Integrated bamboo + pine homegardens: A unique agroforestry system in Ziro Valley of Arunachal Pradesh, India

Sumpam Tangjang[1*], P. K. Ramachandran Nair[2]

[1,2]School of Forest Resources and Conservation, University of Florida, Gainesville, FL 32611
[1]Department of Botany, Rajiv Gandhi University, Rono Hills, Doimukh- 791112, Arunachal Pradesh, India

Abstract— *Numerous "indigenous" and "traditional" land-use systems that exist in different parts of the world have not yet been properly documented. Considering that many agroforestry systems of today have evolved from such systems, it is important to understand the wisdom of the indigenous communities that have continually been experimenting in their own ways to improve and adapt them for their livelihood. The Apatani eco-cultural landscape in Ziro Valley of Arunachal Pradesh, northeast India signifies an excellent example of such a uniquely distinct natural resource management practice. This agroforestry system developed over the years by innovative efforts involves growing bamboo (Phyllostachys bambusoides Siebold & Zucc.) or pine (Pinus wallichiana A.B. Jacks.) or a mixture of both on their fields. The Apatani is the only tribes in the states that manages such a unique land-use system and are highly conscious of maintaining their heritage and commitment to safeguarding nature and natural resources. By enhancing livelihood security and quality of life, conserving ecosystems, and fostering economic growth, this farmer-developed indigenous agroforestry system stands out as an example of ecosystem protection and natural-resource conservation in Arunachal Pradesh where resource-depleting shifting cultivation is still the mainstay of livelihood. Scientific analyses of the experience gained from this system – could offer lessons of valuable traditional ecological knowledge, which when properly assimilated could be useful in the design of sustainable agroforestry land-use systems.*

Keywords— Apatani tribe, Eco-cultural landscape, Eastern Himalaya, Indigenous systems, Resource conservation, Traditional ecological knowledge.

I. INTRODUCTION

Throughout the history of agriculture, the power of human ingenuity in experimenting with new ideas of crops and cropping (and farming) systems has been evident as illustrated by an enormous diversity of the so-called "indigenous" and "traditional" systems around the world. While tracing the history of development of agroforestry, several authors have described how many of the agroforestry systems of today have evolved from such indigenous systems (Nair 2001; Kumar & Nair 2006; Kumar & Nair 2011; Miller & Nair 2006). For example, homegardening, a major agroforestry practice today and one of the oldest forms of agriculture in Southeast Asia, is reported to have been associated with fishing communities living in the moist tropical region about 13 000 to 9 000 B.C. (Wiersum 2006). The dehesa (animal grazing under trees) system of Spain and other parts of southern Europe is reportedly 4500 years old (Rigueiro-Rodríguez *et al.* 2008). Most of such systems are forms of subsistence agriculture, of which a classical example is shifting cultivation. In spite of it being disparaged as unsustainable and resource-depleting, several forms of shifting cultivation are still being practiced by millions of poor farmers in the tropics (Cairns 2007 2015). While many such systems have given way to mechanized and modern forms, especially in the industrialized world, numerous indigenous systems are still prevalent in many parts of the developing world (Nair 1989). Even in industrialized regions, some forms of traditional systems that involve the principles of agroforestry are still being practiced (e.g., Herzog 1998). The satoyama system of Japan (www.satoyama-initiative.org), though strictly not a subsistence system, also embodies some of the ecological characteristics of several indigenous systems of the tropics.

These age-old practices of growing crops and trees together were ignored or bypassed in the development of modern agriculture and forestry, which focused on growing trees and crops in single-species (monocultural) production systems for maximizing their production. Moreover, agriculture and forestry were often treated separately although these two sectors are usually interwoven on the landscape and share many common goals. The realization of the adverse ecological and social consequences of input-intensive monocultural production systems led to the recognition and appreciation by the development community of the values of traditional, age-old practices of growing trees and crops together on the same unit of land (Nair 2007). Today, the significance of such traditional systems to rural livelihoods and the diverse and stable supply of economic products and benefits derived from them are more appreciated than ever before (Shackleton & Paumgarten 2008). It is also

getting recognized that understanding the historical development of indigenous systems will provide valuable information for the design of ecologically desirable agroforestry land-use systems (Miller and Nair 2006), and that researchers have much to learn from the insights of local people who are acknowledged within their own communities as experts on local plants (Cunningham 2001). Thus, documenting the traditional wisdom of the indigenous communities has gained significant attention lately (Jeeva 2006; Sarkar & Maitra 2001). Along with that, efforts have also been made to understand the *modus operandi* of some of the highly successful systems that have been developed by new settlers in some parts of the world, a typical example being the "celebrated" homegarden system practiced by Japanese settles in Tomé-Açu, Pará state, northeastern Brazil (Yamada & Osaqui 2006).

Numerous indigenous systems have been documented in varying levels of details; but many more remain to be even identified let alone studied and documented. Based on what we know about the systems that have been identified, each one is quite unique in its structure and composition, and the way in which its management practices have been developed in harmony with the local ecological and socio-cultural characteristics. Thus, each system is a location-specific entity that has been developed through repeated trial-and-error type of "experimentation" and improvised over the years by local farmers with practically no external help or support. The rural indigenous Apatani farmers in Ziro Valley of Arunachal Pradesh, India, have developed an integrated "bamboo + pine homestead agroforestry system" over the years, the knowledge on the details of which has so far been limited to the relatively small number of practitioners of the system. With the recent recognition of Ziro Valley as a tentative UNESCO World Heritage Site for its "extremely high productivity" and the "unique" way of preserving the ecology (Dollo *et al.* 2009), this hitherto-unknown land-use system is now receiving wider attention. This paper presents an analytical description of this unique bamboo + pine indigenous system.

II. MATERIAL AND METHOD

Arunachal Pradesh, whose name meaning the "Land of Dawn-lit Mountains," is the largest (area ~ 84,000 km^2) among the northeast Indian states, commonly known as the "Eight Sister States". Located at 26°28′ – 29°30′ N and 91°30′ – 97°30′ E, the predominantly hilly and mountainous state is one of the remotest and poorest among Indian states and is sparsely populated (total population: about 1.38 million; population density: 17 persons per km^2 – compared with 382 for India as a whole) (Census Report of Arunachal Pradesh 2011). It is bordered by Bhutan to the west, Myanmar (Burma) to the east, the Tibetan region of the Peoples Republic of China in the north and the Indian states of Assam and Nagaland to the South. The state has a rich diversity of flora and fauna, and is recognized as one among the 200 globally important ecoregions (Olson & Dinerstein 1998).

The state's inhabitants are predominantly rural and represent many of India's so-called Scheduled Tribes. Twenty-six major tribes and about 110 sub-tribes have been recognized in the state that depend largely on agricultural and forest-based natural resources for their livelihood, and these resources have been sustainably maintained with traditional ecological knowledge, TEK (Dollo *et al.* 2009). The traditional farming system in the region is an integrated mixture of crop, forestry, and animal husbandry, with some recent introduction of horticulture-based homestead agroforestry. Each type of land use has a distinct nature of resource management according to TEK that has evolved through informal experimentations over centuries (Ramakrishnan 1994).

2.1 Study area

The bowl-shaped Ziro Valley (Figure 1) is home to the Apatani community, one of the major tribes of Arunachal Pradesh and is famous for its pine-clad gentle hills on the fringes of a wide mosaic of integrated rice (paddy) – fish farming systems, surrounded by thickly forested mountains on all sides forming a picturesque landscape. The 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 River. The Ziro valley is about 1700 m as l, with a mean annual rainfall of about 1,500 mm, concentrated in the rainy season during May – August with relatively little or no rains from November to February. The climate is temperate with mean temperature ranging from 12°C to 25°C during summer and from -5°C to 12°C during winter; frost is common during winter. Geologically, the rocks of Ziro valley belong to Hapoli formation and are considered to represent the lacustrine deposits in the inland basins (Tangjang & Arunachalam 2009).

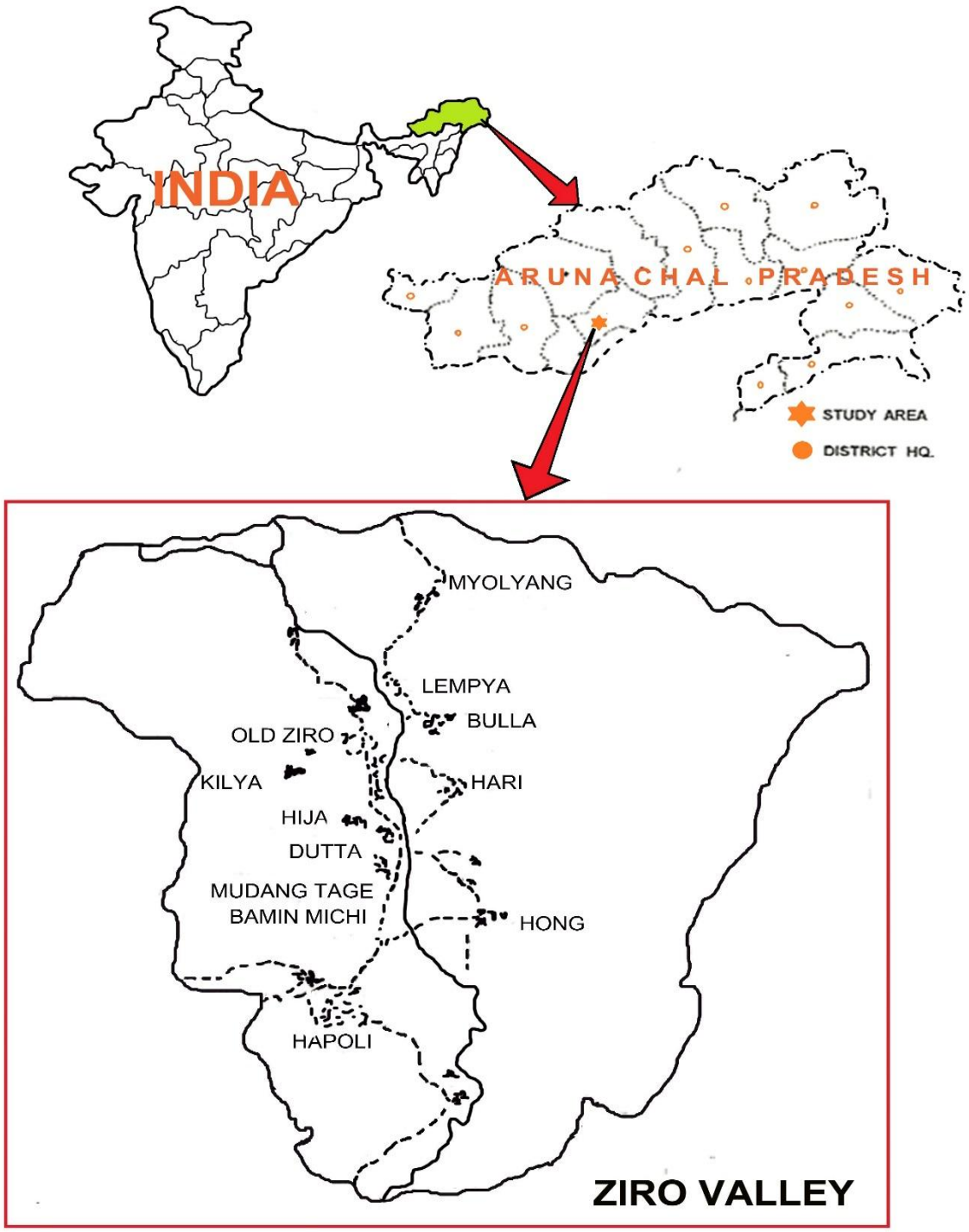

FIGURE 1. MAP SHOWING THE STUDY AREA, ZIRO VALLEY OF ARUNACHAL PRADESH, INDIA

2.2 Data Collection

The study was based on nearly ten field visits of approximately 3-5 days per survey. Household residents were approached with verbal consent and the objectives of the study were clearly explained. Three complementary approaches were adopted, namely; (a) formal interviews targeting primarily local experienced persons (aged between 30 to 65 years), (b) direct filed observations and (c) interactions usually involving 2–3 members of the selected households through questionnaires. The interview schedule comprised of a general introduction concerning traditional management of bamboo + pine agroforestry,

their importance and finally discussions related to contribution of plant species to the households. Group interviews and discussions were important step and conducted in the mornings and evenings when most of the residents were available.

III. RESULTS AND DISCUSSION

3.1 Traditional Ecological Knowledge

The members of rural Apatani community have a vast store of TEK about their particular landscape and how best to maintain it for survival, and this knowledge could be useful for the outside world about the efficient use of landscape for combined agriculture and forestry. The bamboo + pine homestead agroforestry traditions represent a fine-tuning of knowledge concerning the interaction of plants and their environment, and involve as well interactions between agricultural and social systems. Afforestation technique involving plantation of the single-culm (monopodial) local bamboo (*P. bambusoides*) and *P. wallichiana* is a common practice since generations. The exact reason why, how, and when plantation of these two species together started is, however, still obscure. Traditional knowledge concerning the practice has been transferred orally from generation to generation and the pine trees were naturally regenerated from seed. No trees other than pine could survive successfully in the bamboo grove. Similarly, no other shrubs and smaller trees than *P. bambusoides* could grow and survive with the pine trees. These longstanding observations and belief have led the indigenous farmers to conclude that bamboo and pine trees can be grown together as a sustainable land-use system. They also believe that afforestation technique starts with their migration which their forefathers gave to younger generations a pine tree (*Sasisapa*) and bamboo grove (*Bidu Bikan*). Thus, this land-use system, based on traditional wisdom, knowledge, practices and technologies of societies, was developed and enriched through experimentation and adaptation to changing environmental conditions and societal needs over generations (Altieri 2002; Parrotta & Ronald 2012). Now this is extensively practiced in Ziro Valley, and both species (bamboo and pine) are identified as economically and ecologically viable that can be combined into production systems.

3.2 Components and management of the system

In the bamboo + pine system, the farmers incorporate two principal species of trees, bamboo (*Phyllostachys bambusoides*) and pine (*Pinus wallichiana*), in production systems of areas where they have been living since generations. Generally, the plantation of pine with or without bamboo is maintained with utmost care. Pine saplings with soil attached to roots, collected from nearby plantations, are planted in February – March, at a spacing of about 4m X 4m. During the early years after establishment, the lower branches are trimmed regularly to promote upward growth and formation of straight poles required for construction purposes. The bamboo, locally called *Tanii bije*, is inter-planted about four years after establishment of pine trees when the trees would be two meters tall. The bamboo culms, about two years old, with rhizomes exposed, are selected and dug out with traditional *dao* (a traditional cutting implement) from an established bamboo garden in January – February and planted at a spacing of about 1.5m X 1.5m to ensure quick coverage of the plantation area. In about one month after planting, the bamboo puts out two internodes. Moist soil is preferred for planting.

P. bambusoides matures in three years, as indicated by shedding of leaves and the color around the nodes suddenly turning from green to yellow (Figure 2), which is due to the presence of a fungus locally called "*Taipona*" (*Puccinia* sp.). The fungus is eaten as such by the local people. Traditionally, it is recommended to harvest 3-year-old bamboo every year to ensure proper growth of new culms. Harvesting is done during October – February. An established plantation will regenerate on its own and can be continuously harvested for a number of years. The mature bamboo culm survives for approximately ten years, after which it dies. The straight form, smooth and even-toned skin, and an internodal length of about 25 cm make *P. bambusoides* a preferred species. In some cases, even the vegetable- and fruit gardens are being converted into bamboo gardens. Interestingly, according to the local sources, there is no record of *P. bambusoides* having flowered, and it is often referred to as a male bamboo (Sundriyal *et al.* 2002). The harvested bamboo poles are used for construction scaffolding and furniture making, as fuelwood, and in religious and social festivities.

The pine forest in the Ziro Valley is one of the human-managed systems organized as privately owned forest, clan forest, or community forest. Pine forests are found mostly at the foothills of the valley adjacent to the settled farmland of the community locally called as '*Sartii*'. This plantation meets various requirements of the local inhabitants such as timber, planks, poles, fuelwood and medicine. In Ziro Valley, planting of pine trees with or without *P. bambusoides* in the agroforestry system is increasingly appreciated as an important source of timber production. Pine timber is used for various activities like building construction and making furniture and a variety of handicrafts. Pine timber split into fine thin sheets called "*Santha*" is used as roofing of some traditional houses. Pine trees in homegardens have many links with improving the health of the rural poor. For instances, locally tapped pine oil or resin is effectively used as a mosquito repellent. The dried

resin is burned in the evenings to ward off mosquitoes. Ansari *et al.* (2005) suggested that pine oil showed strong repellent action against *Anopheles culicifacies* (malaria vector) and *Culex quinquefasciatus* (pest mosquito). The Apatani tribe also uses the resin for curing cracked heel and also as varnishes. As in many developing regions where medicinal plants are the source of treatment for many diseases and ailments of the poor throughout the developing world (Rao *et al.* 2004), 50% of the rural villagers in Arunachal Pradesh still depend on medicinal plants – mostly planted in their homegardens – for their medical needs, and pine ranks prominently among such plants.

FIGURE 2. MATURE CULM OF *P. bambusoides* INDICATED BY THE APPEARANCE OF YELLOWISH FUNGUS (*Puccinia* sp.) LOCALLY CALLED "*Taipona*"

This case study revealed how these homestead agroforestry systems are used to advance livelihood objectives. It considered the potential benefits of home gardening as part of the farming system, with the capability of raising income and thus improving livelihood of the rural poor. Similar results were reported by Marsh (1998), who stated that homegardens are a production system that the poor can easily enter at some level since it may be done with minimal or no economic resources, using locally available planting materials, natural manures, and indigenous methods of pest control. According to Nair (2006), agroforestry systems provide an important contribution to sustainable agricultural production because of their potential to meet economic, social, ecological, and institutional conditions for sustainable livelihoods. Incorporating trees into a multifunctional, diverse landscape and agricultural systems has been shown to deliver multiple benefits including enhanced global and local ecosystem services, biological diversity, food security and smallholder resilience (Ziegler *et al.* 2012). The multiple roles that trees can play, however, especially at a landscape scale, are less studied and often do not influence the farmers' adoption of agroforestry (Lasco *et al.* 2014).

The potential role of bamboo + pine homestead agroforestry appears to be chiefly the domestic supply of basic traditional housing materials (*Ude*) (Figure 3), fencing (*Sullu/Narung*), handicrafts (*Budu-bugia*), and sacrificial altar during festival like *Myoko/ Murung* festivals, food, and medicine and cash income. The farmers believe that pine trees help in better soil nutrient

cycling while bamboo groves protect soil from erosion, which corroborates the findings of Rao & Ramakrishnan (1989). The local farmers use pine needles as mulch to reduce weeds. In addition to material uses, bamboos embellish the rural environment and fill the minority people's life with vigor and vitality based on the spiritual value of bamboo in their culture. In the past decade, the bamboos are, however, largely overexploited because of their enormous utility for different purposes besides being used as popular ethnic food.

FIGURE 3. NEWLY CONSTRUCTED TRADITIONAL HOUSES OF THE APATANI TRIBE IN ZIRO VALLEY OF ARUNACHAL PRADESH, INDIA. THE SUPPORTING STRUCTURES OF THE TRADITIONAL HOUSES ARE MADE UP OF PINE TIMBER WHILE FLOOR, WALLS AND ROOF ARE CONSTRUCTED OF *P. bambusoides*

3.3 Environmental Sustainability

The bamboo + pine agroforestry can provide ecosystem services for optimizing carbon sequestration and production of renewable biomass as carbon neutral energy. Although it may be also argued that more carbon could be sequestered if the garden was simply left to mature, and hence benefits need to be assessed by considering alternative land-use options (Indrawana *et al.* 2014). As a socio-ecological construct, the quality and maintenance of bamboo +pine agroforestry systems will depend on the existence of adequate ecological knowledge to support the management decisions fitted to respond to current social needs. Ultimately, there is hope that this type of practice can be replicated elsewhere, so that land management can be tailored to the needs and capacities of the ecosystems and the communities that depend on them. It is important to restore the productive relationships between the local communities and the respective resources of the ecosystems (Takeuchi 2011). The value of bamboo + pine is reconsidered to provide not necessarily fuel wood and charcoal, but fixation of carbon, soil protection, and water retention (Figure 4). This traditional system, therefore, has a potential niche in climate change mitigation and adaptation. The importance of the bamboo + pine – like systems in harnessing the values of renewable natural resources in human-influenced natural environments is comparable to satoyama systems in Japan (Indrawana *et al*. 2014), the Kandy home gardens in Sri Lanka and similar homegardens in Borneo, which employ TEK (Kumar & Takeuchi, 2009). The landscape harmony concept can provide residents and visitors with significant cultural and social benefits (Duraiappah *et al.*

2012). Mobilizing community involvement in evolving locally sustainable conservation farming systems through the Landcare approach has shown great promise in Australia, the Philippines, the South Africa (Garrity 2004; Mercado 2001).

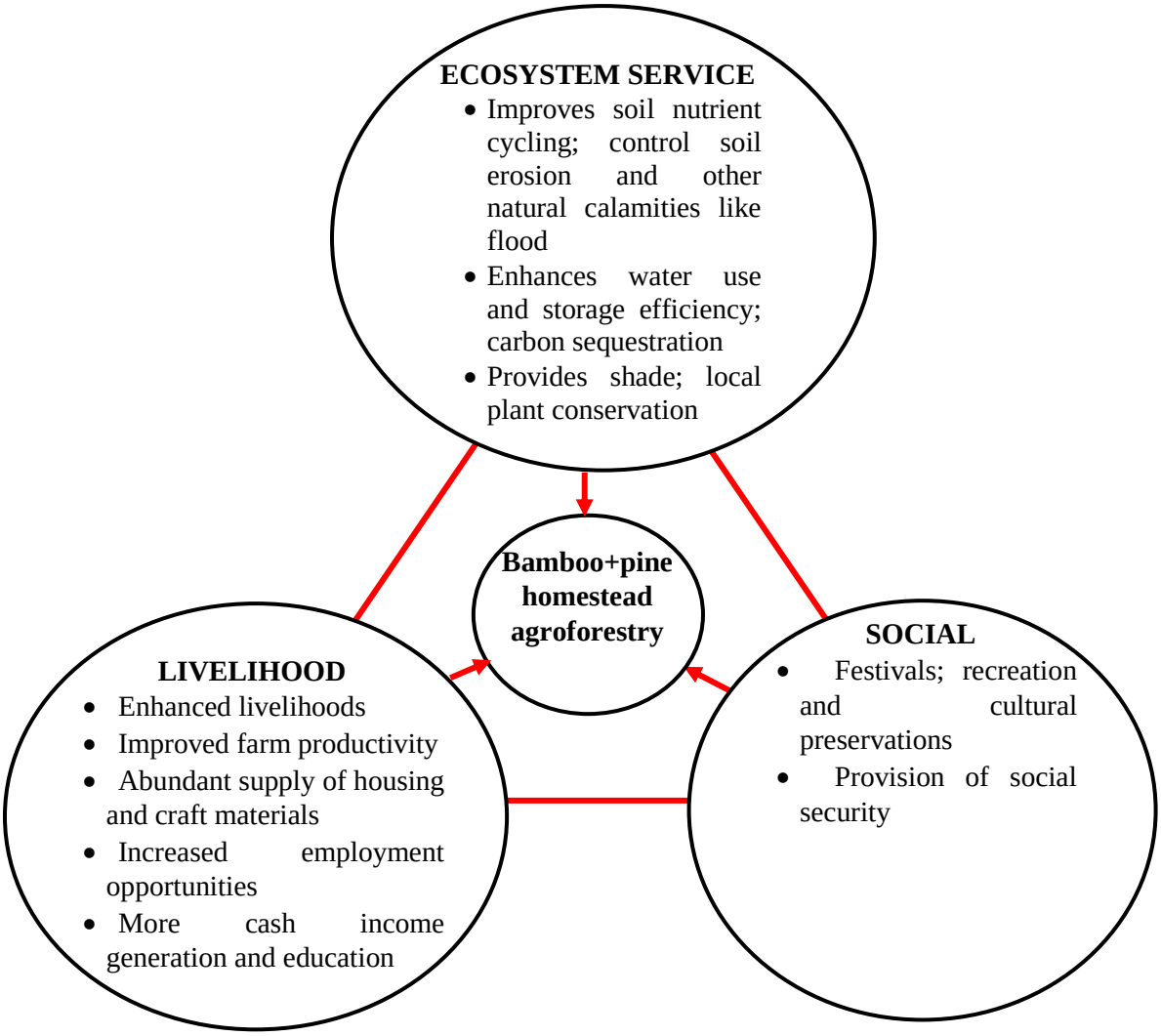

FIGURE 4. A SCHEMATIC DIAGRAM SHOWING THE POTENTIAL ROLES OF BAMBOO+ PINE TRADITIONAL HOMESTEAD AGROFORESTRY IN ENHANCING LIVELIHOOD SECURITY OF THE INHABITANTS OF ZIRO VALLEY OF ARUNACHAL PRADESH, INDIA

In Arunachal Pradesh, there has been a growing awareness that agroforesty system as a sustainable land-use system can be a vital component of development and an effective means to improve the livelihoods of rural poor people. Incorporating trees in agroforestry systems help address food insecurity, increase CO_2 sequestration (Kumar & Nair 2006; FAO 2010) and reduce vulnerability of agricultural systems (Scherr *et al.* 2012; Thorlakson 2011). Existing studies on traditional homestead agroforestry systems have made it easier to choose locally appropriate strategies for maximizing the farm-level benefits based on the production objective of the traditional farmer. The challenge that needs to be addressed is how to comprehensively assess and factor in the potential of trees in providing environmental services, to achieve more sustainable results amidst existing climatic and environmental changes. The economic value and potential yield of each system will depend on existing biophysical and socio-economic conditions as well as the farmers' familiarity with management practices (Altieri 2009). Agroforestry adoption in the farm-scale could be improved in many ways. Another factor that sets the Apatani tribe apart from their neighboring tribes who practice shifting cultivation is their effective utilization of every inch of cultivable land. This practice has won them fame all over India.

3.4 Recreational value

Today bamboo + pine agroforestry is recognized as an important component of the cultural heritage of Apatani tribe. Overall, the recreational values of rice + fish farming and bamboo + pine homestead agroforestry systems in the Ziro Valley have increased, particularly through their appreciation by urbanites and the tourists from different parts of the globe. The fact that bamboo + pine agroforestry are managed landscapes provides an opportunity to engineer a marriage among different ecosystem services, including recreation, cultural preservation, and biodiversity conservation (Figure 4). New business models on this system can be sought after which may also be oriented towards increased tourism needs, banking on the beauty of the mosaic landscape and that this rural landscapes continue to play an important role in Apatani tribes art and culture. It may also provide an educational landscape, even to the extent of providing an open-air museum of historical agricultural management and rural lifestyles. This traditional land-use system may provide a useful model for understanding how it is possible to reconcile the goal of increased productivity without compromising sustainability from social, ecological and political perspectives.

3.5 Outlook

The rural farmers of Ziro Valley are now in a transitional period, mainly due to outside influences. The Apatani are believed to be a conservative community, and now some of the traditional agroecosystem management practices are on the verge of extinction due to the integration of hired labor forces from outside. Nowadays, it is common for the youth to leave the village in search of jobs creating shortages of local labors. Due to sociocultural, climatic and physiographic differences, the hired labor have different management techniques, which often dilute the local practices. The Apatani tribe will still need labor from outside, but they are trying to cope with the emerging situation by being aware that their system is very efficient yet delicate, and realizing the need to preserve their time-tested knowledge, by documenting it for future generations. Outside influences have affected various aspects of farming systems management. For example, traditional soil and water conservation techniques have been replaced by modern methods using concrete constructions, and the bamboo and wooden pipes used in irrigation water supply have been replaced by lead or plastic materials that are environmental-unfriendly.

Realizing the efficiency and importance of traditional management practices, the Apatani are now discussing how to preserve traditional knowledge and practices. It was informed during the survey that penalties are imposed if traditional rituals and practices are violated, according to existing local norms. Although the Apatanis understand the importance of traditional practices, greater awareness is needed in general as most of the TEK and management practices are only passed on orally, and are not documented. Field research of traditional knowledge in Arunachal Himalayas, has shown that the Apatani tribe is one of the most efficient resource managers, yet sustainability is their major concern (Dollo *et al.* 2009). Unfortunately, too little research attention has been given to how the successful agroforestry systems observed in this part of the globe can be more widely expanded for the benefit of the smallholders living in remote hamlets with poor market infrastructure (Garrity 2004). Agroforestry research and development has traditionally focused on trees and their production issues and the smallholder tree production contributes substantially to rural livelihood and national economies, yet these contributions are not adequately quantified or appreciated. Agroforestry research and development must now seriously focus on land management interventions that reach the poorest and most vulnerable land users (Nair & Garrity 2012). The tribal communities in Arunachal Pradesh are highly dependent on natural resources and land-use systems to fulfill their basic needs. Harvesting of natural resources has traditionally been sustainable; however, consequent to increase in population, these resources have been over-exploited.

IV. CONCLUSION

Integrated bamboo + pine agroforestry in Ziro Valley has been an integral part of the local system, which is judiciously guarded and meticulously tended by all community members as it fulfils various basic rural needs. The local ecological setting and the high degree of dependence on natural resources make such practices exceptionally valuable. All the practices adopted for managing such system are highly self-reliant with little external input or technologies and low dependency from external resources, making it extremely sustainable. In this era of globalization, TEK on resource management provides a useful rationale for designing new technologies for sustainable management of valuable natural resources and efficient ways of resource conservation. Generally, the Apatani tribes have a natural inclination towards plantation and ecological conservation, which if properly utilized can have tremendous impact on the development of the areas. This is a unique example in which rich natural resources managed with traditionally conservationist attitude of the Apatani farmers provide

solution to economic needs and provide ecosystem services. The system deserves systematic investigations on understanding the principles of successful management of such indigenous systems that could be extrapolated to other similar situations.

ACKNOWLEDGEMENTS

The authors would like to extend their gratitude to the farmers of Ziro Valley for their invaluable contributions throughout the survey. Financial assistance from the Department of Biotechnology, New Delhi, Government of India, to the first author is highly appreciated.

REFERENCES

[1] Altieri M.A. (2002) Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems and Environment 93: 1–24.

[2] Altieri M.A. (2009) Agroecology, Small Farms and Food Sovereignty, Monthly Review. 61:102–113.

[3] Ansari M.A., Mittal P.K., Razdana R.K. & Sreeharia, U. (2005) Larvicidal and mosquito repellent activities of Pine (*Pinus longifolia*, Family: Pinaceae) oil. Journal of Vector Borne Diseases 42: 95-99.

[4] Cairns M. (Ed.) (2007) Voices from the Forest: Integrating Indigenous Knowledge into Sustainable Farming, Resources for the Future. Washington, DC.

[5] Cairns M. (Ed.) (2015) Shifting cultivation and environmental change: indigenous people, agriculture and forest conservation. Taylor and Francis.

[6] Census Report of Arunachal Pradesh. (2011) http.//www.arunachalpradesh.gov.in/dept/census/do_ letter/hcm.pdf (Last accessed on 9th February 2016).

[7] Cunningham A. B. (Ed.) (2001) Applied Ethnobotany: People, Wild Plant Use and Conservation. London: Earthscan.

[8] Dollo M., Chaudhry S. & Sundriyal R.C. (2006) Traditional farming and land tenure systems in West Kameng district, Arunachal Pradesh. In: Ramakrishnan, P.S., K.G Sexena and K.S. Rao (eds.), Shifting Agriculture and Sustainable Development of North-Eastern India. UNESCO-MAB series, Oxford & IBH, New Delhi, India pp. 293-315.

[9] Dollo M., Samal P.K., Sundriyal R.C. & Kumar K. (2009) Environmentally sustainable traditional natural resource management and conservation in Ziro Valley, Arunachal Himalaya, India. Journal of American Science 5: 41-52.

[10] Duraiappah, Kumar A., Nakamura, Koji, Takeuchi, Kazuhiko, Watanabe, Masataka & Maiko N. (2012) Satoyama-Satoumi Ecosystems and Human Well-Being: Socio-Ecological Production Landscapes of Japan. United Nations University, Tokyo.

[11] Food and Agriculture Organization (2010) Climate-Smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. Rome, Italy: Food and Agriculture Organization United Nations.

[12] Garrity D.P. (2004) Agroforestry and the achievement of the millennium development goals. Agroforestry Systems. 61: 5–17.

[13] Herzog F. (1998) Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe. Agroforestry Systems 42: 61 – 80.

[14] Indrawana M., Yabeb M., Nomurac H. &Harrisond R. (2014) Deconstructing satoyama – The socio-ecological landscape in Japan. Ecological Engineering 64:77–84

[15] Jeeva S.R.D.N., Laloo R.C. & Mishra B.K. (2006) Traditional agricultural practices in Meghalaya, North East India. Indian Journal of Traditional Knowledge 5: 7-18.

[16] Kumar B.M. & Nair P.K.R. (Eds). (2011) Carbon Sequestration in Agroforestry Systems. Springer, The Netherlands p.307.

[17] Kumar B.M. & Nair P.K.R. (Eds). (2006) Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry. Advances in Agroforestry 3. Springer Science, Dordrecht, The Netherlands p.390.

[18] Kumar B.M.& Takeuchi K. (2009) Agroforestry in the Western Ghats of Peninsular India and the satoyama landscapes of Japan: a comparison of two sustainable land use systems. Sustainability Science 4: 215-232.

[19] Lasco R.D., Delfino R.J.P., Catacutan D.C., Simelton E.S. & Wilson D.M. (2014) Climate risk adaptation by smallholder farmers: The role of trees and agroforestry. Current Opinion in Environmental Sustainability 6: 83-88.

[20] Marsh R. (1998) Building on traditional gardening to improve household food security. Food, Nutrition and Agriculture No. 22, Food and Agriculture Organization, Rome.

[21] Mercado A.R., Patindol M. & Garrity D.P. (2001) The Landcare experience in the Philippines: technical and institutional innovations for conservation farming. Development in Practice 11:495-508.

[22] Miller R.P. & Nair P.K.R. (2006) Indigenous agroforestry systems in Amazonia: from prehistory to today. Agroforestry Systems 66: 151-164.

[23] Nair P.K.R. (Ed.) (1989) Agroforestry Systems in the Tropics. Kluwer Academic Publishers, Dordrecht, The Netherlands p.665.

[24] Nair P.K.R. (2001) Do tropical homegardens elude science, or is it the other way around? Agroforestry Systems 53: 239-245.

[25] Nair P.K.R. (2006) Whither homegardens? Kumar BM, Nair PKR, editors. Tropical homegardens: a time-tested example of sustainable agroforestry. Dordrecht: Springer Science pp.355–370.

[26] Nair P.K.R. (2007) The coming of age of agroforestry. The Journal of the Science of Food and Agriculture 87: 613–619.

[27] Nair P.K.R. & Garrity D.P. (Eds) (2012) Agroforestry – The Future of Global Land Use. Advances in Agroforestry, 9, Springer, The Netherlands p. 541.

[28] Olson D.M. & Dinerstein E. (1998) The global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conservation Biology 12: 502–515.

[29] Parrotta J.A. & Ronald L. (2012) Traditional forest-related knowledge: Sustaining communities, ecosystems and biocultural diversity. International Journal of the Commons 6: 388-389.

[30] Ramakrishnan P.S., Purohit A.N., Saxena K.G. & Rao K.S. (Ed.) (1994) Himalayan Environment and Sustainable Development. Indian National Science Academy, New Delhi, pp.84.

[31] Rao M.R., Palada M.C. & Becker B.N. (2004) Medicinal and aromatic plants in agroforestry systems. Agroforestry Systems 61: 107–122.

[32] Rao K.S.& Ramakrishnan P. S. (1989) Role of bamboos in nutrient conservation during secondary succession following slash-and-burn agriculture (jhum) in north-eastern India. Journal of Applied Ecology 26: 625–633.

[33] Rigueiro-Rodríguez A., McAdam J.H. & Mosquera-Losada, M.R. (Eds)(2008) Agroforestry in Europe [Foreword by P. K. R. Nair], Advances in Agroforestry.Springer, Dordrecht, The Netherlands, 6, 2008, p. 452.

[34] Sarkar S. & Maitra D.N. (2001) Bilakkhani: a multipurpose shrub for ecofriendly agriculture. Everyman's Science 36:138-141.

[35] Scherr S.J., Shames S. & Friedman R. (2012) From climate-smart agriculture to climate-smart landscapes. Agriculture and Food Security 1: pp. 2, DOI: 10.1186/2048-7010-1-12.

[36] Shackleton C.M., Paumgarten F. & Cocks M.L. (2008) Household attributes promote diversity of tree holdings in rural areas, South Africa. Agroforestry Systems 72: 221–230.

[37] Sundriyal R.C., Upreti T.C. &Varuni R. (2002) Bamboo and Cane Resource utilization and conservation in the Apatani Plateau, Arunachal Pradesh, India: Implication for management, Journal of Bamboo and Rattan 1: 205-246.

[38] Takeuchi, K. 2011. Rebuilding the satoyama landscapes and human–nature relationships. In: Osaki, M., et al., 2011. Designing Our Future: Local Perspectives on Bio-production, Ecosystems and Humanity. United Nations University, Tokyo.

[39] Tangjang S. & Arunachalam A. (2009) Role of traditional home garden systems in Northeast India. Indian Journal of Traditional Knowledge 8: 47-50

[40] Thorlakson T. (2011) Reducing Subsistence Farmers' Vulnerability to Climate Change: ThePotential Contributions of Agroforestry in Western Kenya, Occasional Paper 16. World Agroforestry Centre, Nairobi.

[41] Wiersum K.F. (2006) Diversity and change in homegarden cultivation in Indonesia. In: B.M. Kumarand P.K.R. Nair (eds.), Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry. Springer, Dordrecht, The Netherlands 3:13 – 24.

[42] Yamada M. & Osaqui H.M.L. (2006) The role of homegardens in agroforestry development: The lessons from Tomé-Açu, a Japanese settlement in the Amazon. In: B.M. Kumar and P.K.R. Nair (eds.), Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry. Springer, Dordrecht, The Netherlands 299 – 316.

[43] Ziegler A.D., Phelps J., Yuen J.Q., Webb E.L., Lawrence D. *et al.* (2012) Carbon outcomes of major land-cover transitions in SE Asia: great uncertainties and REDD+ policy implications. Global Change Biology 18: 3087-3099, DOI: 10.1111/ j.1365-2486.2012.02747.x.