Integrated rice-fish farming in hilly terraces of the Apatani Plateau, Arunachal Pradesh

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The wet rice terraces of Apatani plateau.

Arunachal Pradesh is the largest of the northeast Indian states, situated on the extreme north-eastern tip of India in the trans-Himalayan region. The state has a population of 1.38 million (2011), comprising a mosaic of cultures and traditions, with 28 major tribes and 110 sub-tribes. The land is the richest biotic prefecture of India due to its altitudinal variations and distinctive weather and climatic conditions, which are mostly dominated by the Himalayan system.

Due to the advantageous ecological conditions, agriculture is the main source of earnings in Arunachal Pradesh. Among the important crops grown in the region viz., maize, millet, wheat, pulses, potato, oil seeds, fruits and vegetables, rice is the most congenial as the major crop. These rice fields in turn have an immense potential to augment fish production in the state by providing refuges for fish. This technique of rice-fish farming is most popular among the Apatani tribe in the Ziro valley of Arunachal Pradesh in their wet rice terraces. The strains of fish species include *Cyprinus carpio specularis* (mirror carp), *C. carpio communis* (scale carp) and *C. carpio nudus* (leather carp) cultivated synchronously with local rice cultivars *(Oryza sativa)*, viz. e*amo, ampu, mipya, pyapu, pyaping* and *eylang.* The present communication is based on the information gathered by the authors during a field visit to Ziro valley for research and development programmes at villages of Yachuli, Hapoli, Hong, Hari, Hija, Bula, Dutta and Old Ziro since 2016. We interacted with the rice-fish farmers, village headmen, state fishery officers and the scientific staff of KVK to understand the skills of farming, collect samples, and learn the local socio-economic circumstances and culture in developing this manuscript.

The Apatani Plateau

The Apatani Plateau of Ziro valley is situated at around 1,550 meters altitude. The entire valley is bestowed with a unique and ingenious integrated rice-fish farming practice, locally called *ajii-ngyii*. This form of agriculture occupies around 59% of the total land area and is surrounded by hill forest (14%) interspersed with bamboo and pine agroforestry systems (17%). The land use and land cover map (Table 1) developed from GIS analysis shows a total area of 4,100 hectares as productive in the Ziro valley. The valley is split by the Kiley River and flows between the river valleys of Kamla on the north, Panior in the south and Pein on the east. All of these rivers eventually drain into the Subansiri, a major tributary of the Brahmaputra River in its north bank. The plateau receives a mean rainfall of about 400 mm, mainly during May-August and relatively little or no rains during November-February. The temperature remains mild to warm in summer and cold in winter. The annual temperature in the valley ranges from 5°C - 30°C. The wide temperature range is conducive for growth of both warm and coldwater fisheries. The cool summer weather makes the valley a major destination for

tourists all around the world. Unlike other states of India, there are neither any professional fishers in the state nor a community that can be designated as a fishing community. Thus, fish farming has been practiced on traditional lines and this knowledge has been passed on through the generations. A few of the villages where one can experience this age-old practice in the plateau are Hong, Hari, Hija, Bula, Dutta, Mudang, Bamin and Old Ziro. Hapoli is the headquarters of the Ziro valley or the Apatani Plateau with the established local administration, schools, banks and most essentially to this text the markets.

The integration of rice-fish in terraces

The people of the Ziro valley are known as *'Apatanis'* and henceforth the name Apatani plateau. They are mostly agrarian in habit and possess a rich traditional knowledge in farming practices. The efficient water management and sustainable use of the agricultural land and waste products for integrated wet rice-fish cultivation *(ajii-ngyii)* by these Apatanis in the plateau remains unmatched if compared to other tribes of the north-eastern states. Women play a major role in rice-fish cultivation from land preparation to marketing of the farm produce.

Preparation of rice-fish terraces

The rice-fish terraces are prepared soon after the final harvest of rice in the month of November. The paddy stem is cut in its mid part during the harvest of rice and the left over stems are allowed to remain in the field to decompose. The water from the terraces is completely drained so that the soil bottom is exposed to sun and dried until it cracks. This is done to avoid crop loss from pests present in the soil. During

Preparation of terraces & trenches for rice fish farming.

December-January, the farmers start plowing their fields with economically and ecologically viable conventional chopping implements *(daos)* and spades. The farmers neither make use of animal power, machines nor any advanced tools to plow their fields. This is a traditional practice and emphasis is essentially given to three major components of land preparation (Baruah and Singh, 2018) viz., the strengthening of dykes *(agher)*, the channelisation of irrigated water in the fields and the digging of trenches *(siikho/parkho/hehte)*. The earthen dykes are repaired every year by strengthening the top soil and raising the dykes up to 40-70 cm height. A freeboard of 15-25 cm is kept along the height of the dyke and a width of 30-70 cm is maintained, which is efficiently used for the production of various vegetables such as cucumber, brinjal, tomato, pumpkin, chilies, beans and crops such finger millets and maize. Raising crops on the dykes also prevents erosion of soil in water filled terraces. The irrigation system in wet

Raising of additional crops on the dykes of rice fish terraces.

A feeder channel to the rice fields.

rice terraces is unique in the valley. The system is comprised of a primary channel connected to the main Kiley River. The primary channel in turn drains its water to a highly webbed feeder channel system so that each feeder channel can at least be linked to one of the rice-fish terrace in the plateau. The feeder channels not only optimise the usage of water but also provide nutrient wash-out to the paddy field from the adjoining catchment areas. The water is conveyed from one terrace to another through a bamboo, wooden or galvanised iron pipe installed at a height of 15-25 cm above the bed to ensure proper water level. In order to contain soil erosion, bio-fencing is installed alongside of the primary channels. The trenches (30-45 cm depth) are most distinctively dug within the rice-fish terraces to facilitate movement and provide refuge to fish during warmer hours of the day. The trenches *(siikho/parkho/hehte)* are either dug perpendicular to one another or at times irregularly webbed. The trenches occupy 8-12% of the total area in each of rice-fish terraces. The trenches are provided with two outlets *(hubur)* one at the surface to release excess water and the other at the bottom for draining the field water for harvesting the fish. Both outlets are strictly guarded with bamboo screens to prevent escape of fishes during the culture period. A water level of 25-35 cm is maintained in the rice-fish plots during the season. The soil nutrients of these terraces are also retained in the plots by incorporating organic manures in the form of dung from cows and pigs and poultry litter. Azolla *(tapang)* are naturally grown as nitrogen fixer (Liu, 1995) during the fallow period and are mixed with soil at the time of field preparation. Similarly, *Lemna* spp. *(murta tapang)* is also seen growing in the rice terraces which might serve as fish food as well as a source of organic compost after its decomposition. Other inputs provided in these fields are self-decomposed agricultural wastes, paddy straw, rice husk, ash, weeds and similar materials. Subsequent to harvest, cattle are also grazed in the plots to add manure. Farmers also reported that the litter of decomposed leaves which reach out from the adjoining forest land are collected in separate water channels and are later drained to one of the primary channels to reach the cultivated plots. Treating these terraces with manures enhances the soil productivity on one hand and aids in

Natural fertilisation of the rice fish terraces with azolla and lemna.

Nursery beds for rice transplantation.

natural fish food production on the other hand. Nursery beds *(midding)* are simultaneously prepared near to these terraces on a slightly elevated surface so as to maintain an optimum quantity of water, not allowing the beds to get too dry or too wet. The nursery beds are well protected with bio fencing to avoid grazing stray animals. The seed for these nurseries are prepared in the previous year and utmost care is taken to preserve it for better germination. The rice seeds are sown in the month of February-March in these nurseries for later transplantation in the main fields.

The rice-fish-horticulture system

Efficient water management utilising water from natural streams in well planned manner is the basis for making the Apatani system suitable for rice and fish cultivation together. Women play an important role and share their work equally with men in rice-fish cultivation. Fifteen varieties of the local rice (*Oryza sativa)* are reported to be cultivated in the Ziro valley which is mostly categorised into three cultivars *eamo, mipya* and *pyaping* (Kacha, 2016). Transplantation of rice seedlings from the nurseries to the prepared terraces is conducted in April. The 65-75 day old seedlings of 10-12 cm in height are sowed manually *(aemo lilo)* by hand, keeping a distance of 4-8 cm between each. Timely weeding and partial transplanting over dead seedlings are done periodically. Finger millet *(Eleusine coracana)*, soya beans, buckwheat, maize, and barley are grown on the dykes as additional crops (Fig. 9). Vegetables such as cucumber, brinjal, tomato, pumpkin, chilies and radish are also grown on the dykes. All these crops are sown in April-May using a wooden dibbler *(damu)*. Fruits such as kiwi are grown in the adjoining lands if not directly over the dykes. Successive weeding *(ahru-hodo)* in rice field and dykes is carried out by manual labour using artisanal tools during the growing season.

Fish rearing in the fields involves one batch or two batches in a year depending upon terrace conditions. The most favoured fish species are the strains of common carp, scientifically known as *Cyprinus carpio specularis* (mirror carp), *C. carpio communis* (scale carp) and *C. carpio nudus* (leather carp) for integration with local rice varieties. Young fish of 5-8 cm size are stocked in the rice terraces 10-15 days after transplantation of rice seedlings, preferably during April-May.

Chaudhary et al. (1993) advocated rice-fish systems as an ideal integration in any rice ecosystem having fertile water, even with lower depth.The fish feed on small insects such as water beetle and larvae, which are harmful to the paddy. The waste material voided by fish acts as fertiliser for the rice. Additionally, the browsing habit of some fish such as common carp help to release fixed nutrients from the soil, also improving rice productivity (Halwart and Gupta, 2004). Apart from the common carp, species such as grass carp *(Ctenopharyngodon idella)*, silver carp *(Hypophthalmichthys molitrix)*, *Barbonymus gonionotus*, *Labeo gonius* and other

Table 1: Land use land cover of the Ziro valley

Category	Area (ha)	(%)
Agroforestry	684.34	16.69
Aquaculture	1.64	0.04
Built up (rural)	92.20	2.25
Built up (urban)	117.70	2.87
Forest	577.82	14.09
Rice fish cultivation	2423.88	59.12
Shifting cultivation - abandoned	115.10	2.81
Shifting cultivation - current	4.72	0.12
Transportation	60.29	1.47
River / stream / drain	22.31	0.54
Total area	**4,100.00**	**100.00**

Labeo species are also stocked in the plots. The fish feed on plankton and periphyton (Saikia and Das, 2008) from the system, reducing the need for expensive, externally supplied feeds. Das et al. (2007) recognised the system as a self-subtracting periphyton-based aquaculture system for the role played by rice as a surface for periphyton growth. Among the different fish species cultivated, the best results in terms of fish growth and survival is observed in common carp varieties due to their robust and hardy nature. During weeding in the rice cultivated areas fishes are guided to the dugout trenches. In the event of low rainfall and hot weather, the stagnant water of the open field becomes warm and the water in the deep trenches provides cool hideouts for the fish.

The rice-fish environment

The wet rice field is described as a temporary aquatic environment by Roger (1996) or a special type of wetland that can be considered a successor of shallow marshes or swamps by Ali (1998), which is influenced and maintained by farmers' activities. Wet rice terraces of the Apatanis may be categorised under irrigated rice ecosystems as classified for agro-ecological zones by IRRI (1993). These terraces have a perennial supply of water which has high potential for rice-fish cultivation. The aquatic environment in rice terraces of the Apatani plateau is heavily influenced by water flow in the connecting feeder channels. Typical abiotic parameters of these water channels and rice-fish environments are summarised in Table 2. Likewise, organic inputs in these rice-fish terraces increase the growth of both phytoplankton and zooplankton diversity.

Owing to the nature of the water, the aquatic flora and fauna in rice-fish environments have their origins in the irrigation channels and river sources. In the present study, it was observed that the rice-fish plots are rich in phytoplankton viz., *Spirogyra* (12-47%), *Oocytis* (40%), *Navicula* (5-14%), *Pinnularia* (6-13%), *Nitzschia* (13%), *Ulothrix* (13%), *Closterium* (13%), *Stigeoclonium* (11%) and *Ankyra* (7%). The zooplankton studies revealed that the copepods (11-90%) dominated the rice fish plots followed by cladocerans (5-25%). Similarly, the connecting feeder canals are dominated by phytoplankton such as *Fragilaria* (55%), *Spirogyra* (24%), *Spirulina* (12%), *Nitzschia* (11%), *Navicula* (7%) and *Oscillatoria* (2%). In case of fish ponds, *Euglena* dominated the phytoplankton (63%), followed by *Nitzschia* (17%), *Navicula* (14%), *Stephanodiscus* (10%) and *Desmidium* (2%). Zooplankton composition was not recorded.

The fish seed availability and hatchery facilities

The Apatani plateau is a hill locked area and is devoid of much infrastructure for fish seed production, such as a fish hatchery operated on scientific guidelines. However, some amount of common carp seed is produced by limited farmers of the valley which is not sufficient enough to fulfil the demands of the entire region. Therefore, fish seeds are required to be procured from the neighbouring state Assam in huge quantity. Fish seed vendors from Assam carry the fry and fingerling sized fish seeds to the valley and stock them in small ponds and tanks along the roadside. But the import of fish seed from other states incurs a high transportation

Table 2

Physico-chemical parameters	Water resources			
	Rice fields	**Feeder canals**	**Fish ponds**	**River**
Dissolved oxygen (mg/l)	8.92±0.67	8.97±0.34	8.27±0.21	8.97±0.32
pH	5.69±0.21	5.81±0.20	6.12±0.54	5.75±0.16
Temperature (°C)	23.99±1.30	23.21±0.74	26.58±1.61	21.31±0.19
Total dissolved solids (mg/l)	7.17±3.54	11.00±6.29	34.00±28.48	7.33±0.58
Salinity (mg/l)	0.005±0.005	0.01±0.01	0.02±0.01	0.01±0.00
Atmospheric pressure (psi)	839.48±1.90	837.17±3.46	849.77±20.64	840.00±0.87
Resistivity (MΩ-cm)	0.09±0.04	0.06±0.03	0.03±.002	0.067±0.00
Conductivity (µS/cm)	13.83±6.74	21.67±12.85	68.33±57.18	17.33±3.21
ORP (mV)	103.02±47.63	70.40±11.50	130.63±90.66	78.60±2.46
	Nutrients			
Ammonia (mg/l)	1.04±1.03	0.51±0.83	0.34±0.57	0.51±0.10
Nitrate (mg/l)	1.87±1.33	1.42±0.66	2.00±1.00	1.13±0.63
Nitrite (mg/l)	0.03±0.03	0.07±0.05	0.03±0.02	0.03±0.02
Hydrogen sulphide (mg/l)	0.29±0.12	0.35±0.14	0.27±0.15	0.15±0.06
Alkalinity (mg/l)	63.75±21.34	43.33±16.33	43.33±40.41	42.50±17.08
Total hardness (mg/l)	26±19.18	46.00±12.52	52.00±13.86	29.00±8.87
Phosphate (mg/l)	0.62±0.35	0.42±0.49	0.67±0.58	0.38±0.48
Fluoride (ppm)	0.23±0.22	0.39±0.19	0.50±0.00	0.21±0.05
Residual (free) chlorine (mg/l)	0.02±0.01	0.02±0.01	0.02±0.01	0.01±0.01
Iron (mg/l)	0.73±0.79	0.53±0.73	1.50±0.87	0.31±0.15
Silica (mg/l)	2.50±2.67	3.33±2.58	3.33±2.87	2.50±2.89

Above: Raising of additional crops on the dykes of rice-fish terraces. Below: Plantation of kiwi fruit adjoining fish ponds.

Stocking of juvenile fishes in the rice-fish plots of Ziro valley.

cost, and in turn raises the price of fish seed. Observing this constraint, ICAR-DCFR, Bhimtal, took initiatives in establishing a portable FRP made fish hatchery unit at Hari Village during 2018 in association with the Department of Fisheries, Government of Arunachal Pradesh and with the participation of the Apatani community under the banner of the Gaumco Multipurpose Cooperative Society. Members of the society were given hands-on training in broodstock management, hatchery operation, fish seed production, transportation and marketing by exposing them with the fundamental functionalities of a recognised fish hatchery at Pabhoi Fish Farm, Biswanath, Assam in the same year. This exposure visit helped the society members to undertake the fish breeding programmes, hatchery operation and fish seed production on their own. Furthermore, earthen nurseries were also developed within the premises of the FRP fish hatchery, enabling the farmers to stock different sizes and species of fish seed produced from the hatchery unit. The hatchery is being operated by women members of the society. The sustainable production of fish seed for stocking in rice-fish farming will expand women's participation further in the region.

Harvesting from rice fish terraces

The crop of rice is harvested (*antee pila* or *antee dandu*) during September-October based on the time of sowing of the rice seedlings. Rice grains are collected in a bamboo basket on the field by thrashing the grains from the stalk. The collected grains are then transported in these baskets to the granaries built by the farmers in their villages. The production rate is around 500 kg/ha/season (Saikia and Das 2008). But during our investigation it was found that the rice production may reach up to 10 tonnes/ha/season in the rice-fish terraces.

Below: Lateral dugout trenches provide hide outs for fishes.

Above: Imported fish seed from Assam. Below: Establishment of a fish hatchery at Hari village.

Skill development in fish seed production for fish farmers of the Apatani plateau.

Gear constructed from bamboo, to collect the harvested fishes from terraces.

Additional crops sowed on the dykes such as finger millet, soyabean and maize are harvested during August-September. The vegetables are harvested from time to time during July-October. For harvesting of the fishes, water is completely drained out from the paddy field. This compels the fishes to concentrate in the trenches from where they are caught by hand or by using the traditional bamboo and cane woven gears. The fishes are completely harvested before harvesting rice from the terraces. Common carp generally gain weight up to 300-500 g within a span of 3-4 months as reported by earlier investigators. However, it was observed during our field survey that the farmers start selling the fishes when they attains a weight of 65-80 g. The harvested fishes are cleaned in fresh water and are transported to the fish market.

Marketing and usage of farm produce

The varieties of rice are mostly used for self-consumption as rice is the staple food for the people of Ziro valley. Finger millet is used for food in the form of flour and for the preparation of local wine *(sarse-o)*. Similarly, maize, soyabean, buckwheat and barley are also used as local food and some of them for preparation of wine. Vegetables are sold in the market at varying prices ranged from INR 20-80. The harvested fish are carried to the local market at Hapoli, the district headquarters in Ziro valley in live condition. This short distant transportation is facilitated by carrying the live fishes in finely woven bamboo and cane cone-shaped baskets (*ajii piiwa* or *ajii raju*). The fishes are packed in layers. The basket measures approximately 50-70 cm in height and 30-45 cm at its mouth circumference and 25-35 cm at its base circumference. The transported fishes are immediately released in water filled trays in the market. The trays are made of finely woven bamboo and cane material on which a polyliner is spread to retain the water and to keep the fishes alive. The live fishes are sold at a rate of INR 300 per kg (2018). This price is fetched over the initial cost of INR 1-5 per fingerling at the time of stocking. Thus the net profit for the farmer stands more than 100% earning in addition to their regular crop of rice.

Conclusion

This study on terrace farming in the Apatani Plateau reveals that the integration of rice with fish is a low-cost sustainable practice for the rural masses to obtain high value protein, nutritional security and income from a unit area. Rice-fish farming reduces the usage of fertiliser, pesticides and herbicides in the rice field and with zero input of artificial feed to fish. Such reduction of input costs lowers farmer's economic load and increases their income from fish sale. Having such additional income, the net productivity from rice-fish integrated farming is observed to be much higher than monoculture of rice alone in the valley. Therefore, this low input self-supporting system of traditional rice-fish culture of Apatani plateau can be very well extended as a farmer-friendly avenue in other parts of Arunachal Pradesh, with necessary location-specific refinements. The quality of water is the biggest factor in any rice-fish farming system and are subject to the source of water from the feeder canals and connecting rivers. The abiotic parameters of water in rice-fish terraces of the plateau are within the optimum range and conducive for rice-fish farming. In addition, establishment of a private fish seed hatchery in the Ziro valley, along with a few maintained fish brood banks is an added advantage for ready availability of quality and quantity fish seeds for self-sufficiency among the rice-fish growers. Trials have also been made to upgrade the present strains of common carp to high yielding strains for faster growth and better productivity. The participation of women is an integral part of this farming practice and empowering them with skills in fish seed production will further enhance the farm productivity, and promote ancillary business such as net preparation, mending, feed supply and fish seed trade.

Above: Harvesting of finger millet from rice-fish dykes. Below: Fish harvested from the terraces.

Fish harvested from rice-fish terraces.

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Live fish market at Hapoli, Ziro valley.

Above: Harvesting rice in the Apatani plateau. Below: A market of Ziro valley with locally produced fish and vegetables.