Original Research Article

Sustainable Approach: Paddy-Cum-Fish And Bamboo-Cum-Pine Agroforestry In Ziro Valley, Arunachal Pradesh, India

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Abstract: Ziro, the home to the Apatani tribe and the district headquarters of Lower Subansiri district is one of the oldest towns in the Indian state of Arunachal Pradesh. The Apatanis, one of the major tribes of the beautiful state of Arunachal Pradesh are efficient natural resource managers. They are optimally utilizing the limited natural resources of the Ziro valley. The Apatani plateau is bowl-shaped, surrounded by high hills and interspersed with unique form of paddy-cum-fish and bamboo-cum-pine agroforestry practices. They have a very skilled and a uniquely evolved system of natural resource management in their settled paddy-cum-fish and the bamboo-cum-pine agroforestry system. The paddy-cum-fish cultivation involves a well integrated irrigation system enabling adequate production of both paddy and fish. The locals also possess rich traditional knowledge to maintain the bamboo-cum-pine agro-forestry. They carry out different activities in different seasons as per the needs. Ploughing of the fields, sowing of saplings, induction of fish-fingerlings into the ponds, planting of pines and bamboos, cleaning and maintenance of pine-cum-bamboo groves etc. are all done appropriately in suitable seasons. This article gives a vivid picture of the sustainable approach of the Apatanis towards managing these resources for posterity and to get maximum benefit.

Key words: Apatanis, Sustainability, Paddy-cum-fish cultivation, Bamboo-cum-pine cultivation

Introduction

Arunachal Pradesh is one of the mega biodiversity hotspots of the world and blessed with rare and endemic flora and fauna. With a higher ethnic diversity, this northeastern hill State has 26 different tribes and over 10 sub-tribes, speaking 42 different dialects. Of the total 19 districts, Lower Subansiri district is an important cultural landscape, having 5 distinct ecological zones –foothill region, rolling grasslands, plateau region (the Apatani plateauand the Talle plateau) northern and northeastern hill regions.

The North Eastern part of India is perhaps the most rich region for rice biodiversityin the world. The estimated diversity of rice found in the entire region is about 9650 (Mao *et al.*, 2009). Arunachal Pradesh itself yielded around 616 germplasm collections of rice from 1987 to 2002 (Hore, 2005). Integrated paddy-cum-fish farming systems are found in parts of China, Japan, Indonesia, Philippines, Vietnam, Malaysia, Thailand, Myanmar and India (Sinha, 1985). In India, the Apatanis of Ziro valley of Arunachal Pradesh having a settled rice farming practices along with a well-integrated pisciculture. Due to the perfection of paddy cultivation attained by them over centuries they are regarded as one of the relatively advanced tribal groups in the northeastern region of India (Furer-Haimendorf, 1962). Another distinguishing feature adding fame to them and make them distinct from their neighbors who practice shifting cultivation, is the effective utilization of every inch of the cultivable land. The typical land use pattern is in concentric circles, with privately owned land as the epicenter followed by clan land in the middle and

common village land at the periphery. In Apatani valley, about 48.38% land is under paddy-cum-fish cultivation, followed by 32.64% clan forest, 16.41% bamboo forest and 2.75% home garden. (Rai, 2005). There are six types of land which are differently managed by Apatanis. First is the *Balu* (traditional homestead garden) followed by *Aji* (wet rice field), *Yorlu* (kitchen garden located away from the village), *Bije* (bamboo garden), *Saadi* (plot of woodland especially pine trees) and *Morey* (natural forest). *Balu* and *Yorlu* provide with the vegetables to the people for daily consumption while, *Aji* is the wet rice cultivation system of farming by the locals. The bamboo plantation is called *Bije* whereas, the pine plantation is known as *Saadi*. On the other hand, the *morey* is the source of wild fruits and other non-timber forest products (NTFPs).

The Apatanis have human-managed forests traditionally nurtured by them as: (i) Pine forests and (ii) Bamboo forests, which are the key resources for their day-to-day household needs. While the pine forest is privately owned, the clan forest is a community forest, found mostly at the foothills of the valley adjacent to the settled farmland of the community, called 'Sartii'. This plantation serves the various requirements of the local inhabitants such as timber, planks, poles, fuel wood, etc. on the other hand, the local bamboo (*Phyllostachys bambusoides*) is being grown extensively in the Ziro valley. Apatanis have been managing its cultivation and utilization traditionally since generations. Thus, this article highlights the rich traditional knowledge of the Apatanis with regard to cultivation and conservation of paddy-cum-fish and bamboo-cum-pine agroforestry.

Materials and methods

Ziro, the home to the Apatani tribe and the district headquarters of Lower Subansiri district is one of the oldest towns in the Indian state of Arunachal Pradesh (Fig. 1). It is located between 27.38^{O} N and 27.63° N latitude and 93.50^{O} E and 93.83° E longitude at an elevation of 1688 meters to 2438 meters. The Ziro valley, bifurcated by the river Kele lies between the river valleys of Kamla and Khru on the north and Palin on the south. All these rivers eventually drain into the Subansiri River, a tributary of the Brahmaputra. The

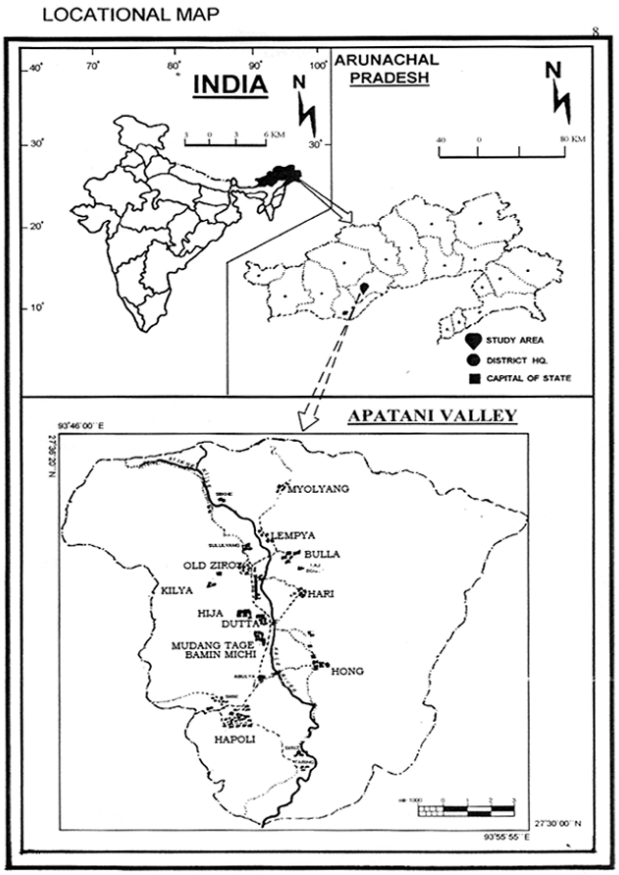

Fig.1. Map of Ziro in Lower Subansiri district of Arunachal Pradesh, India

villages are situated at the periphery of the circular valley with tropical evergreen forests, sub-tropical grasslands, and sub-tropical evergreen forests.

The Apatani plateau is bowl-shaped surrounded by high hills and interspersed with unique form of paddy-cum-fish and bamboo-cum-pine agroforests. The cool weather in the summer season is its major tourist's attraction. Recently, the UNESCO has tentatively put the Apatani valley into the list of a World Heritage Site for its "extremely high productivity" and "unique" way of preserving the ecology.

A detailed household survey was conducted in the Ziro Valley with the help of structured questionnaires, by randomly selecting 7 villages (Bulla, Dutta, Hari, Hija, Hong, Bamin Michi and Mudang Tage), consisting of 50 households in the Apatani plateau. Households were chosen on the basis of clan and house type to determine the average typical utilization pattern of bamboo and pine trees. The questionnaires covered an array of subjects related to the

land use pattern, agriculture, and the utilization of the resources by the people. Extensive interviews were conducted and informal discussions were also held with older farmers to gather information on different land-use patterns including paddy-cum-fish and bamboo-cum-pine agroforestry practices and their conservation approaches. All the observations and points raised by interviewees were noted. The important reserved forest stands of Ziro valley such as Talle wildlife sanctuary, Hakhii-tare and Moko were also visited.

Detailed data on the population, area, land use, flora, fauna, climate, ethnicity and the name of bamboo and pine varieties were collected from the district Statistical Office and Forest department, Hapoli, Lower Subansiri district and some relevant information was also collected from internet sources and were compiled together with the primary data collected from the villagers to get an authentic and first-hand information.

Results

Paddy-cum-fish agroforestry

The wet paddy-cum-fish agroforestry is extensively practised by the Apatanis in Arunachal Pradesh (Fig. 2). This unique skill of integrated paddy with fish farming (traditionally called *Aji-ngyii*) was introduced in 1980s with great success (Ramakrishnan, 1984 and 1992; Dolo, 2009; Dolo *et al*., 2009) and constantly evolved since then. The farmers of Apatani plateau cultivate different paddy varieties such as *Ampu ahare, Ampu hatte, Ampu puloohatte, Duley pyaping, Eylang mipye, Eylang eamo, Empo eamo, Halyang eamo, Hatte eamo, Kogii pyate, Mishang pyaping, Mithu mipye, Nelyi eamo, Pyare mipye, Pyate pyapu, Radhe eamo, Tanii pyaping, Tepe pyaping, Pulu pyaping, Kogii pyaping, Zeehe pyaping, Zeehe pyate, Mishang mipye.* In addition, eight different fish varieties such as common carp (*Cyprinus carpio*), Indian major carp (*Labeo rohita, Cirrhinus mrigala* and *Catla catla*) and Chinese carp (*Hypophthalmicthys molitrix, Ctenopharyngodon idella, Oreochromis niloticus* and *Puntius javanicus*) were cultivated in their wet paddy-cum-fish agroforestry. This distinct agricultural system has turned out to be very productive with 5000 to 6000 kg of rice per hectare. According to the estimation of the villagers one hectare of land yields about 180-200 kg of fish where each fingerling during release weighs around 150-400 grams. Apart from rice and fish, the locals also collect the larvae of dragon flies of Aeshnidae, Libellulidae and Gomphidae found in the water bodies and consume as local delicacy. Additionally, the paddy is supplemented with *Eleusine coracana*, which is cultivated on the elevated bunds between the rice plots.

Fig. 2. Paddy-cum-fish cultivation (1-7) - 1. Paddy field during harvest season, 2. Paddy field after harvest (terraced plot), 3. Distribution channels for the irrigation, 4. Main canal with the bio-fence, 5. Apatani woman mending bund of the field, 6. Weeding of paddy field, 7. trench with the fishes.

The paddy-cum-fish agroforestry has an intricate irrigation network of canals and channels to ensure distribution of water in every corner. The forest streams are diverted into a single canal to which each field is connected with bamboo or pinewood pipe. The water is released to the highest terrace from the main channel. From there, water is again redistributed subsequently to the other lower plots through bamboo and wooden pipes. These pipes are put above 15 – 25 cm above

the bed of the field to ensure proper water level. The main canal may succumb to soil erosion in due course of time, if not taken care of. To arrest erosion, bamboo fencing is made alongside of the main canals. These days even concrete embankments are constructed along the canals. The entire network of water channels ensures proper water supply in each and every plot. Repairing of embankments and leveling of fields are done manually with the help of large flat wooden trays. The bunds are constructed in the fields to hold the water and the nutrient-rich soils in the plots. People do not use any machine or advanced tool to plough their fields, which helps to retain the soil fertility. The fields are prepared with the help of conventional spades only.

Weeding is done manually with the help of bamboo hoes where both men and women participate actively, forming groups called *Patang*. Terraces which are flooded permanently are weeded two to three times while weeding is five to six times in terraces with less watered plots. Before the harvest of the paddy, the fields are usually kept dry for a week so that the paddy seeds would be dry and get proper maturity. Harvest of fish is done after 5-6 months of stocking in the case of seasonal culture system. In case of continuous culture, harvesting is done on yearly basis. During the harvest water is drained out, followed by collection of fish in the sumps or refuges and then it is netted out. The Apatani farmers perform pesticide-free organic farming. The soil nutrients are maintained through recycling of agricultural wastes such as paddy straw, rice husk, ash, weeds, cattle wastes, and domestic household wastes which serve as a good source of manure to the field. Additionally, the decomposed leaf litter leaching out from the forest floor is collected in separate pipes and sent to the plots.

This multi-dimensional farming system bears immense potentiality to be recognized as low-cost, but a sustainable farming practice (Saikia and Das, 2008). Such types of agro-ecosystems have become highly productive with 5000 to 6000 kg per hectare. Fishes are usually cultured well with the late ripening paddy varieties which are grown in the hard field locally called *aller aji*. The early varieties are grown in the soft fields (*zebi aji*) where, there is a risk of roots being damaged by fish. Hence, only one batch of paddy and fish are reared in such fields. On the other hand, in hard fields, two batches of fish are reared in a crop season. The first batch of fingerlings is stocked during late March to early April before the transplantation of paddy saplings which are harvested in mid-June. The second batch saplings put in July are harvested in September. A trench is prepared along the middle of the paddy field where fishes are kept at the time of weeding. During hot weather, the water in deep trench provides with the soothing environment for the fishes. Even during the harvest the fishes are caught easily from the trench using the traditional traps.

It is reported by the local inhabitants that the fish rearing in the paddy field has multiple benefits. The fishes feed on harmful insects present in the paddy fields and in return, their waste materials work as a manure for the plants. But, the fish, grass carp, feeds on paddy leaves and due to this, the grass carp is stocked only when the paddy plants grow well above the water level.

Early varieties of paddy have higher density but reduced basal area as compared to that of the late varieties. Economic yield per plant and per unit area of the early varieties is also significantly lower than that of the late varieties. Moreover, its economically viability and low cost of cultivation with minimal external inputs make it a highly organic and productive agriculture. Needless to mention that the paddy fields of Apatani agriculture are elegantly linked with animal husbandry comprising Mithun, cattle, swine and poultry.

Bamboo cum pine agroforestry

Exact reason for why and when the ethnic Apatani community started the plantation of bamboo and pine together is still obscure. Nonetheless, it was understood that the pine grew on its own when the seeds were blown and dropped in the bamboo grove. No trees other than the pine could survive successfully in the bamboo grove. Similarly, no shrubs and smaller trees could establish in the pine grove except bamboo. These generation long observations have led the local people to conclude that bamboo and pine can be grown together, as

a sustainable land use system and this type of pine-cum-bamboo agroforestry system is extensively practised at present (Fig. 3). Pine trees in the bamboo grove make the soil loose by their roots and help in aeration so that the bamboo grows properly. Pine trees have a shallow root system which makes them prone to toppling during high winds. Therefore, the bamboos growing around the pines reduce the wind force

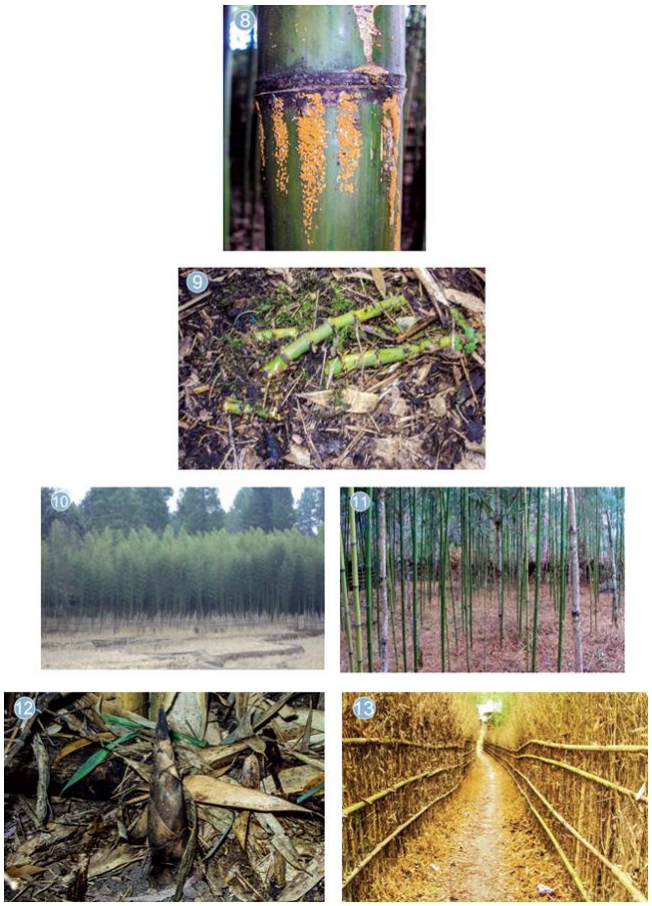

Fig. 3. Bamboo-cum-pine cultivation (8-13) - 8. The bamboo fungus 'Taipona', 9. The bamboo rhizome, 10. Bamboo-cum-pine grove, 11. Bamboo with young pines, 12. Unhealthy young bamboo shoot, 13. Bamboo fence for bamboo-cum-pine plantation.

striking the latter. Mulch produced by the pine trees is a natural soil enhancer that reduces erosion and helps slow down the evaporation of moisture from the soil. It can reduce weeds, protect tender roots and add beneficial nutrients to the soil. The decayed mulch is likely to attract fungi which can release nutrients from the plant debris to both pine and bamboo.

The bamboo varieties such as *Phyllostachys bambusoides, Dendrocalamus hamiltonii, Bambusa tulda, Pleioblastus simonii, Chimonobambusa callosa* , *Arundinaria gigantean* species and the pines such as *Pinus wallichiana, P.longifolia, P.kesiya* and *P. roxburghii* are cultivated by the local farmers. *Phyllostachys bambusoides* and *Pinus wallichiana* are the most preferred varieties of bamboo and pine respectively for co-cultivation in the Ziro valley. Initially, young pine saplings are planted in the field, which are placed at a distance of about three meters from one another. After 3-4 years, when the trees grow to about 2 meters high, bamboos are inter-planted. The bamboos of about 2-3 years with rhizome exposed are selected for planting usually in the month of January or February. Generally for plantation, mostly moist soil is preferred and water is added if the soil is dry. However, clay soil is always avoided. The bamboos are uprooted from the ground with rhizomes running towards both the directions by cutting about 1 meter on both sides. In order to plant properly the soil is dug for about 1 foot deep. The bamboo is cut from the tip below by 2 meters to prevent it from falling, due to wind. Support is also given to the plants using the bamboo frame/stand. *Phyllostachys bamboosoides* matures in 3 years after plantation. The maturity of the bamboo is indicated by the sudden appearance of fungus on the surface of the culms locally called 'Taipona' which is eaten as such by the local people.

After 6th or 7th year the branches of the pine trees are trimmed to facilitate the upward growth of the trees. When the tree circumference becomes about half a meter, then, some of the trees that are very close are cut down in order to maintain distance of about 3-6 meters. This is done after about 10-12 years. After about 25-30 years, the trees are cut for the second time when their circumference is 1-1.5 meters so as to create a space of about 25-30 meters between. Proper fencing is made to prevent the disturbances from animals attack during October-February because after February pests attack the bamboo and anything constructed from bamboo such as fencing, houses, etc. get spoiled quickly. Harvesting of bamboo is also done during this period. The

shoots found in the walking areas in the grove are also removed as they would cause disturbances when grown fully. Shoots in the crowded areas are also removed to create gaps between the growing shoots to facilitate good growth by utilizing the nutrients present in the soil. The smaller one in the group are also removed because they cannot compete with their taller counterparts for the required nutrients. The matured bamboos, if cut, should be those found along the ground, otherwise they will not die and compete with other newly growing shoots for nutrients and sunlight, thus hindering their growth. The soil around the pine trees, inside and outside the fences should be cleared annualy to prevent the fire reaching the pine trees in case of any forest fire. The grove should be cleaned at least thrice a year to facilitate good growth of both the pine trees and bamboos.

Discussion

There is enormous traditional and ecological knowledge embedded in the indigenous Apatanis of the Ziro valley. This knowledge has been derived based on the centuries of informal experimentations with the local environment in the local ecosystems for sustainable resources tapping and conservation. The local ecological setting and the high degree of dependence on natural resources make such practices exceptionally valuable. All the management practices are highly self-reliant with little external input or technologies and low dependency from external resources making it extremely endogenous and sustainable. Otherwise, generally the practice of intensive management, mainly including heavy fertilization and mulching of organic materials decreases the organic carbon pool and hence, changes the quality of the soil (Li *et al.*, 2010).

Traditional forestry in Apatani valley which includes bamboo and pine plantations, clan forests called *Moreh* etc., has been an integral part of the local system, which is judiciously guarded and meticulously tended by all the community members as it fulfils various basic needs right from food to house construction and even in religious ceremonies. Several Non Governmental Organizations, Biodiversity Management Committee (BMC) work vigilantly to preserve the bio-resources of the plateau. The local administration has also taken up some measures in this context by setting up restricted and preserved areas such as Talle wild life sanctuary and Hakhii-Tare Medicinal plants conservation. The rich plantation resources combined with the traditional conservationist attitude of the Apatanis give with solution for many economic needs of the people. Bamboos are excellent reforesting crop. They require very low (or none) consumption of fertilizers, propagates without seeds, counteracts soil erosion and preserves water table as well as the biodiversity (Montano, 2014). Hence, it helps to maintain the ecological stability of the region.

Generally, forests affect the stream water quantity and quality and the erosion (Hock *et al.*, 2009). According to Palma (2005), the plantation forests have high ecological value for water regulation and erosion control but have lesser value for biodiversity. Despite that, the plantations are most likely to contribute biodiversity when established on degraded lands or on agricultural land rather than replacing the natural ecosystems (Bremer and Farley, 2010; Brockerhoff *et al.*, 2008; Hock *et al.*, 2009). In case of Ziro valley, the plantation forests and the natural forests are well distributed, facilitating both ecological and biodiversity conservation simultaneously.

The traditional knowledge and skill related management of natural resources by the Apatani tribe are immense and can be replicated elsewhere. In the era of globalization, traditional ecological knowledge of resource management will pave way for designing new technologies for sustainable management of valuable natural resources and efficient ways of resource conservation. The traditional ecological knowledge of Apatani community on paddy-cum-fish and bamboo-cum-pine agroforestry systems is found to be highly effective in resource conservation and management, which are unique.

With the advancement of age, population of the area also has increased significantly and has put pressure on the traditionally sustainable land use management practices, leading to the introduction of new plantation, such as Kiwi plantations, to meet the local needs and cater to the needs of tourists. The population increase leads to the disintegration of cultivable land.

So, there is a need to manage the available land in such a manner that it will yield both paddy and fish together at a time to meet the need of food and capital simultaneously (Nimachow *et al*., 2010). Globally when predicted, FAO projects that feeding a world population of about 9 billion people in 2050 would require raising overall food production by at least 70 % (Dobermann, 2013). The trial of Chinese bamboo, *Moso* could also turn out to be a serious threat to the existing original bamboo lineage of the land i.e., *Phyllostachys bamboosoides* in the long run.

The challenge for development practitioners is to ensure that poor small farmers can increase the productivity of traditional farming systems, adopting an effective integrated system that produces usable biomass while conserving natural resources and can therefore, be sustainable in the long term. Sustainable development promotes rational utilization of resources and environmental protection without hampering economic growth. The new world technology such as bio-digester can be introduced and integrated to the farming system which can be implemented to utilize the organic wastes in a new dimensional way to ensure nothing to be wasted and the by-product of on ecosystem becomes the input for other (Gupta *et al*., 2012). Likewise, some advanced techniques can be incorporated with the traditional system of farming and the plantations to increase the production without compromising the environmental stability and the originality of the traditional procedures.

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