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Environmentally Sustainable Traditional Natural Resource Management and Conservation in Ziro Valley, Arunachal Himalaya, India

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Abstract: Arunachal Himalaya is the part of Eastern Himalaya with high ethnic and cultural diversity. It shares 2.5% of the total geographical area of the country, 15.76% of Indian Himalayan region and 43.62% of the Biological Hotspot, Eastern Himalaya. Apatani is one of the major ethnic tribal groups of Arunachal Himalaya inhabiting eco-culturally valued zone in Ziro valley, sharing 2.26% population of the Arunachal Pradesh. The community has distinct traditional land use practices and rich traditional ecological knowledge of natural resources management and conservation, acquired over the centuries through informal experimentation. Forest based land use has been classified into 8 sub-types having a plot size of 0.096±0.006 to 8.602±0.385 ha and agriculture with 6 sub-types of a plot size between 0.015±0.001 to 0.098±0.007 ha. Richness of forest is maintained through traditional ecological knowledge by means of selective harvesting, as well as by conserving the potential, ritualistic and socio-culturally valued species. Ziro Valley, a fascinating piece of land comprises of about 33 km^2 of cultivable areas out of 1058 km^2 of plateau, undulated by small hillocks at an elevation of 1525 m msl to a mountains tract ranging from 1830 to 2900 m in altitude. Only a limited area has been brought under cultivation, whereby the rest is under settlement and forest cover, which signifies the ecologically equilibrium management practices. Resource conservation is not only confined to forestry but also to agriculture with high agro-biodiversity (16 and 4 landraces of rice and millet respectively), and strong sense of soil and water conservation practices through indigenous technologies. Agronomic yield is five times as high as state average with maximum of 55 qha^{-1}, and is further strengthened by integration of fish culture. By appreciating the potential role of biodiversity in rural economy of Apatani and its socio-cultural values, conservation of flora and fauna is in their social norm over centuries. This paper explores the ecological management of natural and human modified ecosystems in Apatani plateau of Arunachal Himalaya in North East India. [Journal of American Science 2009;5(5):41-52]. (ISSN: 1545-1003).

Key words: Eastern Himalaya, Apatani, traditional land use, socio-cultural, agro-biodiversity, fish culture.

1. Introduction

The majority of the mountainous population of the Himalaya depends upon agricultural and forest based natural resources for their livelihood (Ramakrishnan, 1997) while the resources are sustainably maintained with traditional ecological knowledge (Dollo et al., 2005; Dollo, 2007; Farooquee et al., 2007). The traditional farming system in the Himalaya is a mixture of crop, forestry and animal husbandry (Gangwar and Ramakrishnan, 1987; Maikhuri and Ramakrishnan, 1990; Ramakrishnan, 1993; Dollo et al., 2006), and more recently horticulture (Dollo and Sundriyal, 2003). The forest is intricately linked with crop farming and livestock domestication, which provides fodder for livestock while firewood, food and medicine for humans and timber for house construction (Maikhuri, 1996; Upreti and Sundriyal, 2001), and nutrient rich runoff from forest floor to valley rich cultivation (Kumar and Ramakrishnan, 1990). Though the forest is the prime land use, agriculture is the mainstay of upland community (Ramakrishnan, 1997), where more than 85% of the total population of Arunachal Himalayan largely depends on it (Dollo and Sundriyal, 2003). Agricultural practices in upland regions are diverse, ranging from a variety of shifting cultivation systems (Ramakrishnan, 1983), fallow systems (Gangwar and Ramakrishnan, 1987), home gardens (Maikhuri and Ramakrishnan, 1990) to sedentary systems such as valley rice cultivation (Ramakrishnan, 1993; Kumar and Ramakrishnan, 1990). Each type of land use has distinct nature of management and is still sustainable where resources are managed through traditional knowledge, which has evolved through informal experimentations over centuries (Ramakrishnan et al., 1994).

Increased population pressure with consequential demand for food and cash has led the farmers to change

in the land uses as well as agro-ecosystems of the region along with rapid depletion of natural resources (Maikhuri et al., 2001). During recent past as a result, there has been a shift from more extensive to intensive systems of land use and the longer jhum fallow cycle has been replaced by shorter fallow cycle and ultimately to sedentary agriculture (Gangwar and Ramakrishnan, 1987). Animal husbandry integrated with agro-ecosystem is an important component of the tribal economic and the prosperity of a tribal family is assessed on the basis of the number of animals it owns (Gangwar and Ramakrishnan, 1987). However potentiality of livestock management has declined over the year and land degradation has taken place due to dilemma of farmers either to adopt modern or maintain traditional systems. Traditional practices in resources management are basically people's innovations to environmental stress and transformation developed and refined through trial and error (Palni and Choudhury, 2000). Of late, there has been a gradual shift the way science perceives such knowledge, which need further strengthening.

Ziro valley is categorized under sub-tropical and temperate forest with huge diversity of potential flora and fauna. The region is also well known for providing diverse NTFPs and having many places of tourist attraction, and has been considered as a centre of developmental activities during recent years. The Apatani with highly developed age-old valley rice cultivation has often been counted to be one of the advanced tribal communities in the northeastern region of India (Haimendorf, 1962). It has been known for its rich economy for decades, and has good knowledge of land, forest and water management (Chaudhary et al., 1993). The high-energy efficiency of Apatani agro-ecosystems is in contrast with that recorded from jhum in northeast India (Kumar and Ramakrishnan, 1990), and highly evolved traditional forest based natural resources management and conservation is unique in upland India (Sundriyal and Dollo, 2004). They have considerable expertise in land and water resources management. Indigenous integration of pisciculture in valley rice cultivation is distinct characteristic of Apatani agro-ecosystem, which has further boosted up the local economy. A number of studies have been carried out on agriculture system, particularly jhum system, natural resource utilization and livestock managements but there is hardly any data available on traditional natural resources management and conservation in Apatani valley with few exceptions of socio-anthropological investigations. The present paper evaluates the value of traditional natural resources management and conservation practices done by Apatani community in Ziro valley, Arunachal Himalaya of Northeastern India. This study will provide a clear understanding on environmentally sustainable indigenous resources management, availability and its future potential, which will help the policy planners and resource managers for efficient management of limited resources in fragile Himalaya in particular and other mountain regions in general.

2. Materials and Methods

2.1. Study Area

North-East India comprises of seven states, namely, Arunachal Pradesh, Assam, Maghalaya, Manipur, Mizoram, Nagaland and Tripura, which is known for high ethnic and biological diversity, and is often referred to as "Biological Hotspot" (Myers et al., 2000). Recently Sikkim is included in this conglomeration. Arunachal Pradesh has an area of 83,743 km^2 with an elevation ranging between 100-7090 m msl. The state is having a total population of 10,91,117, which comprises of 26 major and over 110 sub-tribes. It shares major geographical land area of the Northeast region, and is geo-politically importance as whole of the northern side is bounded by China, the northeastern side by Myanmar, the western by Bhutan, south-western by the state of Assam and on the southern by Nagaland. The Lower Subansiri district is located in the central western part of Arunachal Pradesh and lies between 26° 55' to 28°21' N and 92° 40' to 94° 21' E.

Table 1. Temporal change in demographic of Apatani Tribe and Arunachal Pradesh (Census of India 1961 to 2001)

Year	Population		% to state
	Apatani	Arunachal Pradesh	
1961	10,793	3,36,588	3.21
1971	12,888	4,68,511	2.75
1981	16,580	6,31,839	2.62
1991	22,526	8,64,558	2.61
2001	24,650	10,91,117	2.26

Ziro, a scenic valley, is the home of the Apatani tribe whose unique land use pattern, resource management and culture of conservation have made them a focal point of attraction (Haimendrof, 1962; Kumar and Ramakrishnan, 1990). It is the district headquarters of the Lower Subansiri, and is popularly called as "Rice Bowl of Arunachal Pradesh". It has 35 villages, with a population of 24,650 and a density of 23 people per km^2 (Table 1). The decadal (1991-2001) growth rate of 8.62 is much lower than the state (26.21%). The Valley has an area of more than 1058 km^2, of which 33 km^2 is cultivated land while the rest is under forest, plantations and settlement (http:// lowersubansiri. nic.in /html /forestpractice.htm). The valley lies between Panior and Kamla (Kuru) river at an altitude that ranges from 1525 m msl in valley to 2900 m msl in hilltops (Fig 1). The region is bounded with the areas traditionally belonging to the neighbouring Nishi and Hill-Miri tribes except south-eastern region

by Assam.

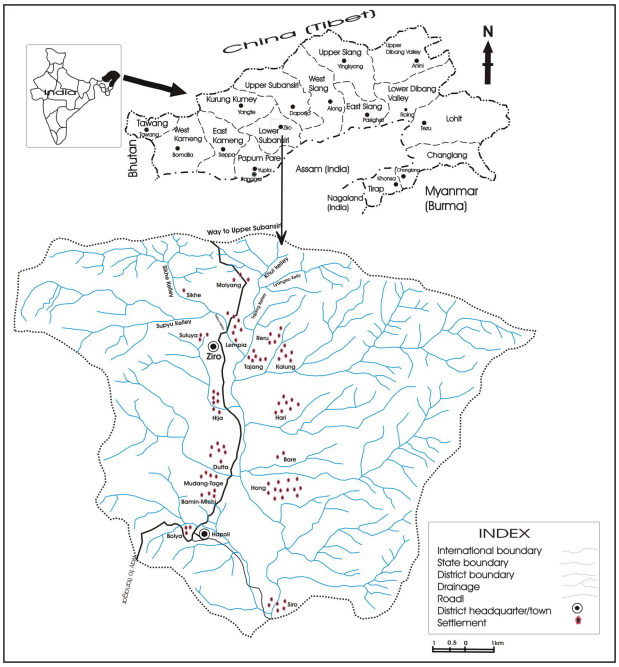

Figure 1. Location map of Ziro Valley (agriculture and settlement land only).

It has a humid subtropical to temperate types of climate with 235 cm of annual rainfall and a temperature ranging from 6.3 to 28.1°C and 1.9 to 18.4°C during summer and winter, respectively (Fig 2). The soils of the valley are humid black and reddish in colour, developed from genesis and schist overlaid on a wide area with older alluvial deposits. The top soils are sandy loam to clay loam in texture, soil pH ranges from 5.10 to 5.64, organic carbon from 1.25-2.87%, available phosphorus from 19 to 32 kgha^{-1} and exchangeable potassium from 300 to 365 gha^{-1}.

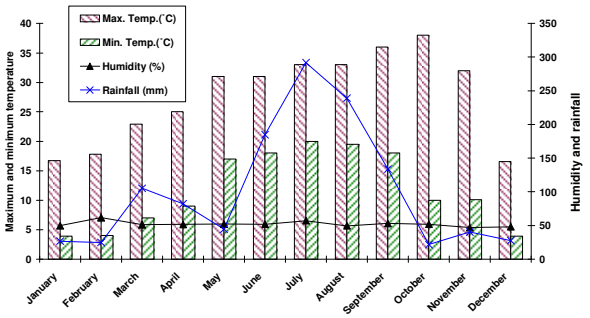

Figure 2. Climatic status of Apatani plateau

2.2. Data collection and analysis

This study is mainly based on field surveys through pre-tested questionnaire, formal and informal interviews with villagers and farmers of 5 randomly selected villages, and quadrate method for yield estimations. Field survey was made during the year 2005-2007, at least by selecting 1/4 households in each village, and the farmers were interviewed by considering all economic and social backgrounds (stratified method). The data were gathered on indigenous land use, natural resources and its sustainable management, economic yield of agro-ecosystem as well as their historical and cultural backgrounds. All the activities in the villages were closely monitored and quantified over the years for resources management. Economic yield were analysed by using thirty 1m^2 quadrates lying randomly. Economic yield per hectare was calculated on the basis of the yield from entire plot (Mishra, 1968). Fish production was measured on the basis on total fish output by 15 farmers in each village, which was further calculated into one hectare basis. Soil analyses were done by TSBF methods of Anderson and Ingram, 1993. Data collected were systematically assessed and analysed, and numerical value was treated statistically to assess the standard error, which was interpreted further for drawing conclusions.

3. Result and Discussion

Apatani tribe has been known as an efficient resources manager with rich traditional ecological knowledge, and conservative in nature, which has been attracting the UNESCO to proposed Apatani or Ziro valley as World Heritage Site. They follow a settled pattern of life and are basically agrarian. The community has evolved with unique skill of rice-fish cultivation, and unlike to most other tribal communities they do not practice shifting cultivation (Jhum). Apatanis are efficient managers of land and depend mostly on their plantations rather than on the forest for their basic needs. Such practice distinguishes them from most of the other tribes of the state and defines their distinctive lifestyle and social system. The community still maintains the age-old tradition for resources management and the modern scientific technology has little influence in this context. They have rather strengthened the traditional systems of forest management, bamboo plantation and land and water resource utilization as compared to other northeast tribal communities who have been impacted by the wind of modernization to a large extent.

3.1. Historical and cultural Background

The people of Apatani were originally belonging to

the Tibeto-Mongoloid stock (Haimendorf, 1962). They trace their descent from one legendary ancestor, Abotani. Apatanis have migrated to this magnificent Valley from northern areas beyond Kuru and Kime rivers. This is revealed from finding of three neolithic celts at Parsiparlo and Raga circle, and historical remains at Talle Valley by Archaeological Survey of India (1992). It is, therefore, apparent that they followed the path of Kuru (Kamala), Kime and Tsangpo rivers. They settled at Talle Valley for few decades and ultimately migrated to Ziro valley. Apatanis live in fairly large villages, which are compact and permanent, although during recent years they are dispersed to avoid damage by fire accidents. Housing patterns are long and made of bamboo and timber.

They believe in indigenous religion 'Donyi-poloism', and are patriarchal in social system. Earlier, they have prominent tattoo marks on the face, which, however, has been discouraged in recent past, and almost abolished now. The community is sub-divided into numerous clans but all the clans are believed to have evolved from same ancestor. The clan is the main social unit, which acts in solidarity. Like many other tribes of Arunachal Pradesh, they are highly co-operative and mutually linked up by kinship, ritualistic and friendship ties through *Binee Aajing*. The tribe practices clan exogamy and community endogamy, and believes in monogamy. Community has diverse types of ritual ceremonies and dances. Among that *Daminda* and *Pakhu-Ittu* are popular dances while *Dree, Yapung, Myoko* and *Murung* are major ritual ceremonies. *Myoko*, the most important festival is celebrated each year in the month of March in cycle manner by forming three groups, each comprised of one or numerous villages. The festivals are celebrated mainly to ensure better crop harvest, protect grain from hailstone, insect, pest, disease and wild animals, and also for the well being of individuals or community as a whole. There is Traditional Village Council to regulate the administration, which is of three tiers, namely *Akha Buliyang, Yapha Buliyang* and *Ajang Buliyang*. In each tier of council, one or two person should represent from each clan. *Akha Buliyang* hold the highest authority on any decision making body while the role of *Yapha Buliyang* is mediator and interpreter in nature and *Ajang Buliyang* acts as messenger. The position of *Buliyang* is hereditary or selected through democratic means. They are arbiters of tribal law and upholders of tribal justice, however, the individual *Buliyang* are primarily the spokesman of their own clan or village.

Apatanis are agriculturists in nature and have good numbers of traditional ecological knowledge on sustainable management of their limited resources. The exact date and time of initiation of wet rice cultivation is still untraceable but through mythology, it is believed that it might have been started at *Pega-Sarang* (name of place). Apatani oral literature suggests that *Hinkun Yari* carrying rice crops from mythological place called *Hinkun Lembyan* met *Ato Pussan* and *Ayo Tane* at *Miido Pyagan*. There, she offered varieties of rice seeds to *Ato Pussan* and *Ayo Tane* for cultivation and till now, through several generations the crops are successfully cultivated. Once upon a time, Apatani Valley was believed to be having sporadic mountains, hills and marshy land. It was the sincere and hard working effort of their ancestors to make it suitable for wet rice cultivation.

Ever since most of the Apatani farmers practice rice-cum-fish cultivation with finger millet on the bund (risers) over an area of 3297 ha, while 1003 ha is under rain-fed farming. The wet rice fields are irrigated through well-managed canal systems. It is managed by diverting numerous streams originated in the forest into single canal and through canal each agriculture field is connected with bamboo or pinewood pipe. Socio-economy of the community is mainly based upon agriculture, fishery and bamboo resources, though majority of its land area is under primary and well managed secondary forests more appropriately can be termed as sacred groves. The blue pine and bamboo plantations on the fringes of a wide mosaic of wet rice fields surrounded by thickly forested mountains on all sides, forms a picturesque landscape. Apatanis, though famed for their agricultural practices, high rice yields and forest and bamboo plantations, quantification of this land and plantation based economy has received little attention. Besides agriculture, they rear Mithun (*Bos forntalis)*, cattle, pig and poultry.

3.2. Indigenous land use

Indigenous land use classification was evolved out of century old experimentation on resource management and their effective utilizations. Categorization of lands by upland farming community of Apatani was largely based on their perception of most appropriate and sustainable use of their limited land resources. It has been well classified and regulated under the traditional customary norms. Broadly, the land is categorized into four major types and each category has numerous sub-types (Table 2). The major indicators of traditional classification of lands are available today in the forms of widely known land use practices having ecological significance, such as forest, sacred groves, agricultural, grassland, etc.

Forest is invariably managed on sloping lands in the fringe of agricultural and bamboo plantations. While human settlement is in the middle of forest and agriculture that the community can access to both the land use easily, this reduced the labour and time. Agriculture is a prime source of livelihood sustenance, which is highly inter-linked with forest ecosystem. Besides agriculture, bamboo plantations have major role

in the tribal economic and socio-cultural practices. Diversification of land uses is an example of highly successful human adaptation mechanism to the rigor and constraints of upland regions. Among all the land uses, clan forest and village forest have the largest mean plot size with 8.60 ha while granary with lowest of 0.011ha. Meanwhile the most important land use, agriculture varies from 0.098 to 0.015 ha and bamboo plantation with 0.62 ha. Sacred groves, an important land use for conservation purpose has only an average plot size of just 0.096 ha (Table 2). However, it has an important role in *in-situ* (germplasm) conservation of socio-culturally valuable, economically potential and ecologically significance species.

Table 2. Indigenous land use classification of Apatani community (*value in mean ±SE.).

Land use Type (Local name)	Plot size (ha)*	Description	Importance
1. Forest			
i) Bije	0.620±0.013	Individual bamboo forest, mixed with pine & *Castanopsis* spp.	Bamboo, timber and fuelwood extraction for construction & household requirement.
ii) Sansung	0.871±0.017	Individual forest (Castanopsis/ pine dominant forest, mostly monoculture)	Extraction of timber, fuelwood and materials for ritual ceremony.
iii) Uru Moreh	2.660±0.181	Sub-clan forest (mostly mixed forest)	Extraction of timber, bamboo, cane, fuelwood & other NTFPs for household requirement. Collection of materials for ritual ceremony, hunting & rearing of mithun.
iv)Hallu morey	8.602±0.385	Clan forest (monoculture of pine, castanopsis dominant & mixed forest)	-do-
v)Lemba Booth Morey	8.601±0.367	Village forest (mixed vegetation forest)	-do-
vi)Supung Booth Morey	-	Community forest	-do-
vii) Polung	0.106±0.009	Community/village grazing land	Grazing land for cattle
viii) Rantee	0.096±0.006	Sacred groves (Village land)	Restriction of extraction except for ritual purpose. Good seed bank for varieties of spp.
2. Agriculture			
i) Ballu	0.053±0.006	Home garden	Varieties of vegetables, pulses, chillies etc., & millet nursery for garden & bund.
ii) Yollu	0.058±0.005	Vegetable garden	-do-
iii) Lyapyo	0.031±0.002	Millet field	Millet cultivation
iv) Jaebe-Aji	0.098±0.007	Wet rice field	Rice-cum-fish culture
v) Ahi-Amii farang	0.054±0.006	Fruit garden	Apple, pears, plum, peach etc.
vi) Ngyi su-per	0.015±0.001	Fish pond	Particularly for raising fingerling for rice field.
3. Settlement			
i) Neshu Nechang	0.011±0.001	Granary	For storing rice, millet and other crops.
ii)Ude Nechang	0.048±0.002	House	Household settlement
iii) Pede Pilley	-	Farm house	Particularly for agricultural purpose
iv) Alyi giiri	-	Pig pane	Rearing pig
4. Miscellaneous			
i) Sukung	-	Well	For drinking water.
ii) Sugang	-	Canal/streams	Irrigation purpose
iii) Lenti lenda	-	Road	Communication
iv) Killey	-	River	Natural gift of water for Apatani valley

3.3. Traditional forestry

Apatanis are managing the forest and its resources through traditional customary norms under above classification. Each of the forest is sustainably managed and the resources are tapped judiciously as well. The forests of Apatani Valley comprised of four well-defined zones (Table 3). In recent time this zonation is lightly disturbed because less effort is being given on management and successional takeover of *Pinus wallichina* (*Pessa)* forest. However, it is still maintained well, which is one of the sustainable systems of forest management and is better than government regulated protected forest. The first zone is just above the rain-fed or wet rice cultivation, which is monoculture of bamboo or mixed vegetation with bamboo, pine and *Castanopsis* spp. The second zone consists of *P. wallichina* forest followed by third zone, which is a monoculture of C*astanopsis* spp., and or mixed vegetation of C*astanopsis* spp. with *Quercus* spp. etc. The fourth zone is the subtropical broad leave mixed vegetation that consists of *Quercus lanata, Castanopsis* spp. *etc.,* and temperate vegetation such as *Taxus wallichiana, Cephalotaxus* sp. etc. (Table 3). Though all forest types are important for the community, there is a high dependency on bamboo and *Castanopsis* spp. forests.

Table 3. Forest zonations and important plant species in Apatani plateau

Forest	Species	Major role
1. Bamboo plantation		
a. Monoculture	*Phyllostachys bambusoides*	Fuel wood, food, handicraft, housing and ritualistic materials.
b. Bamboo + pine	*P. bambusoides, Pinus wallichina, Alnus nepalensis,* etc.	Timber, fuel wood, food, handicraft, housing and ritualistic materials.
c. Bamboo+ castanopsis	*P. bambusoides, Castanopsis indica,, C. hystrix, C. tribuoides, A. nepalensis, Dendrocalamus hamiltoni,* etc.	Timber, fuel wood, food, handicraft, housing and ritualistic materials.
2. Pine	P. wallichina, Pyrus pashia,, Prunus nepalensis, *etc.*	Timber, fuel wood and wild edible fruits.
3. Castanopsis	*C. indica,, C. hystrix, C. tribuoides, A. nepalensis, Myrica esculenta,*	Timber, fuel wood, ritualistic materials and wild edible fruits.
4. Mixed forest		
a. Sub-tropical	*Quercus lanata, C. tribuloides, C. indica, C. hystrix, Michelia champaca, Terminalia chebula, Exbucklandia populnea, Helicia robusta, Spondias axillaris, Illicium griffithii, Actinidia callosa* (wild kiwi), *Dendrocalamus hamiltonii, Chimonobambusa* spp. etc.,	Timber, fuel wood, ritualistic materials, handicraft, wild edible fruits and herbal medicine.
b. Temperate	*Taxus baccata, Pinus wallichina, Cephalotaxus* sp. *Cedrus deodra, Tsuga dumosa, Rhododedndron arboreum, Pleioblastus simoni, Arundinaria* sp. etc.	Timber, fuel wood, ritualistic materials, wild edible fruits and herbal medicine.

All the forests are maintained through century old traditional ecological knowledge of resource management practices, which is sustainable. These forests are maintained not only to meet the fuelwood, fodder, food, and timber need of the community but also for socio-cultural and ritualistic purpose. Bamboo and pine groves meet the requirement of timber for house construction, edible bamboo shoots, fencing, erosion control, fuelwood, handicrafts and materials for ritual ceremonies. The *Sansung* (individual forest) are managed for fuelwood and material source for ritual ceremonies such as *Myoko, Murung, Subu,* etc. In addition, it has an ethno-medico-botanical resource centre for the community. The bamboo plantations are dominated with a single species *Phyllostachys bambusoides*, though the community uses other bamboo species mainly collected from primary forest. Maintenance and plantation of bamboo is done with utmost care. The rhizomes are planted during the month of February or early March, and proper weeding and selective harvesting of young bamboo shoots are done to increase the yield. It is normally carried out just a month before the emergence of young shoots, and the young shoots pruning is done by observing the nature and size of shoots. Maturation of bamboo is recognized through the development of a fungus on the surface of main stem. Normally, it is harvested after every third year.

Pine seedlings are planted during February and looping of branch is done after third year of plantation. It is believed that proper looping enhances growth and straightness of plants, beside it supplies fuelwood

requirement. *Castanopsis* spp., *Alnus nepalensis, Prunus* sp., *Prunus nepalensis, Pyrus* sp. *Quercus* spp. etc. are managed through cutting at the height of 3-8 m. This helps to promote large scale emergence of branches (coppices) and is believed that such type of management gives faster growth of plant in comparison to seedling plantation.

3.4. Farmer groups for sustainable management

It is often thought that underdeveloped or remote regions are inhabited by unorganized farmers but a closer look reveals that these farmers are often knitted together in some way. Traditional farmers groups can play a pivotal role in achieving and maintaining sustainable production in a specific agro-ecosystem. For example, Arunachal Himalaya is globally acknowledged for its rich eco-cultural heritage, and the wealth of traditional ecological knowledge amongst farmers. Shared in farmers groups who form to work on the land together, this knowledge clearly supports sustainable agro-ecosystem management in the region.

The traditional farmers groups of the Apatani people, in the Apatani Valley in the central western part of Arunachal Himalaya, have been successfully managing their natural resources for centuries. The Apatani have different types of traditional farmer groups, which have evolved over the years. There are no written records so it is impossible to trace the exact history and development of the groups. The traditional agro-ecosystems are intricately linked with nature, and are well-fitted to local environmental conditions and cultural needs. These agro-ecosystems are sustainable, self-sufficient and efficient due to strong organisations and sharing of such ecological knowledge among farmers, which has always been transmitted orally from generation to generation. Indigenous classification of agricultural land use into 7 categories for efficient land management, and to produce enough to sustain the population is an example of innovative ecological design by the farmer groups. Traditional wisdom on crop-soil interaction, ethno-pedology, nutrient management, and soil and water conservation are some examples of ecological knowledge which supports the sustainable production system as it has evolved over the decades, and which cannot be managed by individuals. The Apatani have eight different types of informal farmer organisations (Table 4) and each group has their own task and workload. The groups are valued differently by the community, for example, the *Bogo* (that looks after construction and maintenance of water sources) is seen as the most important group as there are limited water sources for irrigation in the Apatani valley, and good water management is essential for efficient production in the paddy-cum-fish system.

Table 4. Types and working nature of traditional farmer groups of the Apatani tribe (texts in italic are in the local dialect)

Local name	Description	Group Manager	Task
1. Bogo	A farmer group sharing the common water sources. The group manager leads all the activities. Posts can be held for 1-3 year(s) and are selected/ elected from within the group. Group size is between 3-600 households depending on village size.	*Bogo Ahtoh* (male)	Construction and maintenance of water supply system and regulation of the efficient sharing of water among the group
2. Aji Lenda	A group which has their fields in the same area. The group manager leads all the activities. Tenure is normally for one year only. Group size is 50-350 households.	*Lenda Kagenee* (male/ female)	Construction and maintenance of foot-paths to allow access to and from fields.
3. Sulu- sikhii	A group, which has their fields in the same area. The group manager leads all the activities. Tenure is normally for one year only. Group size is 50-350 households.	*Sulu Kagenee* (male)	Construction and maintenance of fencing to protect the agricultural fields from domestic and wild animals.
4. Tanser Patang	Groups organised during field preparation and weeding. Group size is 5-15 households.	*Patang Ahtoh* (female)	Field and nursery preparation, seed sowing, and weeding.
5. Konchi Patang	This group works in the morning between 5 am to 8 am. Group size is 5-10 households.	*Patang Ahtoh* (female)	Field preparation, transplantation and weeding.
6. Halying Patang	This group shares labour during seedling transplantation. Group size is 5-15 households.	*Patang Ahtoh* (female)	Transplantation of seedlings, particularly paddy and millet.
7. Enthee Patang	This group forms to share labour during crop harvesting. Group size is 8-12 households	*Patang Ahtoh* (male/ female)	Harvesting and carrying of harvests.
8. Bijee Lenda	A group having bamboo garden at same locality. Here also group manager leads all the activities. Tenure is normally for one year only. Group size is 70-300 households.	*Lenda Kagenee* (male)	Construction and maintenance of foot-path, a way for carrying bamboo, timber and fuelwood.

(source: Dollo, 2007)

The farmers know that traditional practices are very important for maintaining sustainable production systems, and also that the farmer groups are the foundation of these practices. Most farmers recognise that without farmer groups, agro-ecosystem management will easily weaken, and the technical ecological knowledge which supports it will erode fast. In this sense, most farmers think that the groups are effective in managing the agro-ecosystems. Except for financial support, particularly for erosion control, fencing and drainage maintenance, the farmers do not receive or seek any technological interventions or other help from any outside agencies. Outside experts highlighted the Apatani paddy-cum-fish culture system as one of the most efficient crop production systems, which has further encouraged the Apatani farmers to continue their traditional practices.

3.5. Traditional agro-ecosystem

The valley rice cultivation has undergone a steady evolution and modification through the concise management of land that led to well-drained terraces with perfect bunds (*Agher*). Generally the bunds are made up of soil, and supported by splitted bamboo and wooden pieces at base if there is chance of erosion due to splashing of water. The size of riser may vary from 0.5 to 2 m in breadth and 0.2 to 3 m in height depending on the gradient of land and the size and shape of the terraces. Perfect levelling of plots, well-managed irrigation and drainage reduce the soil erosion to a negligible level. Besides, varieties of soil and water conservation are practised by using locally available materials of bamboo, wood and cane. Average plot size is 0.098 ±0.007 ha, however, the size of plot gradually decreases towards the hills and small valleys. The average area for rice field was recorded as 0.36 ha per family in selected study villages of Apatani Valley.

The valley rice cultivation field can be categorised into three types based on practices, viz. *Jaibee-aji, Pitang-aji* and *Miding*. *Jaibee-aji* is the marshy agricultural field, which is normally kept without watering during the fallow period, while *Pitang-aji* is an agricultural land that requires water supply during fallow period, which is essentially required at least for two months otherwise the productivity of the land is considerably low with high weed infestation. *Miding* is a small size (48 m^2) agriculture land maintained for rising rice nursery. In such plots water is maintained round the year though needs to drain out just before the preparation and sowing of seed but always kept with light water supply.

The valley used for cultivation of rice is efficiently irrigated through well-managed water supply canal systems. Since time immemorial, the Apatanis have practiced a scientific system of irrigation through indigenous technique with local materials available in the region. All the diversions are made with wooden piece, bamboo and cane locally called *Bogo* (small dam/barrier). The maintenance of barrier and irrigation canal systems is managed through cooperative efforts among all the beneficiaries under the supervision of selected person(s) (*Bogo-Ahtoh*). Every stream from the surrounding hills is tapped soon after it emerges from the forest, channelized at the rim of the valley and diverted by a network of primary, secondary and tertiary channels. The discharge of the river during monsoon varies from 4.8, 13.9 and 32.2 cubic meter per second at the entrance, middle and end of the plateau, respectively. In absence of large river, the water from minor river or streams is used in such a way that all the fields get equal benefit of irrigation. To maintain this, a volume of water is diverted in feeder canal (*Segang*) and then to pipe (*Huburs/Siichoo*). The feeder canals or pipes are branched to feed many terraces by blocking or opening the connecting pipes.

Table 5. Classification of indigenous rice (*Oryzae sativa)* landraces

Land races	Duration & cultivation
1. Eamo	
i) Ampu Ahare	Early variety, most commonly cultivated, duration 195-210 days.
ii) Ampu Hatte	Late variety, commonly cultivated, duration 245-256 days.
iii) Radhe Eamo	Late variety, rarely cultivated, duration 235-245 days.
iv) Eylang Eamo	Late variety, most commonly cultivated, duration-230-240 days.
v) Ampu Puloo Hatte	Late variety, extinct, duration-260-270 days.
2. Mipye	
a) Pyate Mipye	
i) Kogii Pyate	Early variety, commonly cultivated, duration-205-215 days
ii) Zeehe Pyate	Early variety, rarely cultivated, duration-205-215 days
iii) Pyate Pyapu	Early variety, rarely cultivated, duration 195-208 days
b) Pyaping Mipye	
i) Tepe Pyaping	Early variety, most common cultivated, duration-205-215 days
ii) Pyapu Pyaping	Early variety, rarely cultivated, duration 195-208 days
iii) Kogii Pyaping	Early variety, rarely cultivated, duration 205-215 days
iv) Zeehe Pyaping	Early variety, rarely cultivated, duration 205-215 days
v) Pyare Mipye	Early variety, cultivated nearby settlement, duration 172-180 days
vi) Mishang Mipye	Early variety, rarely cultivated, duration 205-215 days
vii) Mithu Mipye	Early variety, commonly cultivated, duration 195-208 days
viii) Eylang Mipye	Early variety, rarely cultivated, duration 205-215 days

The cross section of main canal ranges between 0.8 to 1.5 m in width and 0.60 to 1.2 m in depth, while that of feeder canal ranges between 0.48 to 0.85 m in width and 0.45 to 0.75 m in depth. To check the erosion, flow of water in each feeder canal or pipe is regulated by wooden planks or stone. The most important aspect of traditional water management by Apatanis, which appears to be scientific, is to keep water layer on the soil surface at the permissible depth. For that, flow of water from one field to another is maintained through a ditch (*Muhgo*) on bund and two outlet pipes. The ditch is especially for outflow of excess water as well as maintaining the desire depth. The desire level of water is maintained by putting straws/weeds in ditches, where the height of straws/weeds is maintained accordingly. Two outlet pipes is placed in such a way that the upper one is for over flow and lower one is for draining the water completely. Normally, 1-2 cm water is maintained just after plantation, which is increased gradually with respect to rice plant growth and size of fish but is not kept more than 15 cm. In the middle of rice field a small depression or canal (*Siikho/Parkho/Hehte*) is made for water and soil management in olden time but is best suited for fish culture in present day. This canal is constructed in perpendicular as well horizontal to the bund with the help of traditional agriculture implement (*Hiita*). During agro-piscicultural activities water is drained out time to time. For weeding, water is drained twice/thrice, which coincides with harvesting of fish. In later stage, water is totally drained from field for early ripening and increase the yield as well as to make it dry during harvesting. The water from the terraces is finally drained into the *Kale* river, which flows through the middle of the valley.

Table 6. Indigenous millet *(Eleusine coracana)* landraces

Landrace	Duration & cultivation
Sarse	
Surpu Ahare	Early variety, duration 162-176 days, commonly cultivated, average productivity.
Surpu Latha	Late variety, duration 183-195 days, most commonly cultivated, high productivity.
Sartii	Late variety, duration 195-210 days, rarely cultivated, low productivity.
Ahki sarse	Late variety, duration 180-190 days, rarely cultivated, low productivity.

Apatani is having high rice diversity with 16 indigenous landraces (Table 5), which differ in height, grain characteristic, nutrition requirement, duration, productivity and resistance to disease and insect pests. All the indigenous rice landraces except *Ampu Puloo Hatte* are grown. The rice crop duration varies from 172 to 270 days with an average of 221 days (Table 5). Since 1992 high yielding rice varieties such as IR-36, Mashuri and IET6666 are introduced but with little success. The bunds of the rice fields are cultivated with millet thus leaving no portion of land unutilized. Only the indigenous millet (*Eleusine coracana*) landraces-*Surpu Latha, Surpu Ahare*, *Ahki Sarse* and *Sartii* are grown in the valley (Table 6). *Ampu Ahare, Eylang Eamo* and *Ampu Hatte* are commonly cultivated in the region, which together cover more than 67.02% of total wet rice fields. These three varieties have high productivity besides socio-religious importance. Among *Eamo* varieties of rice, cultivation of *Ampu Puloo Hatte* is not in practice probably due to its long maturation phase. While *Mipye* has 11 landraces, of this *Tepe Pyaping* is preferred the most by the farmers because of its high yield and that can sustain the marshy land. The *Pyate Mipye* and *Pyare Mipye* varieties are losing importance in recent times due to immature grain falling, which leads to low yield. Normally, the *Eamo* landraces are cultivated in medium fertile soil while *Mipye* varieties are preferred in high as well as very low fertile land. It is believed that the grains of *Eamo* landraces are abortive in highly fertile soils, and at the same time they cannot be sustained in less fertile lands as well. The yield is largely dependent on nutrient flow from villages and recycling of crop residues. Wet rice agro-ecosystems of Apatani largely depend on wash-out from the hill slopes. To sustain the productivity of rice field there is a need to maintain forest cover at high reaches.

The rice is first raised in the nursery (*Miding*) of nearly 48 m^2, which is further divided into 3-4 nursery beds (*Hohe*) of 4x3 m size. The field for nursery is normally selected in narrow valley or just near to the settlement. This is done because nursery requires more nutrients and high speed flow of wind delay the germination. If the settlement is nearby, the nurseries are fed with small canals carrying human wastes and animal excreta. Each landrace is maintained separately in nursery bed to avoid the possible mixed up of seedlings. The beds are prepared just after the completion of *Murung* festival in the month of February with the help of traditional implement (*Hiita*). The seeds are sown at the rate of 75-80 $kgha^{-1}$ that were collected through a selective procedure with high care. The seedlings (*Andee*) are maintained for 55-80 days until they attain height of 12-15 cm and 15-18 cm for lightly wet (*Pitang-aji*) and marshy (*Jaibee-aji*) fields, respectively. The finger millet nursery for bunds and rain-fed millet field is raised at home garden. The sizes, time and preparation technique of nursery beds are almost same as that of rice. After attaining of 12-16 cm height, the transplantation is done with the help of traditional implements (*Dum*). Before transplanting of rice, 5-10 cm apical portion of seedlings are removed to avoid seedling mortality. The *Dum* is used for making hole on bunds for seedlings to be transplanted.

Preparation of agricultural land begins just after the completion of *Myoko* festival in the later part of March. All the land preparations are completed by the end of April. These land operations are done manually by indigenous wooden tools (*Sampeyee, Hiita,* etc) and spade. Transplantation of seedlings begins with in the month of April and is completed by the end of May. In hard soil seedlings transplantation is done by traditional implement (*K-du*), which is mainly used for making hole. Single rice seedling is transplanted at a spacing of 12-18 cm. Terrace bunds are used for finger millet cultivation through transplanted seedlings by maintaining a spacing of 9-12 cm.

Weeds (*Ahru-tamii*) are the major problems for farmers. Weeding (*Ahru-hodo*) is done 3-4 times in a year. First weeding is done before soil preparation for transplantation in the month of February followed by second weeding in the month of July or early August, which is coincided with first fish harvesting. Third is in the late August while fourth is in September that also coincides with final harvesting of fish. Weeds are converted into compost through traditional systems by gathering all the weeds in one place, which is then covered with a thin layer of soil for quick decomposition. The weeds collected in February from bunds are used as compost for rain-fed garden, mainly for cultivation of chilies.

Table 7. Area and yield of rice and millet (*value are mean ±SE)

Crop (% cover)	Total Area in ha (%)	Yield (qha^{-1})*
Rice (97.03%)		
1. *Eamo*	2144 (67.02)	54.89±3.12
2.*Pyaping*	725 (22.66)	49.65±4.86
3. *Pyat*	330 (10.32)	42.93±3.01
Millet (2.97%)		
1. *Surpu Latha*	58(59.18)	21.01±1.03
2. *Surpu Ahare*	28(28.57)	17.23±1.14
3. *Sartii*	7(7.14)	14.35±0.98
4. *Ahki sarse*	5(5.10)	12.98±1.26

The different landraces of rice and millet differ in their yields. Productivity of rice varieties is high due to best management practices. An agronomic yield of rice varies from 43-55 qha^{-1} while that of millet is of 13-21 qha^{-1} (Table 7). Thus valley rice agro-ecosystem in Apatani Valley is highly productive being about four times higher than the average yield of the rice in the state (11 qha^{-1}) while production of millet is double than that of the state average (9 qha^{-1}). The system is economically viable and environmentally sustainable, cost of cultivation being low with minimal external inputs. For all agricultural activities 298-328 mandays are required in one hectare of land.

3.6. Indigenous integration of fish culture

Since several decades, composite of rice with fish culture was traditionally practiced with a stocking rate of 2,500-5000 fingerlings/ha by using common carp, grass carp and silver carp fishes. Integrating fish with rice cultivation assures higher per hectare economic productivity and year round employment opportunities for farmers. The plots utilized for rice-cum-fish culture are mainly fed on organic manure with a variety of animals excreta such as poultry dropping, pig excreta, cow dung and plants waste like rice husk, local beer, ashes from household burnt, and compost like decomposed straws and weeds. The Apatanis utilized varieties of domestic waste products to their rice fields to enhance soil fertility and for fish food, which in turn improves crops productivity. These are done during the fallow period of November to February month. After harvesting the crop residue is recycled by burning and natural decomposition.

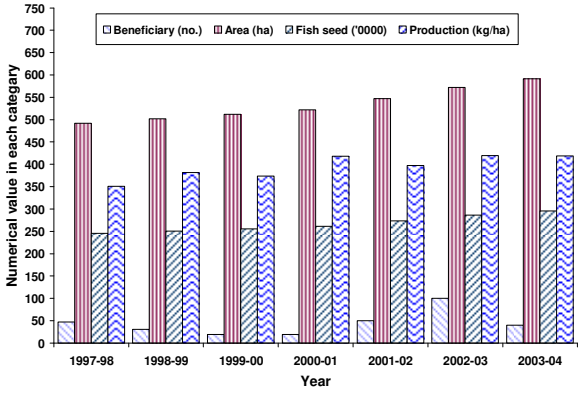

Figure 3. Governmental agency intervention in fish production activity in Ziro valley.

The fish species cultured in the valley are cyprinids viz. common carp (*Cyprinus corpio*), grass carp (*Ctenopharyngodon idelea*), silver carp (*Hypopthalmiclthys rodepix*), rohu (*Labeo rohita*), Catla (*Catla-catla*) and Mrigal (*Cinihnus mrigala*). Almost 80% of the fish production in the valley is produced from common carp followed by grass carp. Common carp breeds freely in pond environment and there is no need of hypophysation (artificial breeding). The eggs adhere to sub-merged vegetation and the egg lying capacity being 1.10 to 1.20 lakh/kg of fish, a high fecundity is maintained (Pussang, 1999). In rice-cum-fish culture 2500-5000 fingerlings/ha are cultured in present day. The size of fish increases to 110-150 g after three months and 250-300g after five months. Therefore, the production rate is about 35-42 qha^{-1}. The area under rice-cum-fish culture and total production have slightly increased over the years, while the number of

beneficiaries have slightly decreased from 47 to 40 numbers during 1997-2004 (Fig 3). The growth rate of fishes is generally higher in the first year where they attain 40-50 cm in length and 1.0-1.2 kg in weight, if proper feeding is given. Moreover, these fish species can be handled very easily without much care or expertise. It is possible to generate additional sources of income and employment generation by bringing more and more water resources of the valley under scientific exploitation with external inputs. It would be an alternative venture to obtain protein rich food for fighting against malnutrition and side-by-side generate employment opportunities for many unemployed youths among the rural population of the valley.

4. Conclusion

There is enormous traditional ecological knowledge embedded in the hilly communities of Arunachal Himalaya, particularly in Apatani community. These knowledge is based upon the centuries of informal experimentations with local environment, being adapted to local ecosystem and are effectively functioning in sustainable resources tapping and conservation. The indigenous knowledge of Apatani tribe is unique in nature and effective in functioning. However, if onslaught of modernisation and cultural infestation continue, this will lead to loss of environmentally sustainable traditional ecological knowledge forever. Traditional practices not only promote the integration and maintenance of diverse land use types, but also ensure the continuity of diverse species and varieties within each component, which are observed in traditional agro-ecosystem with diverse varieties of crop species. 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 make it extremely endogenous and sustainable.

Traditional forestry in Apatani valley has been integral part of the local system, which is judiciously guarded and meticulously tended by all community members as it fulfils various basic needs. The rich natural resources combined with traditionally conservationist attitude of the Apatani can provide solution to many economic needs of the people. The Apatanis have a natural inclination towards plantation and ecological conservation, which if properly utilized can have tremendous impact on the development of the area. The traditional knowledge and skill related to management of natural resources by the Apatani is immense and that can be replicated elsewhere.

In the era of globalisation, traditional ecological knowledge of resources management provides a useful rationale for designing new technologies for sustainable management of valuable natural resources and efficient ways of resource conservation. The ecological traditional technologies of Apatani community, such as fish-cum-paddy cultivation, bamboo and forest resources management are found to be highly effective in resource conservation and management, which are unique in nature, and economically and environmentally sustainable as well. A prerequisite, however, is proper documentation, appreciation and understanding of these ecological practices, which will help to harness the traditional knowledge to develop strategy for sustainable development of the fragile Himalayas. Although few of indigenous knowledge practices of Apatani community have been assessed by scientific world, nevertheless the need of the hour is proper documentation, analysis and in-depth understanding. Besides, sufficient credits need to be given to traditional ecological technologies and the practitionsers. The integration of fish-cum-rice culture is unique in nature, and economically and environmentally sustainable. The choice of blending such knowledge with modern scientific technologies for the well being of the local people in particular and north eastern region in general, lies with the scientific communities, policy planners and administrators. However, undermining of the efficient traditional ecological knowledge of resources management and conservation will create disturbance in social as well as ecological setting.

Acknowledgement

Authors are thankful to Director, G.B. Pant Institute of Himalayan Environment and Development, Almora for providing facilities, and the Apatani community for sharing information. Thanks are also due to Chairman and members of Nature Care and Disaster Management Society, Ziro for their helps during data collection.

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