Fish Farming in Rice Paddy Environments: A Re-look at the Ingenious Agricultural Heritage of the Apatanis of Northeast India

[1]Kuntal Narayan Chaudhuri and [2]Shreyashi Chaudhuri

Abstract: The rice paddy is an agriculturally-managed wetland ecosystem with the potential to produce additional aquatic plants and animals as food, along with the staple rice. A wide range of traditional fish farming methods are practiced by indigenous communities in the ubiquitous rice paddy agroecosystems of Northeast India. The Apatanis of Ziro Valley, Arunachal Pradesh, are a small but unique indigenous people of the Eastern Himalayas. Their intangible cultural heritage represents the time-tested harmonious coexistence between society and their natural environment. These settled agriculturists practice fish culture in their rice paddy terraces in the form of running water terrace rice-fish farming system, the most advanced traditional rice-fish farming technique in this region. This perfect blend of wet rice agriculture and culture fishery, further linked with animal husbandry and social forestry, is an ingenious agricultural heritage system that is integral to their cultural landscape and cultural heritage. This indigenous hill farming system sustainably uses and manages local natural and human resources to achieve a better balance between agriculture and the associated biodiversity that underpins the functioning of this food production system. This agrobiodiversity and the intersecting facets of the intangible cultural heritage of the Apatanis, sustain this advanced rice-fish farming method with socioeconomic and ecological benefits. The significance of this model farming system with innovative strategies in the form of a wide array of traditional knowledge practices is that it caters to the global environmental agenda by supporting the livelihoods of the Apatanis, ensuring their food and nutritional security and protecting their environment.

Keywords: *Apatani, Arunachal Pradesh, fish farming, indigenous agriculture, rice paddy, Northeast India, traditional knowledge practices.*

Introduction

Half of the global population depends on rice as a staple food—including almost all of East, Southeast and South Asia. However, the rice monoculture as a food production system lacks long-term sustainability (Ahmed and Garnett 2011: 84). Rizipisciculture, or integrated rice-fish farming, is the amalgamation of agriculture and pisciculture (or aquaculture). Harvesting fish—both finfish and shellfish—as an additional crop from the rice field is traditionally practiced across the cultural landscapes of Asia (Schuster 1955: 67). This, in the strict sense, involves farming rice and fish concurrently in the same field, and at the same time (Halwart and Gupta 2004: 1). Ecologically, the rice paddy is an agriculturally-managed wetland ecosystem that remains dry during at least a part of

the year. In Asia, the diversity of indigenous fish harvesting practices in rice paddy environments is probably as old as the wet rice cultivation itself (Hora 1951: 171). The water-logged rice field is a natural habitat for wild fish. Therefore, this farming practice probably started as capture fishery. Presumably, as rice cultivation progressed from shifting cultivation in rainforest clearings to sedentary farming in irrigated paddy fields, the aquatic fauna from neighbouring wetlands arriving with flood waters could easily thrive in the stagnant water within the embankments during the wet rice farming cycle. Later, the intentional stocking of selected fish in paddy fields, or culture fishery, evolved possibly due to increased demand for fish production. The rice paddy environment in its flooded state, with varying water depth depending on factors such as land topography and rainfall pattern, is a valuable agroecological system that can potentially producing additional crops of aquatic plants and animals as food for human consumption, in addition to rice—the main staple food in this part of the globe. The traditional cultivation of rice as the primary crop, supplemented with fish as a secondary crop, is economically viable (Rahman *et al*. 2012: 121) and ecologically sound (Noorhosseini-Niyaki and Bagherzadeh-Lakani 2013: 5). This also allows the optimal use of the increasingly limited natural resources such as land and water (Frei and Becker 2005: 140). Interestingly, the integrated rice-fish farming is an ideal food production system for marginalized tribal and rural communities in developing societies by producing rice—a source of plant carbohydrate—and fish—a source of animal protein—in a single agricultural plot, to achieve nutritional balance in their diet at the source itself. This review paper presents a brief overview of the traditional rice-fish farming methods practiced in Northeast India, and then focusing on the rizipisciculture of Apatanis of Ziro Valley, Arunachal Pradesh. The role of the traditional knowledge practices of the Apatanis associated with this indigenous hill farming system in the sustainable use and management of local resources, and their socioeconomic and ecological impacts were explored.

Methodology

The source of information presented here is a review of secondary sources as well as inputs from field trips to the Ziro Valley, Lower Subansri District, Arunachal Pradesh. In addition to the literature cited, general observations and personal interactions (collected with the help of local guides-interpreters) at three villages: Hong (27°33’ N, 93°50’ E), Hari (27°33’ N, 93°50’ E) and Hija (27°33’ N, 93°49’ E) were recorded and analyzed. These field studies were done during May (pre-monsoon) and October (post-monsoon), 2014, 2015 and 2017. The district museum and craft centre was also visited.

Diversity of Rizipisciculture Practices of Northeast India

Geographically, Northeast India comprising of eight states, namely Assam, Arunachal Pradesh, Nagaland, Meghalaya, Mizoram, Manipur, Sikkim and Tripura, lies between 21°34' N to 29° 50' N latitude and 87° 32' E to 97° 52' E longitude. This unique geographical region of India has not only an amazing diversity of ethnic and linguistic groups (Irshad-Ali and Das 2003: 145), but also has an enormous range of ecological habitats and life forms (Mao *et al*. 2009: 97). This region is also part of two biodiversity hotspots: the Himalayas and the Indo-Burma region.

Rice is the staple food in Northeast India. The agro ecology of the paddy fields in this region is extremely diverse in the form of upland or lowland, shallow water or deepwater, rain-fed or irrigated rice agro ecological systems (Das 2002: 43). Here, diverse methods of concurrent rice-fish farming are practised. The more primitive techniques are dependent on the naturally-occurring wild fish resources. But in the more advanced methods, indigenous or introduced carps are selectively stocked in the inundated rice fields. Earlier, Hora (1951: 171), described four indigenous methods of fish harvesting in the rice paddies of Asia: (a) catch on irrigated rice fields, (b) fish rearing as a secondary crop, (c) fish culture between harvest and planting and (d) mixed rice cultivation and fish culture, reported from Java and Kerala, but with no reference to Northeast India. Later, Das (2002: 43) categorized the traditional rice-fish farming practices prevailing in Northeast India as follows: (a) rice field capture fishery system, (b) wild aquatic cropping system, (c) mountain valley rice-fish farming system, and (d) running water terrace rice-fish farming system. The diversity of the little-known integrated rice-fish farming heritage of India's northeast (Table 1) is presented briefly to contextualize the study of the ingenuity of rizipisciculture of the Apatanis.

Rice Field Capture Fishery System:

This is the most primitive method, strictly in the form of capture fishery. The rice paddies are strategically located near wetlands, lakes and rivers in the flood plains of Assam. During the monsoon deluged these turn into an immense, continuous water body that is virtually unmanageable. Wild aquatic fauna freely enter these fields along with floodwaters, thriving alongside the rice crop. The wild fish, confined to these rain-fed, deep-water, lowland rice ecosystems, is captured over an extended period from the initial inundation of the fields by the floods (in June) to the recession of the flood waters (in November). The fish is captured by gill nets, cast nets and other indigenous devices either in rice-free patches in the fields or at their water entry-exit points. The reported average yield is 45-280 kg/hectare/year (Das 2002: 44). Along with diverse indigenous fishes, snails, crabs and aquatic vegetables like *Ipomea*, *Alternathera*, *Nymphaea*, etc. are also harvested.

Wild Aquatic Cropping System:

This is a relatively less primitive rice-fish culture method, largely in the form of capture fishery. The rice fields are situated in the foothills of all the states, surrounded by embankments to retain rainwater flowing from irrigation canals and natural watercourses with which they are well-connected. Waterlogged during the monsoons, these habitats are used to deliberately lure, trap and rear the wild aquatic fauna. Trap pits are frequently dug in each rice plot to facilitate the entry of fish into the field and to give them refuge. Often jute retting tanks are used as trap ponds. Tall local cultivars of rice such as *sali*, *bao*, *aman*, etc. are traditionally grown in these seasonal wetlands with water depth as much as 2.5 m. In addition to the direct capture of wild fish over an extensive period as described above after their entry into these irrigated, deep-water, lowland rice ecosystems, gravid females and young fingerlings are also trapped to intentionally stocked the fish and allow them to grow for 3-4 months (from June to October). When the flood waters recede, the fish moves into the trap pits and natural ditches in the plots, where they are harvested. The average yield usually ranges between 200-300 kg/hectare/year (Das 2002: 44).

Mountain Valley Rice-Fish Farming System:

This is a relatively more advanced method, mostly in the form of culture fishery. The rice fields are firmly positioned in the terraced mountain valleys of Arunachal Pradesh, Mizoram, Meghalaya, Nagaland and Tripura, surrounded by dykes to retain water flowing down the mountain streams through a system of irrigation canals. During the monsoons these flooded fields are deliberately stock with both indigenous and introduced fish species. Entry of wild fish from the neighbouring water bodies to colonize the flooded rice paddy is also allowed. The stocked fingerlings grow in the flooded field and their connecting canals, facilitated by a specially dug refuge pit in each rice plot. The canals are blocked with bamboo screens to prevent fish escape, while allowing the entry of wild fish from canals and streams. Dwarf cultivars of rice are grown in these irrigated, shallow-water, highland rice environments. After few months of growth, the fish is harvested at the end of the rice season, either in the canals or refuge pits. The average yield is about 200 kg/hectare/year (Das 2002: 45). Usually, the introduced common carp (*Cyprinus carpio*) and selected indigenous fish such as *Labeo rohita*, *Catla catla*, *Cirrhinus mrigala*, *Channa* spp. *Puntius* spp. are stocked.

Running Water Terrace Rice-Fish Farming System:

This is the most advanced method, solely in the form of culture fishery. The rice fields are precariously perched on the terraced mountain slopes of Meghalaya, Sikkim and Arunachal Pradesh, surrounded by high dykes and well-connected through an extensive system of rain-fed canals to establish an intricate water flow system from the higher terraces to the lower ones. During the monsoons these rice paddies are exclusively stocked with the introduced common carp at a high density of up to 6,000 fingerlings/ hectare. The stocked fish grows in the flooded fields on the terraces with a refuge trench in each rice plot. Dwarf cultivars of rice are generally grown in these rain-fed, shallow-water, highland rice environments. The opening of the canals is blocked with bamboo screens to prevent fish escape from the rice fields. After the few months of growth the fish is harvested during the weeding cycles or finally at end of rice season, from the refuges pits where the fish retreats as the water in the field is intentionally drained out. The average fish yield could be as high as 500 kg/hectare/year (Saikia and Das 2008: 126).

The Apatanis and their Cultural Landscape

The Ziro Valley (1,524—2,738 m), in the Lower Subansiri district of Arunachal Pradesh (22° 34' N, 88° 24' E), is considered as the 'rice bowl' of the Eastern Himalayas. This small (1,058 km^2) remote area is home to the Apatani people, a distinct hill tribe of the Tani group of central Arunachal Pradesh. However, their language, beliefs and practices are distinct from all the other Tani tribes (Goswami and Das 1990: 166). They belong to the Mongoloid stock, speak a Tibeto-Burmese language, and practice the animistic Donyi-Polo religion. Their traditional ecological knowledge has evolved since the colonization and transformation of this desolate valley in the thirteenth century (Blackburn 2004: 26). Their oral tradition (*miji-migung*) has stories to store, use and transmit this knowledge (Blackburn 2008: 16).

The indigenous hill communities of Northeast India practice rice-based subsistence farming that ranges from shifting to sedentary agriculture (Majumder *et al*. 2011: 297). Rich genetic resources of the Asian rice (*Oryza sativa*) are available in this region on account of its climatic and ethnic

diversity (Hore 2005: 1130). Diverse indigenous methods of rice-fish farming in this region have already been described. In this context, the cultural landscape of the Apatanis of Ziro Valley is a jewel among jewels. They have transformed and preserved their natural environment with their advanced sedentary agriculture, in contrast with the primitive slash-and-burn (*jhum*) farming of their neighbours. As settled agriculturists, the Apatanis have perfected the rain-fed, shallow-water cultivation of upland rice. Their complex and productive agroecosystems consist of terraced rice paddies (33 km^2) buffered by forest tracts (288 km^2). Their vast mosaic of terrace farms, spread up to the forest edges, have an intricate system of water channels connected with the river Kale, and are integrated with nearby houses (*ude*), granaries (*nesu*), burial grounds (*simaliko*), gardens (*ballu-yollu*), ponds (*ngyi super*), pens (*alyigiiri*), pastures (*polang*) and plantations (*naarun*). These are all community-managed. Their system of communal labour involves both men and women. All agricultural activities involve specialized farmer groups. Working with indigenous farm implements, human labour is the major input. Animal labour is complete absent. This results in high energy output and energy efficiency as documented before (Rai 2005: 69). The local village council (*buliang*) of male elders administers the management of natural and human resources. The biodiversity-rich natural vegetation adjoining the farms are well conserved (Rechlin and Varuni 2006: 22). This protection of the local biodiversity is though informal institutions such as social taboos and customary laws (Barooah 2007: 125). Like other indigenous communities in this underdeveloped region, the Apatanis as traditional agriculturists have entrenched cultural beliefs and practices (Chaudhuri 2008: 4). There is a fixed agricultural calendar, which is linked with agrarian rituals and festivals (Table 2). The traditional knowledge practices of the Apatanis described below in details are bio cultural innovations in these agro ecosystems where nature and culture are inexorably linked in a complex and dynamic union, as an integral part of this unique cultural landscape in this remote corner of the Eastern Himalayas.

Ingenuity of Rizipisciculture Practices of the Apatanis

The Apatanis of Ziro Valley traditionally practice the wet-rice farming in the form of an advanced indigenous hill farming system called *jaebe-aji*—the running water terrace rice-fish farming system, one of the most efficient and productive method of integrated rice-fish cultivation in Northeast India (Das 2002: 43). This ingenious agricultural strategy is an example of the indigenous agricultural approach of biodiverse farming with multiple species, and even cultivars, for the sustainable production of diverse food products. This integrates the cultivation of the major cereal rice (*pyapin*) with the farming of the common carp (*ajingiyi*) in the terrace plots (*aji*), along with the minor cereal finger millet (*sarse*) (*Eleusine coracana*) grown on the earthen bunds or dykes (*agher*) separating them. This remarkable agroecosystem has produced diverse dwarf landraces of japonica rice (*O. sativa* var. *japonica*) with unique agronomic features (Dollo *et al*. 2009: 48), as well as those of millets (Dollo *et al*. 2009: 49). Millets and maize are also separately cultivated in the uphill, drier plots (*yapyo*). This is in turn supplemented with their animal husbandry (Hazarika *et al*. 2010: 688) and social forestry (Rechlin and Varuni 2006: 23) as well.

Preparing the Rice Paddy Environments

The agricultural activities of the Apatanis start in mid-winter. In January, the fertility rites of the Murung festival herald the commencement of the agricultural calendar. Like the rest of Northeast India, this hill farming system is practised in arrays of terrace farms cut out of mountain slopes. Their skilful management of this limited land resource is vital to the running of this rice-fish farming. Each terrace plot is small (250 to 3,000 m^2) and has a small (25-35 cm deep) pit or refuge trench (*siikho*) for the fish at its centre. These plots are separated by earthen bunds that are strong (about 1.5 m in breadth and 0.5 m in height) and fortified with bamboo, cane or timber. The finger millet grown on them as a soil binder adds to this strength. A wooden shovel or crowbar called *sampeyee* is used to level the plots, raise the bunds and dig the pits. The perfect levelling of the plots and the presence of the bunds are designed to reduce soil erosion and check the loss of soil fertility. These bunds are repaired in January before the Murung festival. The *aji-lenda*, a traditional farmer group led by a male or female (*lenda-kagenee*) maintains this extensive network of dykes. The penalty for any damage to these bunds is to personally repair the damage, and bear its cost along with the fine of an adult cattle. The perimeters of these terraces are fenced with local materials to keep away marauding wildlife. Strategically, the early-maturing, low-yielding rice cultivars such as *mipya* (harvested in July), are farmed in the far-flung plots near forest margins with incidence of crop raiding by wild animals, poor soil nutrients and erratic water supply. The late-maturing, high-yielding rice cultivars such as *amo* (harvested in October), are grown in plots near the village limits. The fences are also repaired in January before the Murung festival. The *sulu-sikhii*, another farmer group supervised by a male (*sulu-kagenee*) looks after this elaborate farmyard fencing. The penalty for any damage to this fencing is to pay twice the cost of repair and the fine of an adult cattle and a traditional sword (*chirrisoye*). As in the rest of Northeast India, this hill farming system is entirely rain-fed and dependent on the monsoon. Their efficient management of the seasonally available rainwater is critical to the success of this rice-fish farming. The terrace plots are classified as *jebi*, *aane* and *ditor* based on their increasing aridity. These hill terraces are fed by an intricate system of efficient rainwater harvesting. The subtropical and temperate forests of the surrounding hills are critical in maintaining this water supply. The water of each rain-fed stream in these forest tracts is channelized into a complex succession of main canals that are meticulously planned along the edges of the valley. This water flow under the influence of gravity gets diverted through a vast network of carefully engineered primary, secondary and tertiary branch canals (*siikho*) to feed this entire succession of hill terraces. The *sampeyee* is used to dig the canals as well. During the monsoon, each terrace plot receives continuously water flow from an earthen feeder channel (*sugang*), branching off through a bamboo or wooden pipe (*hubur*). The excess water in each plot continuously flows out from to the next lower terraces through a ditch (*muhgo*) with two pipes. By simply blocking or reopening these connecting pipes each plot can be drained or flooded to a desired depth. Intentionally, pegs and pebbles are placed as energy dissipaters, and the tall reed (*pepu*) (*Phragmites karka*) is grown as a soil binder on the bed of these conduits to check soil erosion, leaching and nutrient wash off. The excess water flows through the main canals into the river Kale without much loss of organic nutrients. These canals are also repaired in January before the Murung festival. The *bogo*, another farmer group administered by a *bogo-ahtoh* (male),

maintains this intricate irrigation system. The penalty for any damage to these canals is the same as that for the bunds. The Apatanis have privately-owned plantations in the form of intensely managed bamboo groves (*bije*) located inside the villages with monocultures of runner bamboo (*tanii bije*) (*Phyllostachys bambusoides*) or tufted bamboo (*yayii*) (*Dendrocalamus hamiltonii*), and moderately managed pine groves (*sansung*) located outside the villages with the predominant blue pine (*piisa sanii*) (*Pinus wallichiana*). Their clan-owned adjoining natural forests (*moorey*) are the least managed. These habitats provide construction materials for maintaining and repairing of bunds, fencing and canals, as well as for making indigenous farm implements. The farmer group called *bije-lenda*, supervised by a male *lenda-kagenee* keeps these plantations accessible by clearing their footpaths amidst the dense undergrowth. The penalty for any damage to the plantations is to pay the cost of repair along with the fine of an adult female cattle and a calf. In February, rice seeds are sown (*andhi-lilo*) in special plots (*miding*) with rice nurseries. *Huta* a wooden trowel is used to prepare the nursery beds. Headed by a *patang-ahtoh* (female), the farmer group called *tanser-patang* prepares the beds and sows rice seeds. This farming is integrated with animal husbandry, social forestry and even their homesteads to recycle organic wastes. During the fallow season, after the panicle harvesting of rice, the plots with most of the crop biomass are used as grazing pastures. These crop residues and the cattle dung are naturally recycled to enrich the soil. Likewise, women dump organic waste from households such as kitchen waste, rice chaff (*piina*), firewood ash (*mubu*), pig excreta (*alyiekha*), poultry droppings (*paropai*) and cow dung (*siiekha*) into the fallow fields for recycling and replenishing the soil humus. Even leaf litter (*ankho*) from *moorey* forests is added to the rice fields. In March, the land is prepared for cultivation. The remaining stubbles are bunt to return nutrients to the soil. Decomposed straw (*liisi*) and burnt straw (*muyu*) are also mixed with the soil. The plots are finally levelled with the *sampeyee*. Again, headed by a *patang-ahtoh* (female), the farmer group called *konchi-patang* prepares the fields. In nearby fish ponds (*ngyi-super*) the fingerlings are raised. This coincides with the kinship festival of Myoko. The *myokung* ritual is done for restoring soil fertility. The *kide* ritual protects the crop from pests and diseases.

Fish Farming in the Rice Paddy Environments

The pre-monsoon showers usher in the main farming season for the Apatanis. The *tamu* ritual is performed now or later for protecting the crop from sudden pest attacks. In April, the rice seedlings are transplanted (*andhi ali*). This involves a seed planting technique called dibbling, widely practiced in the hill terraces where ploughing and harrowing are difficult. During the transplantation, a water level of 1-2 cm is maintained in the plots. The seedlings are put in holes (5 cm apart) made in the plots with a pointed wood or bamboo stick called *kdu*. The millet seeds are directly planted on the bunds by dibbling holes with a similar *dum*. In the higher slopes, the millet and maize seeds are likewise planted in the dry plots with the *kdu*. Yet again, headed by a *patang-ahtoh* (female), the farmer group called *halying-patang* transplants the rice seedlings and plants the minor crops. After the transplantation, fingerlings are released into the pits of the waterlogged plots, up to 5,000 fingerlings/ha (Dollo *et al*. 2009: 50). As the rice and fish grow, this water level is gradually increased up to 15 cm depending on the height of the rice cultivar and the size of the stocked fish, to ensure continued inundation of the rice fields especially for late ripening varieties. During the monsoons, the fish comes out of the trench and moves into the submerged paddy fields.

All the water outlets are blocked with bamboo screens to prevent fish escape. In July, in terraces with late-maturing varieties, fingerlings are again released after the harvest of the early batch of fish. The two crops—rice and fish—support each other through a complex interflow of matter and energy within the rice paddy environment. On one hand, the carp, an opportunistic omnivore, feeds on the detritus, phytoplanktons, periphytons, roots, buds, stem, leaves and even seeds of submerged rice field weeds, submerged leaves of the rice crop, zooplanktons, and benthic arthropods and molluscs. No fish feed is required. The carp gets enough nutrition without the farmers incurring any additional expenses. On the other hand, the bottom feeding activities of the carp also loosens the soil, increases soil aeration and enhances microbial activity to allow better recycling and availability of soil nutrients to the rice crop. The fish adds its excreta to the soil which get recycled to increase its fertility. The feeding activities of the carp create microclimatic conditions in the paddy field that are unfavourable for weeds, pests and pathogens. Their feeding behaviour uproots weeds, consumes their propagules and turns the water too turbid for their growth. They also eat the submerged plant parts of aquatic and semi-aquatic weeds that are potential hosts of rice pests, submerged plant parts of the rice crop that in diseased state are likely sources of fungal pathogens, and insects and snails including their larvae that are probable rice pests. The fish also strips off leaves at the base of the rice crop to improve air and light conditions that do not favour fungal intensifications. No agrochemicals such as fertilizer, herbicide, pesticide or fungicide are needed. The rice crop gets enough nutrients and support without any extra expenditure by the farmer. However, like any other wet rice farming system these wetland environments suffers from nutrient washout. The Apatanis additionally manage soil fertility by organic means only. The paddy fields receive natural nutrient washout from the nearby hills. The houses and granaries on higher grounds supply decomposed waste that is drained down to the rice fields. *Azolla* floating in the plots function as nitrogen fixing biofertilizer. These nutrient-rich environments are also infested with competitor plants, and antagonistic microbes and animals. The biodiversity of this agroecosystem plays a key role in the biological control of weeds, pests and pathogens. Many of the local rice cultivars are resistant to pathogens and pests (Dollo *et al*. 2009: 48). The rice ear-head bug (*Leptocorisa oratorius*) is ingenuously managed by the Apatanis by fixing short wooden or bamboo sticks in the paddy fields with impaled animals trapped from the paddy field itself to distract the adult bugs away from the rice crop (Singh and Bag 2002: 235). The finger millet growing on the bunds suppresses weeds. However, the plots require weeding (*tami-hodu*) in two or three cycles. For early-maturing varieties this is done in May during tillering and then in June during flowering. For late-maturing varieties this is done in May and June during tillering and then in August or September during flowering. During weeding cycles, the water in the field is completely drained out. The fish retreats into the trenches. This avoids extreme turbidity of the water by stirring up the soil which can harm the fish. *Kele*, a long-handled bamboo hoe with a metal apex is used for weeding the rice fields. *Pale*, a short-handled hoe is similarly used for the nearly kitchen gardens (*ballu*) and vegetable gardens (*yollu*). The extracted weed (*tamih*) is dumped in a corner of the rice field for recycling and replenishing the soil humus. The farmer group involved in preparing the rice fields also carries out the weeding. The penalty for trespassing the rice paddy (or its supporting human-modified and natural habitats such as gardens, plantations and adjacent forests) is to pay

twice the cost any damage and the fine of an adult cattle. In July, during the main agricultural festival called Dree, the *sodu* ritual is performed for ensuring seasonal rainfall and a bumper harvest from the fields and plantations. In September, the *yapung* ritual is performed to protect the nearly mature crop from the danger of torrential rains and hailstorms.

Fish Harvesting in the Rice Paddy Environments

The farming season of the Apatanis reaches its climax in October as the time of harvesting (*antee dandu*). The rice (97%) and finger millet (3%) are harvested together. In terraces with early-maturing varieties, only one fish harvest is possible, but in those with late-maturing varieties there is enough time for two or three harvests. In most terraces, harbouring late-maturing varieties, the rice, millet and last batch of fish are harvested in October. However, in fewer terraces, with early-maturing varieties, this takes place earlier in July. In terraces with late-maturing varieties, the first batch of fish is also harvested at this time. Sometimes, another batch of fish is harvested between these two seasons. The millets and maize in the drier plots of the upper slopes are also harvested in October. After the crop matures, the paddy field is finally drained off and kept dry till the next transplantation. The fish retreats into trench where they are captured after 2-3 months of growth reaching 40-50 cm length and 1.0-1.2 kg weight (Dollo *et al*. 2009: 51). A small metal sickle called *taggi* is used to harvest the cereal panicles. After threshing on a wooden board, winnowing is done with a large bamboo tray called *yapyo*. The farmer group called *enthee-patang* headed a *patang-ahtoh* (predominantly a female) is involved in threshing and winnowing the harvested crop and then transferring the grains to the granaries. After the harvest, there are few activities for the rest of the year. In November, the fences are repaired before winter. The paddy fields are left fallow and used for livestock grazing during winter. The fish capture employs indigenous bamboo devices. Predominantly, the fish is caught from the refuge trench using a conical net called *tajer*. At times, the fish is also harvested in the plot with a bag-like net called *barju*. Rarely, they are ensnared in the plot with a tray-like trap called *nyiyepakhe* or at the water outlet with a funnel-like trap called *takhung*. The harvested fish is cleaned and transported to the local market in finely-woven, conical bamboo or cane basket called *ajii-piiwa*. Different varieties of the common carp such as mirror carp (*Cyprinus carpio specularis*), scale carp (*C. carpio communis*), leather carp (*C. carpio nudus*) are cultivated (Tayo *et al*. 2016: 67). These represent 80% of the fish harvest. The rest are other introduced fishes such as grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), etc. which adds to the diversity, but are less productive (Dollo *et al*. 2009: 50). The rice production is up to 10 tonnes/ha/season (Baruah et al. 2019: 30). The fish productivity is 400-500 kg/ha/season (Rai 2005: 69). A major part the rice harvest is consumed as a staple in preparing food as grain (*empi*) and powder (*yatang*), and beverage as beer (*o*), as well as used in rituals. Still, as much as 40% of this staple is bartered with the neighbouring Nishis and Hill Miris. (Rai 2005: 69). The millet and maize are also used as food and beverage. However, most of the fish harvest is sold in the local markets with good returns (Reena and Nani 2014: 3; Baruah and Singh 2018: 189). In general, the biodiversity underling this food production system is also protected in the adjoining refuges for biodiversity. The river Kale harbours wild fish such as *tali-ngiyi* (*Channa* spp.), *papi-ngiyi* (*Puntius* spp.), *ngilyang-ngiyi* (*Schizothorax* spp.), *tabu-ngiyi* (*Macrognathus* spp.), *ribu* (*Nemaucheilus* spp.), *ngiyi-papi* (*Rasbora* spp.) (Nimachow *et al*. 2010: 27). The village-owned

natural vegetation functioning as biodiversity buffers includes the unmanaged remote forest tracts (*myodi*), as well as isolated patches of virgin forests near the villages in the form of sacred groves of blue pine (*ranthii*) or banyan (*saro-san*), two ecologically-sensitive tree species. The penalty for any unauthorized bioresource extraction from the forests is a fine that ranges from a chicken to adult cattle. The penalty for breaking any taboo of the sacred groves is the fine of an adult female cattle.

Conclusion

Global food security is a serious challenge faced by humanity on account of multiple factors such as the growing world population (Godfray *et al*. 2010: 812), limitation of agricultural resources (MacDonald 2010: 21259) and negative effects of climate change on agricultural productivity (Brown and Funk 2008: 581). The challenge before world agriculture today is to sufficiently increase food productivity while minimizing the detrimental environmental effects of modern agricultural expansion (Tilman *et al*. 2011: 20262). The rhizipisciculture of the Apatanis of Ziro Valley is a perfect blend of wet rice agriculture and culture fishery, linked with animal husbandry and social forestry. This is an ingenious agricultural heritage system encompassing diverse and complex agroecosystems maintained by this indigenous society, that are managed as an integral part of their cultural landscape, and conserved as an vital component of their cultural heritage. This traditional hill farming system of Northeast India had sustainably used limited natural resource such as land, water, nutrients and forests, effectively managed common agronomic problems such as weeds, pests and diseases, and efficiently organized abundant human resources as specialized farmer groups, to successfully adapt themselves to this challenging terrain. The Apatanis have made four key modifications in the traditional rice paddy terraces of in the Eastern Himalayas to make them more suitable for farming the introduced common carp: increased bund height, and provisions for drainage, fish refuges and fish screens. A better balance between agriculture and biodiversity benefits both (Erisman *et al*. 2016: 158). The crucial ecological services provided by the crop diversity present in these human-made habitats along with the surrounding natural habitats as refuges for the wider biodiversity underpins the functioning of this food production systems. This agrobiodiversity, intersecting with diverse aspects of their intangible cultural heritage including social practices, traditional knowledge and skills, has sustained this advanced rice-fish farming with socioeconomic and ecological benefits. These agroecosystems are still free of the multifarious threats faced by global agriculture with changes associated with the intensification of its productivity. This includes increasing dependence of farm mechanization, elite cultivars and agrochemical such as fertilizers, herbicides, pesticides and fungicides, that can degrade ecosystems, damage biodiversity, and harm the health of agricultural workers and consumers alike. The significance of this model rice-fish farming system is that it caters to the global environmental agenda by adopting diversified land usage patterns, ingenious techniques for irrigation, organic waste recycling, and biological control of weeds, pests and diseases, preference for local materials, and entrenched knowledge practices, social customs and cultural beliefs, to grow local cultivars of rice and millets along with the exotic carp, but with minimum inputs due to complex interactions between its diverse components resulting in the absence of farm machinery, modern hybrids and synthetic chemicals. In this inimitable rice-fish farming system, nature and culture are inexorably

connected in a complex and dynamic relationship that sustains the viability of their livelihoods, the resilience of this food production system and the richness of the biodiversity underlying it. This study contributes to the global mission of food security by highlighting a local solution from the rice terraces of the Ziro Valley. The traditional knowledge-based innovative practices of a sedentary farming system of the Apatanis can be explored elsewhere as a model system for the long-term sustainability of food production that is economically, environmentally and socio-culturally viable. Therefore espousing the ingenious agricultural heritage of the Apatanis could help ensure food security without compromising on the needs of future generations.

Acknowledgements

The authors are grateful to the inhabitants of the Apatani villages of Hong, Hari and Hija for their cooperation during the field work. We are grateful to Mr. Christopher Tajo and Mr. Nada Paul for their support as local guides and interpreters during our trips to Ziro Valley. We also thank the Director, National Library, Kolkata, and the Library-in-Charge of the Ramakrishna Mission Institute of Culture, Kolkata, for all the facilities extended.

References

Ahmed, N. and S. T. Garnett. 2011. 'Integrated Rice-Fish Farming in Bangladesh: Meeting the Challenges of Food Security'. *Food Security*, 3 (1): 81-92.

Barooah, J. 2007. *Customary Laws of the Apatanis of Arunachal Pradesh with Special Reference to their Land Holding System*. Guwahati: Law Research Institute.

Baruah, D, R. Posti, K. Kunal, P.A. Ganie, R.S. Tandel, D. Sarma, Garima, K. Tamang and G. Rinyo. 2019. 'Integrated Rice-Fish Farming in Hilly Terraces of the Apatani Plateau, Arunachal Pradesh'. *Aquaculture Asia*, 15 (3): 24-35.

Baruah, D. and N.D. Singh. 2018. 'Rice-Fish Cultivation of Apatanis: A High Altitude Farming System in Arunachal Pradesh. Cultivation'. *Journal of Krishi Vigyan*, 7 (1): 187 191.

Blackburn, S. 2004. 'Memories of Migration: Notes on Legends and Beads in Arunachal Pradesh, India'. *European Bulletin of Himalayan Research*, 25 (1): 15-60.

Blackburn, S. 2008. *Himalayan Tribal Tales: Oral Tradition and Culture in the Apatani Valley*. Leiden: Brill Academic Publishers.

Brown, M. E. and C. C. Funk. 2008. 'Food Security under Climate Change'. *Science*, 319 (2): 580-581.

Chaudhuri, S.K . 2008. 'Folk Belief and Resource Conservation: Reflections from Arunachal Pradesh'. *Indian Folklife*, 28 (1): 4-6.

Das, D.N. 2002. 'Fish Farming in Rice Environments of North Eastern India'. *Aquaculture Asia* 7 (2): 43-47.

Dollo, M., P.K. Samal, R.C. Sundriyal and K. Kumar. 2009. 'Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalayas, India'. *Journal of American Science*, 5 (5): 41-52.

Erisman, J.W., N. Van Eekeren, C. Koopmans, J. De Wit, W. Cuijpers, N. Oerlemans and B. Kokset. 2016. 'Agriculture and biodiversity: a better balance benefits both'. *Journal of AIMS Agriculture and Food*, 1 (2): 157-174.

Frei, M. and K. Becker. 2005. **'**Integrated Rice-Fish Culture: Coupled Production Saves Resources**'**. *Natural Resources Forum*, 29 (2): 135-143.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S.,Thomas S.M. and C. Toulmin 2010. 'Food Security: the Challenge of Feeding 9 Billion People. *Science*'. 327 (5937): 812-818.

Goswami, M.C. and P.B. Das. 1990. *The People of Arunachal Pradesh: A Physical Survey*. Itanagar: Directorate of Research, Government of Arunachal Pradesh.

Halwart, M. and M.V . Gupta. 2004. *Culture of Fish in Rice Fields*. Rome: FAO.

Hazarika, A., U. Borah, M.M. Borah, L. Bordoloi and H.N. Sarma. 2010. 'Documentation of Ecology and Food Plant of *Bos frontalis* (*Mithun*) in Arunachal Pradesh (India)'. *Journal of Environmental Research And Development*, 4 (3): 687-694.

Hora, S.L. 1951. 'Fish Culture in Rice Fields'. *Current Science*, 20 (7): 171-173.

Hore, D.K. 2005. 'Rice Diversity Collection, Conservation and Management in Northeastern India'. *Genetic Resources and Crop Evolution*, 52 (8): 1129-1140.

Irshad-Ali, A.N.M. and I. Das. 2003. 'Tribal Situation in Northeast India'. *Studies of Tribes and Tribals*, 1 (2): 141-148.

Majumder, M., A.K. Shukla and A. Arunachalam. 2011. Agricultural Practices in Northeast India and Options for Sustainable Management. In: E.J. Lichtfouse (ed.) *Sustainable Agriculture Reviews* (*Vol. 5*): *Biodiversity, Biofuels, Agroforestry and Conservation Agriculture*. pp. 287-315. Heidelberg: Springer.

Mao, A.A., T.M. Hynniewta and M. Sanjappa. 2009. 'Plant Wealth of Northeast India with Reference to Ethnobotany'. *Indian Journal of Traditional Knowledge*, 8 (1): 96-103.

MacDonald, G.M. 2010. 'Climate Change and Water in South-Western North America'. *Proceedings of the National Academy of Science*, 107 (50): 21256-21262.

Nimachow, G., J.S. Rawat, O. Dai and T. Loder. 2010. 'A Sustainable Mountain Paddy-Fish Farming of the Apatani Tribes of Arunachal Pradesh, India'. *Aquaculture Asia*, 15 (2): 25-28.

Noorhosseini-Niyaki, S.A. and F. Bagherzadeh-Lakani. 2013. 'Ecological and Biological Effects of Fish Farming in Rice Fields'. *Persian Gulf Crop Protection*, 2 (2): 1-7.

Rahman, M.A., S. Haque and P.K. Sarma. 2012. 'Socioeconomic Impact of Rice-Cum-Fish Culture in Selected Areas of Bangladesh'. *Journal of Bangladesh Agricultural University*, 10 (1): 119-123.

Rai, S.C. 2005. 'Apatani Paddy-Cum-Fish Cultivation: An Indigenous Hill Farming System of Northeast India'. *Indian Journal of Traditional Knowledge*, 4 (1): 65-71.

Rechlin, M.A. and V. Varuni. 2006. 'A Passion for Pine*:* Forest Conservation Practices of the Apatani People of Arunachal Pradesh'. *Himalaya*, 26 (1): 19-24.

Reena M. and A. Nani. 2014. 'Pisciculture Oriented Agriculture in the Ziro Valley'. *International Journal of Scientific and Research Publications*, 4 (4): 1-4.

Saikia, S.K. and D.N. Das. 2008. 'Rice-Fish Culture and its Potential in Rural Development: A Lesson from Apatani Farmers, Arunachal Pradesh, India'. *Journal of Agricultural and Rural Development*, 6 (1&2): 125-131.

Schuster, W.H. 1955. 'Fish Culture in Conjunction with Rice Cultivation'. *World Crops*, 7 (11-14): 67-70.

Singh, K.A. and Bag, T.K. 2002. Indigenous Technical Know-How Relevant to Farming Systems of Arunachal Pradesh. In: K.A. Singh (ed.) *Resource Management Perspective of Arunachal Agriculture*. pp. 234-237. Basar: Indian Council of Agricultural Research.

Tayo, T., V. Safi, T. Meena, T. Heli, T. Tabyo and N. Longjam. 2016. 'Integrated Paddy, Fish and Finger Millets Cultivation by Apatani Tribes in the Eastern Himalayan Region- Arunachal Pradesh'. *Indian Journal of Hill Farming*, 30 (1): 63-69.

Tilman, D., Balzer, C., Hill, J. and B.L. Beforta. 2011. 'Global Food Demand and the Sustainable Intensification of Agriculture'. *Proceedings of the National Academy of Science*, 108 (50): 20260–20264.

Table 1: Diversity of indigenous methods of fish production in rice paddy environments of Northeast India.

Indigenous Methods	Rice field capture fishery system	Wild aquatic cropping system	Mountain valley rice-fish farming system	Running water terrace rice-fish farming system
Rice Paddy Type	Lowland, deep-water		Highland, shallow-water	
	Rain-fed	Irrigated		Rain-fed
Fishery Type	Most primitive as exclusive capture fishery of wild fish only	Moderately primitive as capture fishery along with some culture fishery, of wild fish only	Moderately advanced as culture fishery of carps along with some capture fishery of wild fish	Most advanced as exclusive culture fishery of mostly the common carp
Geographical Distribution	Floodplains of Assam	Foothills of all Northeast states	Mountain valleys of Arunachal Pradesh, Meghalaya, Mizoram, Nagaland and Tripura	Mountain slopes of Arunachal Pradesh Meghalaya and Sikkim

Economic Productivity	45-280 kg/hectare/year (Das 2002: 44)	200-300 kg/hectare/year (Das 2002: 44)	About 200 kg/hectare/year (Das 2002: 44)	Up to 500 kg/hectare/year (Saikia and Das 2008: 126)

Table 2: Traditional agricultural calendar of the Apatanis of Ziro valley, Arunachal Pradesh, Northeast India.

Month	**Local Name**	**Agricultural Activities and related Rituals and Festivals**
January	*Murung Pulo*	Application of manure in paddy fields; repairing of bunds, fences and canals; the Murung festival as a fertility rite.
February	*Karpa Pulo*	Application of manure in paddy fields; raising of rice seedlings in nursery beds.
March	*Myoko Pulo*	Stubble burning, plot levelling and other preparation of paddy fields; raising of fingerlings in fish ponds; the Myoko festival as a kinship feast; the *myokung* ritual for soil fertility; the *kide* ritual to protect crop from pests and diseases.
April	*Halying Pulo*	Beginning of rice transplantation; plating of millets and maize; first release of fingerlings in fish pits; the *tamu* ritual for protecting crop from pest attacks.
May	*Enda Pulo*	Weeding of paddy fields.
June	*Empii Pulo*	Weeding of paddy fields.
July	*Millo Pulo*	Harvesting of early-maturing rice and millets, and earlier batch of fish; further release of fingerlings in fish pits; the Dree festival as the main agricultural celebration; the *sodu* ritual for adequate rainfall and plentiful harvest.
August	*Haalo Pulo*	Weeding of paddy fields.
September	*Bunchi Pulo*	Weeding of paddy fields; the *yapung* ritual to protect the crop from natural calamities.
October	*Bunti Pulo*	Harvesting of late-maturing rice, millets and maize, and later batch of fish.
November	*Emmo Pulo*	Application of manure in paddy fields; repairing of fencings.
December	*Nenka Pulo*	Application of manure in paddy fields; paddy field left fallow for livestock grazing.

Bio Profile of the Authors:

[1]Department of Botany, Vivekananda College, Kolkata

[2]Department of History, Calcutta Girls' College, Kolkata