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Household differentiation and on-farm conservation of biodiversity by indigenous households in Xishuangbanna, China

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Abstract. With diversification of field type among households in same eco-environment and social situation, even in the same ecosystem, merging household socio-economics with biodiversity initiative values to determine incentives and optimum strategy of on-farm conservation of biodiversity. Botany survey of agroecosystems at landscape level in Daka and Baka, Xishuangbanna, Yunnan, China, as well as household differentiation of biodiversity in agroecosystem and on-farm conservation strategy merging household socio-economic characters were studied. There were 73 families 179 species distributed in 0.1 ha of different agroecosystems in Daka, and 70 families 166 species distributed in 0.08 ha different agroecosystems of Baka respectively. The cosmopolitan families, such as Gramineae and Compositae decreased the percentage of tropical families and subtropical families. Botany survey among 12 random selected households from Daka in 46 sampling plots of different agroecosystems showed significant differentiation of the species richness indices of natural biodiversity and agrobiodiversity as there were differences of cognition and utilization of plant species besides management practices among households. Dengrogram using the Ward method of hierarchical cluster analysis based on annual questionnaire interview of 60% household from 1998 to 2001 in Daka showed disparity among different households' socio-economics which underpins management diversity. There were significant correlation coefficients between household socio-economics and species richness indices of different agroecosystems. Fallow size had significant positive correlation coefficients with species richness index of rubber plantation. By contraries, production input had negative correlation coefficients with species richness index of upland rice field. Meanwhile, cereal crop income had significant positive correlation coefficient with agro-species richness index of rubber plantation. By contraries, other income such as off-farm income had negative correlation coefficients with agro-species richness index of rubber plantation. Innovations of the expert farmer on agrobiodiversity on farm conservation were admiration.

Introduction

Agrobiodiversity has been widely accepted as a scientific term only in recent years. It has been defined as ''management and direct use of biological species, including all crops, semi-domesticates and wild species'' (Huijun et al. 1996). Farmers maintain a level of agrobiodiversity through their farm-specific production system, employing individual decision-making at the farm level. Conservation and sustainable use of agrobiodiversity on farm level is a new challenge and there are many lessons to be learned from the field (Brookfield and Padoch 1994; Wood and Lenné 1997; Rerkasem et al. 2002). Meanwhile, the role of agrobiodiversity in farm-household livelihood and food security, as well as relationship between agrobiodiversity and society has also become a focus of interest (Hardon-Baars 2000). Biodiversity and agrobiodiversity has been given more and more recognition in China, including gene, species and ecosystem diversity (Chunlin et al. 2003; Yuming et al. 2004). Agrobiodiversity plays an important role in all agroecosystems. In sum, policies and actions to support agrobiodiversity at many levels are needed, and will lead to multidimensional economic and ecological gains in both the short term and the long term. The strategy for on-farm agrobiodiversity conservation will only succeed if the needs and problems of indigenous communities are solved (Pinedo-Vasquez et al. 2002).

Contrasts among provinces, counties, and villages are common because natural resources, eco-environment, social and ethnic identities are different. There are also differences among households in the same eco-environment and social situation, even in the same ecosystem (Huijun et al. 2002). What are the impacts of such diffferences? How should we assess the differences of natural biodiversity and agrobiodiversity among households? Can we assume that an increase of agroecosystem field type diversity will improve the future food and economic security, as well as sustainable development? The authors choose Daka and Baka, Xishuangbanna Yunnan China, two of the demonstration sites of the Global Environmental Facility and United Nations University project on People, Land management and Environmental Change as a case study where we spend 7 years studying biodiversity of agroecosystems and socio-economic development.

Materials and methods

Study area

Xishuangbanna Dai Autonomous Prefecture is located in southern part of Yunnan province. SW China, within the north latitude 21°10′–23°40′ and east longitude 99°55′–101°51′, and with the area of 19200 km^2 (Figure 1). This prefecture is the only area in China where stands of virgin tropical rainforest can be found. Xishuangbanna land area is only 0.2% of China, but it has 5282 higher plant species that takes 1.8% of plant species in the world, 14.9% of China and 34.8% of Yunnan Province’s. Xishuangbanna is a multi-cultural nationality area. Dai, Hali, Yao, Jinuo and Bulang people have a long history living in Xishuangbanna. Thirteen ethnic groups are recognized by the State Council of China in this area. This prefecture is characterized by both cultural

Figure 1. The study area, Daka and Baka, in southernmost Yunnan Province, China.

and biological diversity. The agroecosystems of the region strongly reflect this dual richness.

Daka is a Hani/Ahka village located in Menglun town, Mengla county in Xishuangbanna Prefecture. Area of Daka is 727 ha, consist of community forest, rubber and fallow in turn. Its most recent census recorded 304 people in 53 families in the village. Daka is located about eight kilometers from Menglun town and 10 km from the Menglun State Nature Reserve at approximately 21°41′ N, 101°25′ E. The average annual temperature in Daka is 21.5 °C, rainfall averages 1563 mm per year. The prevailing soils are leached red earths. The original vegetation in the Daka area is tropical seasonal rainforest, now long managed by human populations.

Baka is a village of Jinuo township, Jinhong City, Xishuangbanna Prefecture, with an elevation of 720 m. Area of Baka is 173 ha, consist of fallow and cash crop plantation. Its most recent census recorded 269 people in 68 families in the village. The village is close to Menglun State Nature Reserve at approximately 21°59′ N, 101°9′ E and 6 km away from Xishuangbanna Tropical Botanic Garden. The average air temperature is 21.5 °C, annual rainfall 1556.3 mm per year, and annual mean relative humidity is 82%. The original vegetation is tropical seasonal rainforest.

Field methods

Landscape level: 11 quadrats of different agroecosystems in Daka and 9 in Baka were established and studied. Botanical survey is based on guidelines on assessment of plant species in agricultural landscapes (Zarin et al. 2002). The habitat of different agroecosystems was recorded. Trees and shrubs with more than 6 cm girth at breast height were identified and their girth measured at

1.3 m from ground level, and the height measured together. Young trees and shrubs with less than 6 cm girth at breast height were identified and individual tree number recorded. Four 1×1 m grass quadrats were established in the corner of the quadrat to investigate the individual number of seeldings and grasses. On-plot investigation of utilized plants of different agroecosystems was finished at the same time.

Household level: The determination of sampling households and sampling plots is based on the Household-level Agrobiodiversity Assessment (HH-ABA) (Huijun et al. 2002). In Daka, 20% households were determined randomly for plot survey in base of the residence booklet with the assistance of suggestion by local households. The land distribution and land shape determines sampling plots of HH-ABA, the shape and area of sampling plots is based on the land owned by the household. We have chosen homegarden, fallow field, upland rice field, rubber plantation and *Cassia siamea* plantation as the research targets according to the actual situation of Daka. Forty six quadrates of 12 households were established and studied. Management diversity including land preparation manner, land construction manner, water and soil erosion control, pest and weed control, fertilizer keep etc., were investigated on farm. Population densities and distribution patterns, cultivation pattern, seed origin, harvest quantities of some key agrobiodiversity were determined at the same time. In addition, we conducted annual questionnaire interviews of socio-economic characters of 60% of the population of the whole village. Questionnaire interview including demographic and cultural aspects, land and crop yield, gender aspects, produce and life input, income resource, limitation factors. All fieldwork has been undertaken from 1998 to 2001.

Data analysis

(1) *Species richness and utility*: using the methods of Gleason' species richness index ($D_{Gl} = S/\mathrm{Ln}\ A$, S: number of species, A: quadrat size), and the agro-species richness index determined by Huijun and Zhenyu (1998), which means the utilized species of a certain quadrate to analyze the species richness of different household and of different agroecosystems (Keping 1994; Huijun and Zhenyu 1998; Coffey 2002). Agro-species richness index can be modified from Gleason' species richness index ($D'_{Gl} = S'/\mathrm{Ln}\ A$, S': number of utilized species, A: quadrat size). At the same time, the number and percentage of utility species were analyzed.

(2) The comparative analysis and similarity analysis among different sampling plots: using the methods of Whittaker index ($\beta_{ws} = S/\mathrm{ma} - 1$, S: the total number of species in the quadrat, ma: the average number of species in each sub-quadrat) and Jaccard' coefficient index ($C_J = j/(a + b - j)$. j: number of species in both quadrat; a and b: number of species respectively in quadrat A and B) for comparative analysis and similarity analysis among different sampling plots (Huijun and Zhenyu 1998; Coffey 2002).

(3) Principal component analysis and cluster analysis of household's socio-economic characters with analysis software of SPSS 11.0 (Zhigang 1999) as principal component analysis and cluster analysis are both statistical tools for condensing data sets (Coffey 2002). Correlation coefficient analysis and statistics test including *F*-test and *t*-test between socio-economic characters and species richness indices of different agroecosystems with Microsoft Excel.

Results and discussions

Landscape level assessment and conservation

There were 73 families, 139 genera and 179 species distributed in 0.1 ha of different agroecosystems in Daka, and 70 families 146 genera and 166 species distributed in 0.08 ha different agroecosystems of Baka respectively. The cosmopolitan families, such as Gramineae, Compositae and Papiloinaceae take about 20% in Daka and 30% in Baka that means land management decreased the percentage of tropical families and subtropical families. Compared with tropical rainforest in Xishuangbanna, the percentage of tropical families and subtropical families in different agroecosystems are decreased greatly.

According to our botanical survey, there are 10 important kinds of species in agroecosystems of Daka and Baka, such as *Pometia tomentosa*, *Mitrephora wangii* and *Horsfieldia tetratepala* belongs to the third level category of vulnerable and endangered species under national conservation. *Pterospermum menglunense* and *Tetrastigma lenticelatum* are endemic to Xishuangbanna. These species have been destroyed in the agroecosystems of Daka and Baka. Floristic element analysis of agrobiodiversity assessment provided scientific basis of priority conservation of natural biodiversity and agrobiodiversity.

The species richness index is a simple and useful measurement of diversity. Biodiversity and agrobiodiversity of different agroecosystems of Daka and Baka was measured and studied respectively. There were great variations in diversity indices of different agroecosystems. In Daka, the species richness index varied from 2.0 in wet rice fields to 10.0 in holly hill forest, while the agro-species richness index varied from 1.1 in wet rice field to 5.2 in holly hill forest (Table 1). At the same time, the species richness index varied from 1.5 in orchard to 11.1 in Chinese cardamom cultivated under natural forest while the agro-species richness index varied from 1.3 in orchard to 4.3 in Chinese cardamom cultivated under natural forest in Baka.

The Whittaker indices varied from 0.58 to 1 in Daka. This means there were differences of species composition among agroecosystems. Correspondingly, there were great variations of Jaccard' coefficient index among different agroecosystems. The similarity index varied from 0 to 0.26 in Daka. For instance, the biggest similarity index between monoculture rubber plantation and *Cassia siamea* plantation as monoculture perennial crops is only 0.26. At the same time, there are great discrepancies of plant community among different

Table 1. Species richness indices of different agroecosystems in Daka and Baka.

Quadrat and agroecosystems	Size (M^2)	Number of species	Number of utilized species	Percentage of utilized species	D_{GI}	D'_{GI}
Daka						
1. Community forest	100	41	18	43.9	8.9	3.9
2. 3-year fallow field	100	43	22	51.2	9.3	4.8
3. Passion fruit plantation	100	27	14	51.9	5.9	3.0
4. Monoculture rubber plantation	100	19	14	73.7	4.1	3.0
5. Holly hill forest	100	46	24	52.2	10.0	5.2
6. *Cassia siamea* plantation	100	24	21	87.5	5.2	4.6
7. Homegarden	100	18	15	83.3	3.9	3.3
8. Paddy field	100	9	5	55.6	2.0	1.1
9. Water reservior	100	17	16	94.1	3.7	3.5
10. Chinese cardamom under forest	100	20	14	70.0	4.3	3.0
11. Tea cultivated under forest	100	28	24	85.7	6.1	5.2
Baka						
1. Upland rice field	100	14	8	57.1	3.0	1.7
2. Rubber + passion fruit	100	20	11	55.0	4.3	2.4
3. Holly hill forest	100	42	15	35.7	9.1	3.3
4. Orchard	100	7	6	85.7	1.5	1.3
5. Chinese cardamom under forest	100	51	20	39.2	11.1	4.3
6. 2-year fallow field	100	26	13	50.0	5.6	2.8
7. *Cassia siamea* plantation	100	36	16	44.4	7.8	3.5
8. Homegarden	100	18	15	83.3	3.9	3.3
9. Paddy field	100	18	7	38.9	3.9	1.5

agroecosystems as the Whittaker indices varied from 0.63 to 1 in Baka, and the similarity indices are low (below 0.23). For example, the biggest similarity index between upland rice field and wet rice field in Baka is only 0.23. The mean of β_w among all agroecosystems in Daka and Baka is 0.9 and 0.9 while mean of C_J is only 0.06 and 0.05 in Daka and Baka correspondingly. Great variation of the diversity indices means that different agroecosystems contain different species composition, and lead to different succession processes during land conversion (Zapfac et al. 2002). Meanwhile, land conversion from community forest to rubber plantation lead to biodiversity loss while species richness index decline from 8.9 to 4.1 in Daka, similar to biodiversity loss from forest to crop land in an Amazon forest zone (Fujisaka et al. 1997). Most of all, holly hill forest maintains high plant species richness in both Daka and Baka as indigenous knowledge, especially traditional belief helps to conserve biodiversity.

Household level assessment and conservation

Households manage rich biodiversity in agroecosytesms. For example, there are 156 species in 4400 m^2 sample plots of 3-year fallow field and in which 67 species are utilized by local households. The peasant household is the basic unit of agrobiodiversity conservation and rural sustainable development in China since 1978–1982 under the Household Responsibility System. Different households have different strategies and developed different technologies for agroecosystem management, agrobiodiversity conservation and economic development. The results showed that there were great discrepancies of plant species richness among different households (Table 2). For example, the average of species richness indices of 3-year fallow fields among the 11 sampled households is 6.0, while the maximum of the index is 55% more than average and the minimum is 63% less than the average. At the same time, the average of the agro-species richness indices of 3-year fallow fields among the 11 sampled households is 2.7, while the maximum is 37% more than the average and the minimum is 44% less than the average.

Homegarden is one of the important agroecosystems of local people in Xishuangbanna. As local people introduce some wild species into homegarden that are collected usually in the wild, some biodiversity and agrobiodiversity have been preserved in homegarden. Sampled households differ significantly in terms of the Gleason's species richness index and the modified agro-species richness index (Table 2). Some smallholders in Daka, for instance, did not plant wild vegetables in their gardens, instead they relied on collection of these species from fallow forests. Others chose to plant these "wild" vegetables to assure that the family found their supply easily. Meanwhile, others prefer to cultivate exotic vegetable varieties. For example, β_{w} and C_{J} of homegarden between household 4 and household 7 is 0.98 and 0.01 indicate otherguess species component. Furthermore, β_{w} and C_{J} of homegarden indicated that plant community similarity among different households were low. Similarly, the choice of plant species, their arrangement and management varies between and within tropical homegardens in the same community in Nicaragua (Mendez et al. 2001). The mean of β_{w} among all households is 0.82, 0.68, 0.68, 0.69, 0.57 and 0.66 of homegarden, 3-year fallow fields, rubber plantation, upland rice fields and *Cassia siamea* plantation while mean of C_{J} is only 0.1, 0.19, 0.19, 0.28 and 0.21 correspondingly.

In addition, household disparity within agroecosystem has resulted from management diversity among different households. For instance, some households seldom dig tree roots when preparing fallow cultivation for better natural regeneration. Some households plant alley crops such as taro in upland rice fields to conserve water and soil besides food harvest, etc (Figure 2). Some households weed by hand while some households use weedicide. Some households cover rubber roots with herb stems to conserve water and soil. Some household practice monoculture of rubber plantation while others practice agroforestry system of rubber alley cropping with tea as monoculture is one of factors leading to agrobiodiversity loss (Uppeti and Uppeti 2002).

Relating the diversity index above with socio-economic data of those households, the authors find that economic value of the biological resource in homegarden varied substantially among different households (Figure 3).

Table 2. Species richness indices of different agroecosystems among different households in Daka.

Agroecosystems	Household	Size (M^2)	Number of species	Number of utilized species	Percentage of utilized species	D_{Gl}	D'_{Gl}
Homegarden	1	240	51	38	74.5	9.3	6.9
	2	144	41	20	48.8	8.2	4.0
	3	340	35	27	77.1	6.0	4.6
	4	423	65	61	93.8	10.7	10.1
	5	151	45	39	86.7	9.0	7.8
	6	105	44	35	79.5	9.5	7.5
	7	240	32	24	75.0	5.8	4.4
	8	84	29	20	69.0	6.5	4.5
	9	65	32	28	87.5	7.7	6.7
	Mean	199	42	32	76.2	8.1	6.3
3-year fallow field	1	400	25	13	52.0	4.2	2.2
	2	400	31	10	32.3	5.2	1.7
	3	400	13	9	69.2	2.2	1.5
	4	400	26	15	57.7	4.3	2.5
	5	400	33	15	45.5	5.5	2.5
	6	400	56	22	39.3	9.3	3.7
	7	400	43	18	41.9	7.2	3.0
	8	400	41	18	43.9	6.8	3.0
	9	400	27	15	55.6	4.5	2.5
	10	400	56	20	35.7	9.3	3.3
	11	400	46	22	47.8	7.7	3.7
	Mean	400	36	16	44.4	6.0	2.7
Rubber plantation	1	400	19	9	47.4	3.2	1.5
	2	400	31	18	58.1	5.2	3.0
	3	400	18	10	55.6	3.0	1.7
	4	400	23	13	56.5	3.8	2.2
	5	400	28	17	60.7	4.7	2.8
	6	400	22	15	68.2	3.7	2.5
	7	400	22	13	59.1	3.7	2.2
	8	400	19	9	47.4	3.2	1.5
	9	400	21	12	57.1	3.5	2.0
	Mean	400	23	13	56.5	3.8	2.2
Upland rice field	1	400	43	30	69.8	7.2	5.0
	2	400	45	16	35.6	7.5	2.7
	3	400	30	18	60.0	5.0	3.0
	4	400	38	19	50.0	6.3	3.2
	5	400	54	28	51.9	9.0	4.7
	6	400	36	15	41.7	6.0	2.5
	7	400	49	30	61.2	8.2	5.0
	8	400	42	23	54.8	7.0	3.8
	9	400	41	18	43.9	6.8	3.0
	Mean	400	42	22	52.4	7.0	3.7

Table 1. Continued.

Agroecosystems	Household	Size (M^2)	Number of species	Number of utilized species	Percentage of utilized species	D_{GI}	D'_{GI}
Cassia siamea plantation	1	416	57	21	36.8	9.5	3.5
	2	400	74	30	40.5	12.4	5.0
	3	400	41	19	46.3	6.8	3.2
	4	400	34	12	35.3	5.7	2.0
	5	412	73	34	46.6	12.1	5.6
	6	400	50	19	38.0	8.3	3.2
	7	400	41	19	46.3	6.8	3.2
	8	396	40	16	40.0	6.7	2.7
	Mean	403	51	21	41.2	8.5	3.5

This provides some basic ideas for household-level agrobiodiversity on-farm conservation. For example, some households have kept rich biodiversity and developed rich agrobiodiversity and realized high economic value in home-gardens to be regarded as expert farmers. We can summarize their experience and technology and demonstrate their methods to other households who have kept and developed poor biodiversity and agrobiodiversity with low and

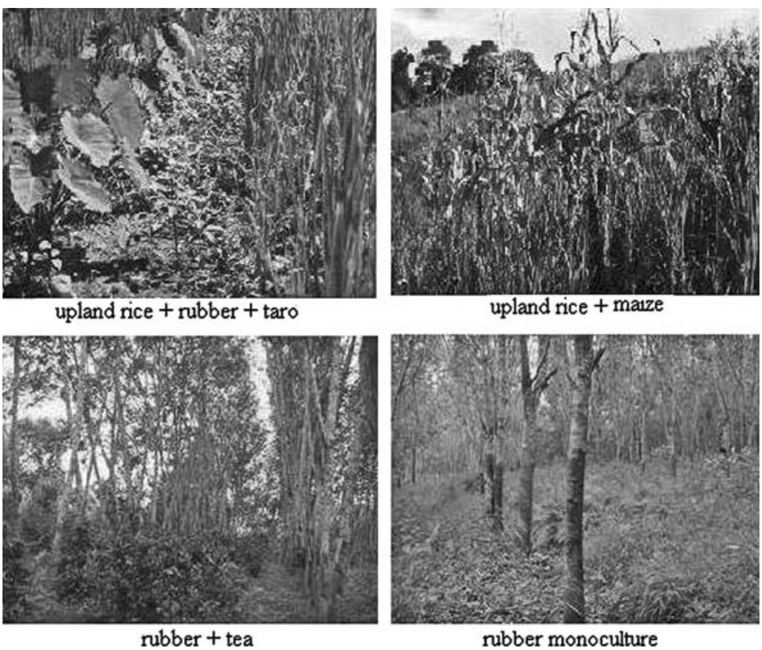

Figure 2. Household disparity of upland rice field and rubber plantation in Daka. Photo by Fu Yongneng.

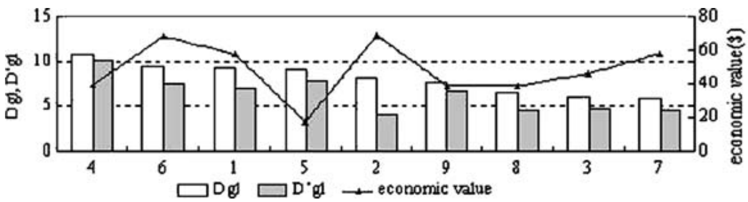

Figure 3. Economic value and species richness indice of homegarden among different households.

unstable economic value. It is important to adapt agricultural practices and land use to local agroecological and socio-economic conditions adjusted to local diverse needs and aspirations, and building upon local successful experiences as recognition of farmers' innovation in agrobiodiversity management has increased over the past decade (Montecinos and Salazar 2000; Backes 2001).

In addition, agrobiodiversity assessment at landscape level is the base for assessment at household level. Household level comprehensive result corresponds to landscape level assessment. The correlation coefficient of agrobiodiversity assessment between household level and landscape level is 0.933 and 0.945 of natural biodiversity and agrobiodiversity show consistency in results at different level. In addition, correlation coefficients between household level and landscape level both are notable at 0.01 level of t-test (Table 3). Biodiversity is the base of agrobiodiversity of different agroecosystems. The correlation coefficient between biodiversity and agrobiodiversity are 0.697 and 0.601 of household level and landscape level. On the other hand, rich biodiversity does not necessarily correspond with rich agrobiodiversity with different agricultural technology. In addition, the correlation coefficients between natural biodiversity and agrobiodiversity both at household level and landscape level do not achieve significance even at 0.05 level of t-test.

Table 3. Correlation coefficient of agrobiodiversity assessment between household and landscape level of 5 different agroecosystems in Daka.

	Household D_{Gl}		Landscape D_{Gl}		Household D'_{Gl}		Landscape D'_{Gl}	
	r	t	r	t	r	t	r	t
Household D_{Gl}	1							
Landscape D_{Gl}	0.933	12.48	1					
Household D'_{Gl}	0.697	2.35	0.536	1.30	1			
Landscape D'_{Gl}	0.65	1.95	0.601	1.63	0.945	15.30	1	
$t_{0.05,\ df\ =\ 3}$								3.18
$t_{0.01,\ df\ =\ 3}$								5.84

Household disparity of socio-economic characters

It was necessary to test the hypotheses linking on-farm agrobiodiversity with household socio-economics. According to repeated annual questionnaire interviews from 1998 to 2001, the socio-economic characters of sampled households vary greatly (Table 4). This mainly resulted from land distribution policy among households. The present status of farmland tenure is still based on the past population of 1983. Since 1983 the farmland tenure of different households has not changed. Some households have more land since the land belongs to the old people does not return to the village after the old people pass away. However, some households have less land now because of the later marriage and adding children. Households with enough wet rice and fallow land can transfer most of fallow to rubber plantation to get cash income besides food consumption while households with less wet rice or fallow can only transfer part of fallow to rubber plantation for food consumption mainly.

Classification of farm households into homogeneous groups is helpful to investigate questions such as why certain categories of households are wealthier; why some categories of households more successful at growing certain crops or rearing animals and what constraints each household category faces in terms of agricultural production. Understanding these questions allows solutions to be identified, which could help the poorer and/or the less technically able households. Principal components analysis of socio-economic characters shows that other income, cash crop income, gross person income, production input, as well as cereal crop income and population are principal factors. Meanwhile, a dengrogram using the Ward Method of hierarchical cluster analysis with SPSS 11.0 software (Zhigang 1999) of socio-economic characters among sampled households shows low combinative level among households that indicates household socio-economics' variability too. In addition, 12 households can be divided into 3 clusters according to 6 principal factors (Figure 4), especially according to other income and gross person income at 0.01 level of F-test, as well as cash crop income at 0.05 level of F-test (Table 5). For example, household 1 was divided into one independent cluster as who had great amount of other income of off-farm income.

Correlation coefficient of agrobiodiversity and socio-economics of sampled households

The study of traditional agroecosystems includes both biophysical and socio-economic variables, essential for understanding these complex systems was considered appropriate (Mendez et al. 2001). Socio-economic diversity forces farmers to try different crops and varieties for their livelihood. It is through this attempt of trying to overcome the prevailing production constraints that the agroecosystems diversity is introduced. For example, rich households prefer to select varieties with good quality in spite of low yield. On the other hand, poor

Table 4. Disparity of average socio-economic characters during 1998 to 2001 of 12 sampled households (Size: ha; income/input: $, the same below).

	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Male	3.0	3.3	3.0	2.5	4.0	2.0	2.0	2.8	1.8	3.0	4.0	2.0	2.8
Female	1	2	2	3	3	3	1	3	3	2	4	2	2.4
Population	4	5	5	5	5	5	3	5	5	5	8	4	4.9
Under 16 age	1.0	1.0	0.5	1.3	2.0	2.0	0.3	1.8	2.3	0.3	2.3	2.0	1.4
16–40 age	2.5	3.3	2.8	2.0	3.0	2.0	1.5	2.0	2.3	1.8	2.8	2.0	2.3
40–60 age	0	0	2	1	2	0.75	1	1.25	0.25	2	0	1.5	1.0
Above 60 age	0.5	1	0	1	1	0	0	0.25	0	0	0	1	0.4
Labor	3	3	5	3	3	3	3	3	3	3	4	4	3.3
Paddy size	0.21	0.51	0.21	0.59	0.59	0.21	0.15	0.67	0.11	0.11	0.39	0.22	0.33
Fallow size	0.32	3.03	1.37	1.23	1.23	0.62	0.29	1.15	0.66	0.33	1.69	2.31	1.19
Cash crop size	0.32	3.03	1.37	1.23	1.23	0.62	0.29	1.15	0.66	0.33	1.69	2.31	1.19
Production input	88	84	124	53	53	54	29	67	27	205	69	75	77
Rubber income	341	560	431	393	393	195	389	406	196	310	341	330	357
Chinese cardamom income	45	163	156	243	243	223	33	62	114	156	108	84	136
Tea/passion fruit income	47	82	126	109	109	104	32	55	25	73	65	35	72
Cereal crop income	3	91	4	37	37	26	2	0	3	42	36	5	24
Other income	1090	51	212	0	0	0	0	218	0	0	73	0	329
Gross person income	300	176	150	150	150	110	153	109	74	126	87	128	143

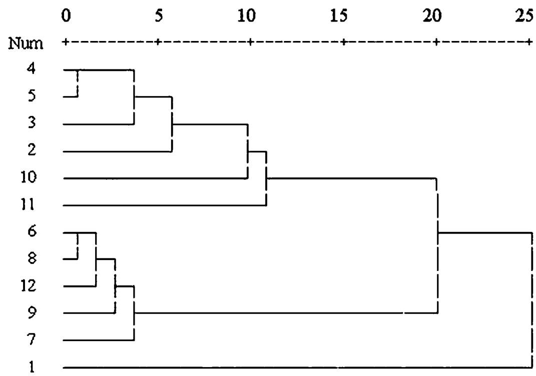

Figure 4. Dendrogram using Ward method of sampled households in Daka.

households prefer to select varieties with high yield in spite of bad quality for home consumption. Culture and traditions also influence what to grow in addition to labor and gender issues as pertaining to resource management. Socio-economic disparity underpins and helps to explain management diversity and agrobiodiversity among households as management diversity is helpful for biodiversity conservation (Muller 2002).

The exact nature of the relationship between household socio-economics on the one hand and species richness indices of biodiversity and agrobiodiversity, on the other, is very difficult to establish. Do households with higher income levels manage more or less biodiversity and agrobiodiversity? For example, it is reported that poorer households are currently facing more restricted access to community forests than 'less poor' or relatively better off households for some key forest products in Nepal (Adhikari et al. 2004). For example, some researchers have suggested that agricultural intensification is likely to lead to crop specialization and a loss of diversity while some researchers have argued that intensification maintains or even increases agro-diversity with highly population density (Conelly and Chaiken 2000). In addition, labor inputs were high considering the small size of the homegardens, although no clear relationships between labor investment and plant number were observed. (Mendez et al. 2001). Using principal component analysis, we focus to the correlation coefficient of household population, cash crop size and income, cereal crop income and production input in detail.

Fallow size, cash crop size, and cash crop income has significant positive correlation coefficients with species richness index of rubber plantation at 0.05 level of *t*-test, as well as cereal crop income has significant positive correlation coefficient with rubber plantation at 0.01 level of *t*-test (Table 6). With more cereal crop income from wet rice field, households prefer to transfer fallow fields into rubber plantation with extensive management to keep natural biodiversity. On the other hand, production input has negative correlation coefficients with species richness index of upland rice field and 3y fallow field at

Table 5. *F*-test of hierarchical cluster analysis of sampled households in Daka.

	Cluster 1		Cluster 2		Cluster 3		Cluster MS	df	Error MS	df	F	$F_{0.05}$	$F_{0.01}$
Households	1		2, 3, 4, 5, 10, 11		6, 7, 8, 9, 12								
Item	Average	S^2	Average	S^2	Average	S^2							
Population	4	–	5.5	1.5	4.4	0.8	3.3	2	1.2	9	1.77		
Cash crop income	433	–	677	14508.2	457	5884.3	132280.1	2	10675.3	9	7.08		
Cereal crop income	3	–	41	785.4	7	113.7	3146.5	2	486.8	9	3.72		
Other income	1090	–	56	6811.6	44	9504.8	419.3	2	8008.6	9	61.88		
Gross person income	300	–	140	920.2	115	838.7	1709.1	2	884.0	9	16.23		
Production input	88	–	98	3442.4	50	474.8	6179.3	2	2123.5	9	1.48	4.26	8.02

Table 6. Correlation coefficient of species richness indices and main socio-economics component of sampled households.

	Homegarden		Rubber plantation		Upland field		3y fallow field		*Cassia siamea*	
	D_{Gl}	t	D_{Gl}	t	D_{Gl}	t	D_{Gl}	t	D_{Gl}	t
Male	0.10	0.28	0.46	1.54	0.39	1.23	−0.50	−1.79	0.71	3.72
Female	0.38	1.20	0.18	0.50	−0.15	−0.40	0.25	0.69	−0.04	−0.10
Population	0.37	1.12	0.21	0.58	−0.38	−1.19	−0.16	−0.44	0.19	0.52
Paddy size	0.26	0.75	0.41	1.29	0.28	0.80	−0.05	−0.14	0.18	0.49
Fallow size	0.02	0.06	0.67	3.27	−0.01	−0.02	−0.29	−0.82	0.50	1.74
Cash crop size	0.02	0.06	0.67	3.27	−0.01	−0.02	−0.29	−0.82	0.50	1.74
Cash crop income	0.23	0.64	0.62	2.62	−0.05	−0.14	−0.46	−1.55	0.36	1.08
Cereal crop income	0.41	1.29	0.90	12.60	0.21	0.58	−0.01	−0.02	0.66	3.04
Other income	0.10	0.27	−0.45	−1.49	−0.07	−0.18	−0.35	−1.05	0.07	0.19
Gross person income	0.24	0.67	−0.08	−0.22	0.16	0.43	−0.45	−1.49	0.30	0.87
Production input	−0.20	−0.54	−0.27	−0.76	−0.59	−2.40	−0.72	−3.94	0.09	0.23
$t_{0.05,\ n\ =\ 7}$										2.37
$t_{0.01,\ n\ =\ 7}$										3.50

Table 7. Correlation coefficient of Agro-species richness indices and main socio-economics component of sampled households.

	Homegarden		Rubber plantation		Upland rice field		3y fallow field		*Cassia siamea*	
	D'_{Gl}	t	D'_{Gl}	t	D'_{Gl}	t	D'_{Gl}	t	D'_{Gl}	t
Male	−0.05	−0.13	0.26	0.74	0.27	0.78	−0.52	−1.89	0.80	5.77
Female	0.45	1.52	0.22	0.62	−0.54	−2.03	0.31	0.92	−0.24	−0.67
Population	0.27	0.77	0.19	0.51	−0.71	−3.81	−0.17	−0.47	−0.05	−0.13
Paddy size	0.16	0.45	0.23	0.66	−0.01	−0.02	−0.05	−0.12	0.40	1.24
Fallow size	−0.29	−0.84	0.54	2.02	−0.48	−1.68	−0.56	−2.18	0.44	1.46
Cash crop size	−0.29	−0.84	0.54	2.02	−0.48	−1.68	−0.56	−2.18	0.44	1.46
Cash crop income	0.08	0.21	0.53	1.98	−0.26	−0.74	−0.47	−1.61	0.63	2.76
Cereal crop income	0.03	0.08	0.83	6.95	−0.39	−1.21	−0.29	−0.85	0.54	2.00
Other income	−0.03	−0.08	−0.59	−2.42	0.46	1.54	−0.25	−0.72	0.08	0.22
Gross person income	0.02	0.05	−0.19	−0.51	0.53	1.97	−0.39	−1.20	0.43	1.41
Production input	−0.31	−0.92	−0.26	−0.75	−0.18	−0.48	−0.67	−3.21	0.37	1.13
$t_{0.05,\ n\ =\ 7}$										2.37
$t_{0.01,\ n\ =\ 7}$										3.50

0.05 level and 0.01 level of *t*-test respectively. Production input includes weedicide, and this has destroyed natural vegetation greatly.

Meanwhile, cereal crop income has significant positive correlation coefficient with agro-species richness index of rubber plantation at 0.01 level of *t*-test (Table 7). Households with more income from wet rice fields prefer to interplant more kinds of cash crops with rubber leading to more and stable cash income in spite of market changes. This finding is similar to the diversity of the agricultural production was found to be important in ensuring food security and reducing the risk of temporary food shortages in a Philippine upland region (Frei and Becker 2004). On the other hand, other income such as off-farm income has negative correlation coefficients with agro-species richness index of rubber plantation at 0.05 level of *t*-test. For example, agroforestry systems of rubber plantation with tea and with pineapple need more labor to manage. Household with more off-farm income prefer to monoculture rubber with limitation of labor. Population has negative correlation coefficients with agro-species richness index of upland rice field at 0.01 level of *t*-test for household food demand mainly.

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