities to be undertaken in the selected farmers' field were highlighted. Scientists-farmers-stakeholders interaction on importance of water harvesting and conservation, efficient recycling through MUW for higher water productivity was also organized.

Developing farm ponds

The pond size ranged from 170 m^2 to as large as 1000 m^2 with average size of about 500 m^2 and depth of 1.25-1.5 m. The existing underutilized and defunct ponds of the farmers were renovated during the dry season (December to March) by removing the silts, repairing the dykes and spill ways. The unwanted weeds, bushes, weed fish, etc. were removed from the pond before stocking the fish. A total of 18 beneficiaries was selected covering 16 villages in Ri-Bhoi District of Meghalaya. Participatory approach was adopted for renovation of ponds, repairing dykes, cleaning, etc. The full cost of external materials and inputs such as GI sheet, fingerlings, lime, fertilizer, etc. were provided from the project. Whereas, for digging, repairing, making livestock sheds, etc. only 50 to 60 % costs were provided from the project and the rest were the contributions of the beneficiary farmers. The average pond sizes of the selected farmers were about 500 m^2. Wherever, the pond size was less than average size (500 m^2), additional digging was undertaken to enlarge the pond for water harvesting to promote MUW.

Liming and manuring of pond

Liming was done to raise the pH of water to about 6.5 to 7.0 for better fish growth. About 60-70 kg lime was required for a pond area of 500 m^2 in one year. About 50 % of lime was applied during the dry season (after renovation, silt removal, etc.) and rests of the limewas applied in 3-4 splits at the 30-day intervals after stocking the fingerlings. Manuring is very important for better growth of plankton (phytoplankton and zooplankton) and promoting natural food organisms for fish. Hence, 500 kg cow dung (1 kg/m^2) was applied in 4 to 5 splits. The first split application was done along with first dose of lime in dry season. The pig shed washing was effectively diverted to pond to promote growth of plankton as fish feed in pig based MUW. The droppings of ducks served as fish feed and encouraged plankton growth in fish based MUW. The manurial value of pig dung and duck droppings were analyzed and presented in Table 3. Manuring and diverting livestock washing to pond was stopped whenever excess algal gloom (green colour) observed in the pond. The piglets and ducks were fed with available on-farm materials like rice bran, broken maize, sweet potato, colocasia, kitchen waste, etc. Mineral mixture and common salts were added to the feed for better health of animals.

Table 3: Manurial value of pig dung and duck droppings

Type of Manure	Moisture (%)	N (%)	P (%)
Pig dung	70	1.6	0.35
Duck dropping	80	1.0	0.40

Pig and duck components

Low cost pig (2 x 2 m^2 size) and duck shed (2 x 1 m^2 size) were made on the pond embankments utilizing locally available materials like bamboo, wooden logs, thatch grass, Tina, etc. for providing shelter to pigs and ducks. The duck shed was constructed over the water body so that the droppings directly fall into the pond. Improved pig breeds (75 % Hampshire x 25 % Khasi local) and ducks (Khaki Campbell, Sonali) were reared for better productivity and income. Composite pisciculture was integrated with duckery (10 nos.) or pigs (2 females + 1 male) for enhancing productivity and income. The stocking was done in June/July with the onset of monsoon. A stocking density of 10,000 fingerlings/ha (1 fingerlings/m^2 pond surface area) was followed for integrated farming system (IFS). The surface, column and bottom feeders were simultaneously cultured for effective utilization of water resources. Catla, rohu, mrigal and common carpwere stocked in the ratio of 2:2:1:1. For a pond with surface area of 500 m^2, the numbers required were 166 catla, 166 rohu, 84 mrigal and 83 common carp.

Integration with fruits and vegetable

Fruits like banana, citrus, guava, papaya and vegetables like carrot, tomato, broccoli, etc. were cultivated in the pond dykes/banks, vicinity of the animal shed to generate additional income. The plant nutrition of crops was mostly met from the livestock excreta based organic manures. Some farmers used minimal amount of fertilizers (<20 kg/ha) such as di-ammonium phosphate for nutrient supply to crops. Life-saving irrigation was provided to crops manually or using 1HP Tulu pump whenever needed. Climbing vegetables like chow-chow, bottle gourd, pumpkin, etc. were trained over the water bodies using bamboo made structure for efficient utilization of space to promote vertical intensification. Furrow liming @ 500 kg/ha was advocated for higher productivity of crops and vegetables.

Pest and disease management

Adequate prophylactic measures were followed for various livestock components in farming system. The diseased animals were separated for treatment; netting was done to enhance fish health at regular intervals. For protecting crops from pest and diseases, mostly indigenous means such as application of wood ash from kitchen, *neem* oil (3 %), hand weeding, stripping diseased leaves, etc. were followed. All the produce of farm was converted to Fish Equivalent Yield (FEY) considering the local market price for comparison. B: C ratio was computed by dividing the gross return with cost of production.

Technical support

Farmers were provided with improved seeds/ breeds of crops, fruits, vegetables, fingerlings and livestock for higher productivity and income. Improved cross bred piglets (25 % Meghalaya local and 75 % Hampshire) of 2 females and 1 male was provided to each beneficiary farmer. Starter feed was also given to farmers for better growth of the piglets. Ten adult ducks (Sonali breed/Khaki campbell) were integrated with the system. Fingerlings were distributed to each farmer depending on the area of the pond (1 m^2 = 1 fingerling) during the month June-July. For small-scale mechanization, tools and implements such as an electric pump along with pipe, sprayer, cono-weeder, furrow opener, rose can, etc. were being distributed to the farmers. For technology demonstration and dissemination, leaflets in local language were prepared and distributed to the farmers. Need based technical backstopping for nutrition, and healthcare was provided to the farmers. For nutrition of crops and vegetables, effective recycling of on-farm biomass through composting, mulching, residue management, etc. was encouraged.

RESULTS AND DISCUSSION

A total of 18 farm ponds were renovated through excavation, dyke repairing, cleaning, etc. and made functional under the project. The pond size ranged from 400 m^2 to as large as 1000 m^2 with average size of about 500 $m^2$and depth of 1.25-1.5 m, which could harvest 625 m^3 to 750 m^3 of water when completely filled during the rainy season. An electric *tulu* pump (1 HP) was given to each farmer for irrigating their crops and cleaning the animal sheds, etc. Necessary training for integrated farming system to promote MUW was provided by the ICAR Research Complex for NEH Region, Umiam. After two years, the farmers could harvest about 150 kg fish from their respective ponds with an average productivity of 2800 kg/ha (Table 4). The improved ducks on an average were laying 100eggs/ annum. Improved pigs in farmers' field could give two farrowing in a single year with 7-11 piglets/ farrowing as compared to 5-7 from local breeds. However, the average number of piglets per unit was 15/year. The income from vegetables (Tomato, French bean, broccoli, *laipatta*, etc.) and fruits (Guava, Assam lemon, papaya, etc.) grown on pond dykes were also encouraging. For effective utilization of space, vegetables like mustard (*laipatta*), chilies, etc. were intercropped in between fruit plants.

The average pig dung production was 6 kg/day (2 kg/pig/day) and considering 10% washings; at least 600 g pig manure was diverted to pond every day. Similarly, average duck dropping per day was 1.5 kg (150 g/day) which was directly falling on the water body and served as fish feed. On an average, farmer earned a net income of Rs. 28,250 annually from crop-fish-pig integrated farming system unit of 1500 m^2area, i.e. Rs. 1,88,333/ha compared to the net income of only Rs. 7,360 from farmers' practice (Rs. 49,060/ha). The net return obtained from crop-fish-duck integration was Rs. 20,350 from1500 m^2area, i.e. Rs. 1,35,666/ha. Due to the adoption of diversified farming activities, the farmer's employment enhanced by about 179 % and 117% under pig and duck integrated MUW system compared to farmers' practice. Similarly, the net returns enhanced by 284% and 176% over farmers' practice with pig and duck integrated MUW system, respectively. Enhancement in cropping intensity, employment generation and farm income owing to rain water harvesting and its efficient recycling in farm ponds (Das et al. 2013) and micro rain water harvesting structure (Ghosh et al. 2009) has been reported by other researchers.

The fish equivalent yield from the pig and duck integrated MUW was 352 % and 190% higher than the farmers' practice (No integration), respectively. The water productivity under these MUW systems was also enhanced by about 2.04 and 0.98 times over farmers' practice, respectively (Table 5). The benefit: cost ratio under farmers' practice was marginally higher compared to MUW, mainly because of low investment and sustenance production system.

The interaction with the farmers and field observations revealed that the operational expenses in feed, fertilizer was minimized to a great extent (by about 50 %) due to integration of various components and effective recycling of on-farm resources such as biomass, farmyard manure, farm litters, etc. The farmers could harvest one or other components throughout the year and thus, improved nutritional security. Due to MUW in a farming system mode, the farmers' risks reduced and in the events of failure or poor performance of one enterprise, farmer got assured income from other components. Therefore, fish based integrated farming system has an immense potential to prosper in hilly states of Meghalaya, mostly due to the food habit, small land holdings, low investment requirement and high profitability.

Feedback and impact

The ponds before FPARP-II interventions were mostly defunct, underutilized, filled with garbage, infested with aquatic weeds and were mostly under unproductive domestic uses. Only local weed fish species were grown under natural condition without following any management practices. Under the presentprogramme, the renovation works were undertaken to make the ponds functional and depth was maintained at about 1.25-1.5 m through earth works. About 750 m^3 of rain water could be harvested in each pond. Thus, in 18 ponds, about 13.5 million litre rain water was harvested. In some areas, farmers filled the pond with spring water, other sources during dry season and used for multiple agricultural activities. Considering the availability of about 50 % water for life-saving irrigation, it would be possible to irrigate about 8 hectare areas under multiple crops (2 cm/irrigation) with 3 to 4 irrigations in each crop. Rest of the water

Table 4: Production, employment and income from various components of IFS

Particulars	Area allotted (m^2)	Production (kg)	Employment (Man- days)	Cost involvement (Rs.)	Gross return (Rs.)	Net return (Rs.)
Multiple use of water (Integration of components)						
Composite fish culture	500	150	10	5000	15000	10000
Tomato	250	500	15	2000	5000	3000
French bean	250	250	10	1750	5000	3250
Mixed vegetables: Chow-chow, mustard (*laipatta*), chilli, cucumber, broccoli from pond dyke /adjacent areas.	500	200	10	All sides of Pond dyke 2500	4000	1500
Banana, Assam lemon, papaya, Guava (20 plant)	-	50	2	3 sides of pond dyke 500	1000	500
Duckkery (Eggs)	9 F + 1 M	900 nos.	5	1500	3600	2100
Piggery (Piglets)	2 sow + 1 boar	15 piglet /annum	20	12500	22500	10000
Total						
Crop-fish-pig	1500		67	24250	52500	28250
Crop-fish-duck	1500		52	13250	33600	20350
Farmers' practice (Without integration)						
Fish Culture	500	50	5	1000	5000	4000
Pond dyke	500	-	-	-	-	-
Maize	200	64	5	600	960	360
Frenchbean	100	80	4	700	1600	900
Others (Chilli, turmeric, mustard (*laipatta*), etc.)	200	200	10	2000	4000	2000
Total	1500	-	24	4300	11560	7360

Table 5: Equivalent fish production, water productivity and benefit: cost ratio

Farming practice	Fish equivalent (kg)	Water productivity (kg fish/m^3 water)	Water productivity (Rs./m^3 water)	B:C ratio
Crop-fish-pig	525	0.70	70	2.16
Crop-fish-duck	336	0.45	45	2.53
Farmers' practice (no integration)	116	0.23	23	2.69

could be used for multiple activities such as composite fish culture, livestock, domestic purpose, etc.

Mr. Phringstar Umdor, from Ladsyat village Ri-Bhoi District, Meghalaya narrated that "Before adopting this improved method of farming system, I used to practice only fish culture. This is the first time that I am practicing fish-livestock cum vegetable cultivation. By following the suggestion given by the experts and field staffs from ICAR, I could easily manage this system. We were overwhelmed to see that the sow provided by the ICAR has delivered eleven (11) piglets in one farrowing. My family members are very happy, and I hope that the other sow would also deliver the same number of piglets. We have learned to cultivate bottle gourd over water bodies (pond) thus, enhancing income by vertical intensification. My family income is really boosted due to adoption of the multiple water use model demonstrated under FPARP."

CONCLUSIONS

Multiple use of pond water (MUW) through integrated farming system approach enhanced production, yield,and employment and reduced dependence on external resources. The pond water was efficiently utilised for fish culture in addition to meet the water requirement of various diversified farming activities. It was possible to get year-round employment and income due to diversification. The livelihood of farmers improved substantially due to higher income, better food and nutrition. In addition, t water productivity enhanced by about one to two times due to MUW compared to farmers' practice. The technical skills and level of exposure of farmers, to manage multiple agricultural production systems and resource recycling, enhanced substantially. In the event of failure of one component, farmers can compensate the loss through another component and hence, enhances the farmers risk bearing ability and provides resilience against risks associated with climate change. Depending upon farmers' choice, resource availability and demand in the local market, the components of farming system models for MUW has to be chosen for higher productivity, income and livelihood security.

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