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Article

Perceptions of Local People toward Community Development and Forest Conservation in Bangladesh: The Case of Sal Forests

Mohammad Abdullah Al Faruq*[1], Sourovi Zaman*[2] and Masato Katoh*[1]

ABSTRACT

During the last few decades, forest resources in most developing countries have declined alarmingly, due to extreme pressure from population and poverty. Bangladesh has lost most of its forests during the last 40 years. Nevertheless, degradation of forest remains a matter of concern, emphasizing the fact that effective conservation of natural resources is possible only with an understanding of the attitudes and perceptions of local community. Community involvement in forest management, a relatively new practice in Bangladesh, was initiated with the dual purpose of limiting forest degradation and enhancing community development. In Bangladesh, many forestry projects have been introduced to manage forest resources involving local communities, although few of them have been sustained. The Forest Department of Bangladesh has implemented a program to conserve forests, by improving the livelihoods of people dependent on forests in the Madhupur Sal area. This study examined the perceptions of local people toward community development and forest conservation, and further analyzed factors that present the changing trends in forest conservation and livelihoods in and around forested areas. We conducted a household survey in the forestry project, surveying 200 community forest workers (CFWs). The CFWs were randomly selected and interviewed, and we analyzed human, physical, financial, natural, and social livelihood capitals. The forest conservation program improved the livelihoods of the local community. The perceptions of the community about the general conditions of the forests, and attitudes of the local population about forest conservation, were improved. Dependence on the forests has also noticeably declined during the last few years. An additional outcome of the management program was empowerment and increased dignity of female participants. Such improvements would likely lead to improvements in livelihoods, as well as more sustainable forest management and conservation.

keyword: Forest conservation, community development, participatory management, Sal forest, Bangladesh

INTRODUCTION

Forests serve as important sources of water, food, shelter, medicine, fuel wood, fodder, and timber for local people and adjacent communities. They also provide a wide range of environmental services, including biodiversity conservation, watershed protection, soil protection, and global climate change mitigation (Landell-Mills and Porras, 2002). However, losses of forests and tree diversity have increased globally at unprecedented rates (Kaimowitz and Angelsen, 1998). In developing countries, the degradation of forests has become very severe (Panta et al., 2008; Pelletier et al., 2010).

People in most of the developing world depend on forests for their livelihood. In the case of a developing country such as Bangladesh, the livelihoods of many depend on forests, in terms of direct and indirect income, ecotourism, and the collection and sale of wood and non-wood products. However, in many cases, access to natural resources is not uniform within and between communities (Shackleton et al., 2007). Many local people living in and around forests face high levels of poverty, with limited work opportunities (Shackletom et al., 2007). However, sustainable use of forest resources could provide an opportunity to integrate conservation and social development objectives (Sunderlin et al., 2005).

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Review of Sal forest

Among the wooded tracts in Bangladesh, the Madhupur Sal forests are located in the greater Mymensingh and Tangail districts, also known as Madhupur Grath (Rahman, 2003). Sal forests are considered environmentally and economically important (Alam et al., 2008). Sal forest is the third largest forest ecosystem in Bangladesh (BFD, 2011), covering an area of about 0.12 million ha representing 4.7% of the total wooded area of the country (GOB, 2010).

Sal forests are surrounded by dense populations that include ethnic minorities. They have functioned for centuries as homelands for ethnic communities such as the Garo and Koch (Ahmed, 2008). The once-biodiversity-rich Madhupur Sal forest has been degrading since 1950. Thousands of people have become directly and indirectly dependent on this forest, placing it under severe pressure in recent decades from illegal logging and clearing for agriculture and industrialization, among other threats (BFD, 2004). In addition, sal trees have higher economic potential due to longer durability compared to other tree species. These pressures have caused significant changes in the forests and associated resources, severely depleting Sal forests. Such exploitation, combined with inappropriate management, has made the current use of forest resources unsustainable (Iftekhar, 2006). Recently published statistics have shown that only 30.1% of the original Madhupur Sal forest remains intact (Faruq et al., 2016) (Fig. 1).

Review of forestry project

In many developing countries, the management of natural resources has gradually become participatory and typically involves a broad range of stakeholders (Turyahabwe et al., 2012). The Forest Department (FD) of Bangladesh started people-oriented forestry programs in the 1980s, when conservation of degraded Sal forests became a top priority (Muhammed et al., 2008; GOB, 2010). Previous projects failed, due to a shortage of funds and lack of proper implementation plans, as identified by the FD (Nath and Inoue, 2008).

In Bangladesh, the latest forest policy established in 1994 provided general direction rather than legislation to regulate realistic issues such as land tenure, sharing benefits, and market processes (Ahmed, 2008). The local populations in and around forests have important and long-standing relationships with their forests. Hence, their needs, aspirations, and attitudes should be considered in forest management; otherwise, the long-term survival of forested areas will be jeopardized (McNeely, 1990).

To this end, the FD launched a new project entitled "Revegetation of Madhupur Forest through Rehabilitation of Forest-Dependent Local and Ethnic Communities," with the broad aim of protecting forests, sharing resource management among forest communities, and ensuring secure livelihoods for those dependent on forests.

The initial 3-year project was initiated in 2010, but was extended to 2015. The FD policy was to identify people who were involved in illegal tree felling, provide motivation and training, and transform the population into guardians of the forest, as CFWs (Community Forest Worker), working in parallel with forest staff. We investigated the conservation of the Madhupur Sal forests, the attitudes of the people dependent on them, and the impact of the project on their livelihoods.

METHODOLOGY

Study site

The Madhupur deciduous Sal forest (24°32'−24°47'N, 89° 59'−90°11'E), the major such forest in Bangladesh, covered an area of approximately 25,495.9 ha in 1982 (Islam and Sato, 2012). The study involved the entire area covered by the project. A large portion of the forest (approximately 8499 ha) was given protected status in 1982, when the reserve was renamed the Madhupur National Park.

The Park is located in the northeastern section of the Tangail Forest Division, a small segment that runs along the boundary of the Mymensingh Forest Division (Fig. 2). The forest is divided into four beats (small administrative units of the FD), namely, Jatyo Uddyan, Dokhola, Aronkhola, and Madhupur. The forest is located approximately 20 m above sea level. The mean annual rainfall is 2000−2300 mm, and the

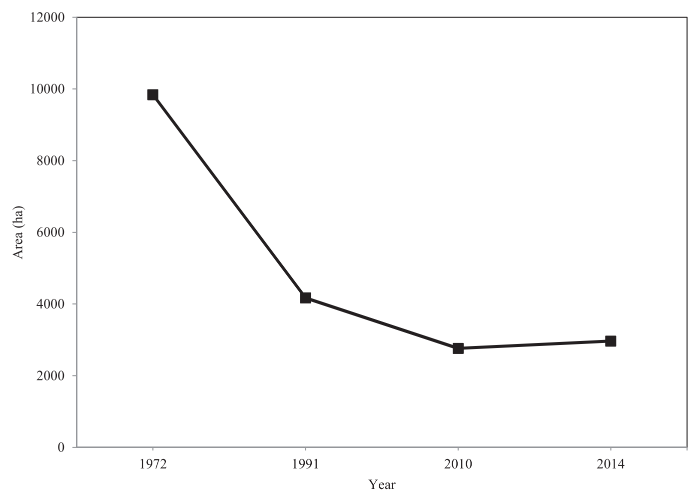

Fig. 1 Changes in Sal forest cover over time in Madhupur (Source: Faruq et al. 2016)

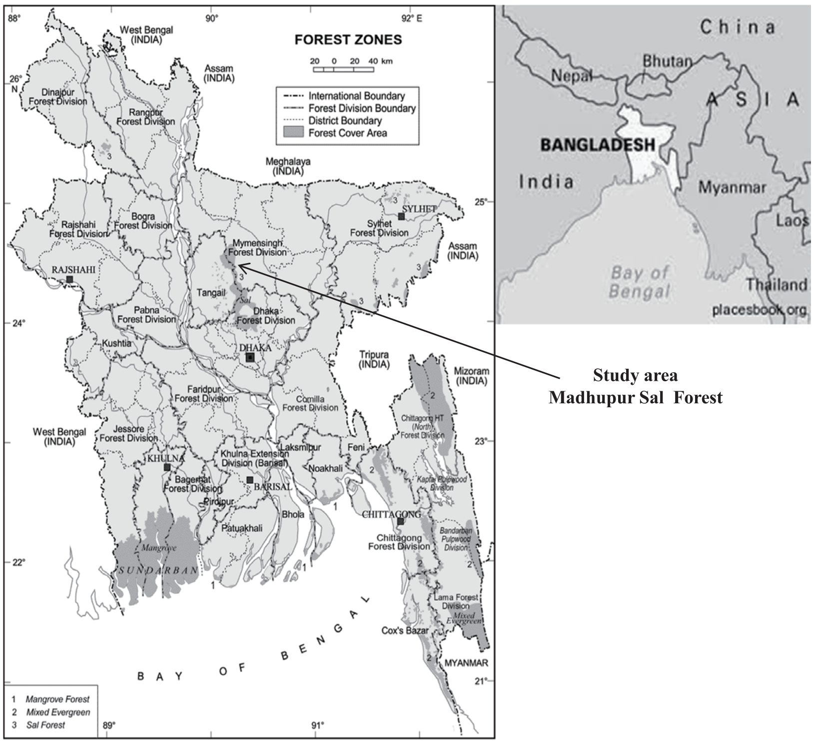

Fig. 2 Location of study site

mean annual temperature is 26.3℃ (Rahman, 2003).

The Madhupur Sal forest, commonly known as the Madhupur Garh, is on a tract of land approximately 1−2 m higher than the surrounding plains. The ridges, known locally as Chala, are covered with forest formations and are not continuous. The forest is dense in some parts and sparse in others. Scrub jungle can also be found on the ridges.

The Madhupur Sal forest area has been subjected to some degree of exploitation. Many animal species (e.g., tiger, leopard, elephant, sloth bear, and spotted deer) have gone extinct, although much plant diversity still exists (NSP, 2008). The height of the forest canopy varies between 10 and 30 m. The dominant species (80−100% of trees) is the commercially profitable Sal tree (*Shorea robusta*), which dominates the upper canopy. It is associated with Ajuli (*Dillenia jpentagyna*), Amlaki (*Phyllanthus emblica*), Koroi (*Albizia procera*), *Terminalia* sp, and Sonalu (*Cassia fistula*), among other taxa. The understory includes *Bambusa* sp., *Alsophila* sp., and several ferns and epiphytes (Feeroz and Islam, 2000). There are 140 tree species, 19 mammal species, 19 reptile species, and four amphibian species (NSP, 2008).

Project description

The project, called the Bangladesh Climate Change Trust, was started in the Madhupur Sal forest area in June 2010 (FD, 2012). It was implemented with an integrated and holistic approach, under direct supervision of the local forest office of the Madhupur Forest Range. The project was initially launched for 3 years, but was extended for another 2 years, ending in June 2015.

The project has involved forest resource users, ethnic communities, Bengali communities and different organizations acting together to develop conservation and social development activities for sustainable forest management. The local forest office identified a total of 700 forest-dependent individuals from the Madhupur forest area, and trained them in different income-generating initiatives. Among the participants, 500 illegal loggers were listed, according to the records of FD offenses, and another 200 poor forest dependents (income less than 1 US dollar/day/person) were selected for training. The participants received 2 months of intensive training. The training included growing trees in nurseries and reforestation, mushroom cultivation, medicinal plant cultivation, fisheries, poultry rearing, cattle fattening, apiculture, pisiculture, vegetable gardening, compost preparation, jam and jelly production, forest fire protection, and motivation to change attitudes. During the training period, every participant was given 4500 Taka (78 Taka = 1 US dollar) per month as a training allowance. The trainers were also given uniforms, identity cards, and training materials. Trainers included public representatives, political leaders, journalists, government officials, NGO representatives, and academicians. After being trained, the participants were treated as CFWs, participating in the development of activities and helping the forest guard to protect the forests.

All CFWs received a 15-day refresher training organized by the FD 3 months after the main training. Every CFW received 800 Taka per month as a wage after the training. Each forest range office was responsible for monitoring the activities of the CFWs. Under each range, there was a representative committee of CFWs nominated by the general CFWs. All CFWs met monthly in the Madhupur forest office.

In addition, another 5500 families dependent on the forest were selected. These families, together with 700 CFWs, received incentives totaling 11,000 Taka. The families planted 200 saplings, including 50 fruit trees, 50 timber trees, and 100 fuel wood species, to gradually reduce dependence on forests and secure their livelihoods. The project also rejuvenated forests that were disturbed and/or depleted by other locals. During the project period, 1000 ha of degraded forest was replanted, mostly with native tree species in different forest beats.

Questionnaire and data collection

This study used the descriptive research design whereby a survey was conducted to assess the perceptions of people towards community development and forest conservation. A survey was conducted during January and February 2016 among the CFWs of the forestry project. Both quantitative and qualitative data were collected from primary and secondary data sources. Primary data was gathered using structured questionnaire while secondary data was sourced from books, reports and other published and unpublished sources. The literature from secondary data sources was used either to authenticate or support findings of this study.

The questionnaire was prepared in English and translated into the Bangla language. It was designed to gather information based on socioeconomic, demographic, cultural variables, and attitude regarding forest conservation. The questionnaire was administered to a small number of people (15% of total participants) before the final survey was done. The pilot survey was important to this study because it assisted in checking the reliability of information that was going to be gathered. We got similar results when repeated our questionnaire soon after the pilot.

The sample population was selected from 12 villages in the area, consisting of 186 males and 14 females of various ages (20–75 years old). The participants responded to the questionnaire with the help of other family members, as necessary. In addition to the questionnaire, informal meetings were held in each household. A focus group discussion was arranged in each village to gain a more complete understanding of community perceptions and to cross-check the validity of the data recorded during the interviews. The flow chart in Fig. 3 represents the overall study process used in our research.

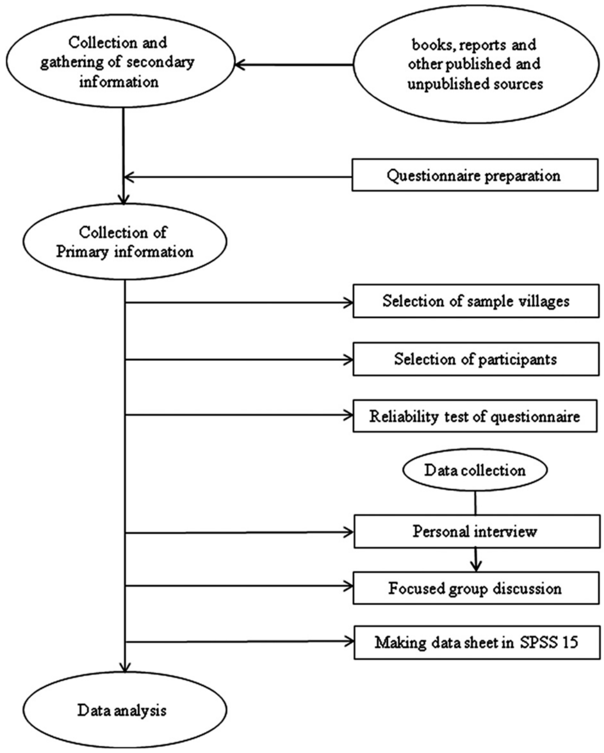

Fig. 3 The flow chart represents the overall study process used in our research.

Livelihood analyses

Livelihoods were viewed in a sustainable livelihood framework, to analyze and understand the complexity of rural development and its balance with forest conservation. We explored human, physical, financial, natural, and social livelihood capitals. Quantitative data were analyzed using SPSS 15.

RESULTS

Demographic characteristics

The characteristics of participants are listed in Table 1. Briefly, the average age of respondents was 44 years, and most were middle-aged. There were similar numbers of ethnic and non-ethnic respondents, and 97.5% of participants were married. The literacy rate was 51%. The average family size was 4.64, slightly above the national average of 4.50 (BBS, 2011). The average farm size was 0.59 ha, lower than the national average of 0.67 ha (Krishi Dairy, 2012). The religion of all ethnic respondents was Christianity, whereas the majority of non-ethnic respondents (97%) were Islamic. Before the forestry program was started, the main source of income was illegal tree harvesting (80.5%); after the program, the major occupation was farming (65%).

Livelihood capital

We assessed multiple forms of livelihood capital, as detailed below.

Human capital

Human capital represents the skills, knowledge, health, and ability to pursue different livelihood strategies and achieve objectives (Roberts and Yang, 2003). To enhance knowledge and skills related to community development and forest management, the FD conducted 2 months of intensive training (requiring 15% of the project budget) (FD, 2012). Such training can improve human capital, leading to improved household income (Islam et al., 2010). To understand the skills and improvement of the areas of the training program, we evaluated participant's skills according to five areas of training programs. We found that 96% of the participants able to explain in the area of vegetable gardening training program, compared to 85%, 83%, 78%, and 74% in areas of nursery raising, Cattle fattening, Compost preparation, and Poultry rearing, respectively (Table 2). The training programs helped to build strong networks, enabling

Table 1 Demographic characteristics of participants

Variables	Frequency	Percentages (%)
Sex		
Male	184	92
Female	16	8
Ethnicity		
Banglee (Non ethnic)	114	57
Garo (Ethnic)	86	43
Age (Year)		
(Young age) up to 30	70	35
(Middle age) 31−50	89	44.5
(Old age) > 50	41	20.5
Marital status		
Married	195	97.5
Unmarried	3	1.5
Widow	1	0.5
Widower	1	0.5
Distribution of respondents by religion		
Muslim	112	56
Hindu	3	1.5
Christian	85	42.5
Family Size (Member)		
Small (<5)	77	38.5
Medium (6−8)	106	53
Large (>8)	17	8.5
Education		
Illiterate (No schooling)	98	49
Primary (1−5)	57	28.5
Secondary (6−10)	35	17.5
Higher secondary (college and university)	10	5
Farm size (Hectare)		
Landless (<0.02)	8	4
Marginal (0.02−0.2)	79	39.5
Small (0.2−1)	94	47
Medium (1−3)	17	8.5
Large (>3)	−	−

Table 2 Participants' performance in major training programs

Areas of Training	Key objectives	Participant capable of explanation (%)	Skill evaluation
Nursery raising	Nursery establishment, raise income	85	Very good
Vegetable gardening	Meet household demands, additional income	96	Excellent
Compost preparation	Improve soil health, additional income	78	Good
Poultry rearing	Improve nutrition, raise income	74	Good
Cattle fattening	fast income	83	Very good

participants to work together as a team. In addition, illiterate participants were given more attention during the training sessions. After the training, 15 days of refresher courses were arranged for all of the participants. All participants reported enhanced skills after the program.

Physical capital

Physical capital comprises the basic infrastructure and goods required to support a livelihood (Jonathan, 2000). All project participants received incentive money to improve house and developed their household with guidance from project staff (Table 3).

Housing is obviously an important family asset. Prior to the project, participants owned mud houses with tin roofing (75%), houses with bamboo-matt walls and tin or straw roofs (22%), or brick houses with tin roofs (3%). After the program, the proportions of each type of housing were 77%, 18.5%, and 4.5%, respectively. Houses consisted of 3−4 rooms, compared to 2−3 rooms before the project. In addition, 47.5% of participants had tube wells and 36% had toilets before the project, whereas 98.5% and 87.5%, respectively, had these basic utilities after the program.

Prior to the project, most participants (91.5%) possessed various livestock, including cows, buffalos, goats, pigs, chickens, and ducks. Every participant bought a cow, goat, or pig after receiving the project incentive of Taka 5000. Approximately 75% of the participants raised poultry (chicken and duck) after the project, which was 13% higher than prior to the project. Participants also tended to raise more cows but fewer goats, pigs, and buffalos after the project.

Use of expensive appliances (e.g., TV, CD player, motor bike, power tiller, irrigation pump) increased among the participants after joining the program. Moreover, 32% and 35% of the participants used solar panel power and electricity, respectively, whereas only 12% of the participants used electricity before the program.

Table 3 Incentives provided by the project to locals

Taka (73 Taka = 1 U.S. dollar)	Purpose
3000.0	Improve homes
5000.0	Purchase a ruminant (e.g., cow, goat, pig)
1000.0	To plant 200 seedlings on land
1000.0	Vegetable cultivation
1000.0	Compost preparation
Free	Eco-friendly burner (one per family)
Total = 11000.00 Taka	

Source: BFD (1016)

Natural capital

Natural capital is the term used for natural resource stocks from which resource flow and services that are useful for livelihoods are derived (Goldman, 2000). Land is an important natural capital. The land provided by the FD for community forestry was not included in the measurement of each participant's holdings. The majority of respondents were marginal (44.7%) to small farm holders (47%). There were no large farm holders (Table 2).

The land provided for community forestry (mentioned above) was a 1 ha plot given to each participant and on which they were allowed to practice agro-forestry by planting local timber, fuel wood, fodder, and fruit species. Agro-forestry systems offer multiple alternatives and opportunities for farmers, with a view to improve farm production and income, and also provide productive and protective functions for the ecosystems (Sharma et al., 2007). Moreover, participants planted about 1,100,000 tree species (fruit, timber, and firewood species) on homestead premises.

Most participants (65%) who engaged in agriculture reported that they planted high-yielding crops. Only a few (8.5%) of the households reported collecting non-wood forest products (NWFPs) from the forest to supplement their livelihoods. The intensity of NWFP collection was highest among very poor people living in the forest.

Finally, 96% of informants reported that they had stopped illegal cutting after the program. Changes in energy use, shifting from forest products to alternative fuel sources, were reported by 91.5% of the participants. More specifically, all of the participants started using improved stoves provided by the project, and 63% of the participants stated that the stoves saved 30–40% fuel compared to traditional stoves (Table 4).

Table 4 Fuel saved using improved stove

Fuel saving category (%)	Participants' opinion	
	Frequency	Percent (%)
10–20	15	7.5
21–30	47	23.5
31–40	57	28.5
41–50	77	38.5
>50	4	2

Financial capital

Financial capital represents the monetary resources that people use to achieve livelihood objectives (Lasse, 2001). Financial capital includes two main sources: available stock (e.g., savings, cash, liquid assets) and regular flow of money (e.g., wages, pension, sale of agriculture products). A remarkable change in the respondents' primary means of securing a livelihood was noticed in the community. Before joining the project, illegal tree cutting was the primary source of income for 80.5% of the participants, followed by farming (10.5%), and forest product collection (5.0%). After initiating co-management activities, the majority of participants (65%) reported farming (crop cultivation, vegetable gardening, fruit cultivation, etc.) as their primary source of income/livelihood (Table 5). Illegal cutting and selling of trees was another livelihood that almost stopped during the project period, being replaced with alternative livelihoods.

Table 5 Changes in occupations in the study area

Period	Occupations	Relative frequency (%)
Before joining the project	Illegal tree cutting	80.5
	Farming	10.5
	Forest product collection	5.0
	Day labor	2.5
	Others	1.5
After joining the project	Farming	65.0
	Day labor (agric. and non agric.)	16.5
	Small business	7.0
	Poultry rearing	5.0
	Livestock rearing	3.5
	Others	3.0

The project supplied wages to the participants to guard the forest and sale of trained participant's (16.5%) labor to agriculture and commercial farms to sustain their livelihood. In some cases, such as family financial crisis, participants were forced to sell their trees, cattle, and goats for money. A remarkable number of participants (71.5%) received loans from NGOs, relatives, neighbors, or local banks for crop cultivation, livestock rearing, small businesses, and other purposes. An increase in the average monthly income was observed in the community. The lowest-income group was reduced from 35.8% before the project to 19.4% after it (Fig. 4).

Social capital

There is much debate about what exactly is meant by the term *social capital* (DFID, 1999). Social capital refers to the social resources that people draw on to make a living, including relationships with more powerful people (vertical connections) and others such as themselves (horizontal connections), as well as memberships to groups or organizations. We analyzed relationships between participants and FD staff as well as the general community (Table 6). Among participants, 40.5% indicated that they felt that they had good relations with FD staff; only 1% indicated that they did not. In addition, 48.5% and 54.0% of the participants felt that they received more respect after the program from FD staff and from their family members, respectively. About 49.5% of the participants reported that, since joining the

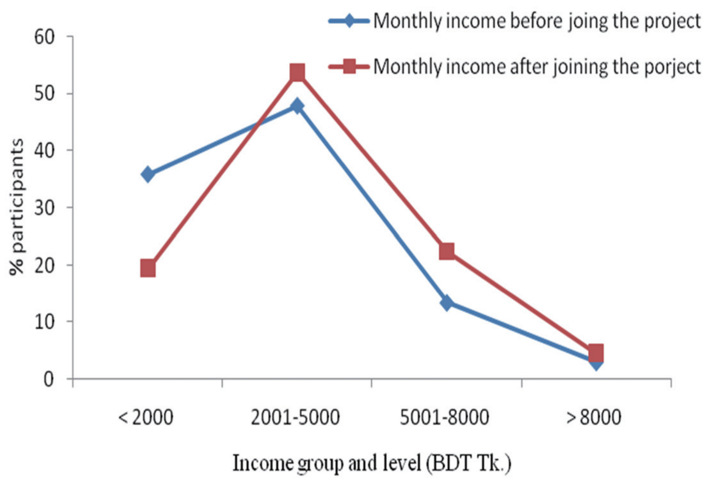

Fig. 4 Comparative monthly income of participants before and after joining the project

Table 6 Improved social parameters

Parameters	Participants' opinions (%)				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Do you feel that you have good relations with FD staff?	40.5	37.5	11.5	9.5	1
Do you feel more respected by the FD staff?	48.5	37.5	12	2	–
Do you feel more respected by family members?	54	38	6	2	–
Do you get more invitations to social ceremonies?	53.5	35	8	3.5	–
Do you get more help from neighbors in emergencies?	49.5	32	15	2.5	1
Do you think that your skills have been developed?	46.5	30.5	15	8	–
Do you make decisions in consultation with your spouse or other family members?	36	42	15.5	6.5	–

project, they received more invitations to social ceremonies such as weddings, religious activities, and other social events. The same percentage reported receiving more help from neighbors during emergencies.

Female participants were asked three specific questions: Has there been a reduction in discrimination by others when you go outside the home? Has there been a reduction in abuse by your husband? Has there been a reduction in demand for dowry by your husband or husband's family? A remarkable reduction was reported for all three situations.

Forest conservation

Forest conservation refers to the successful protection, improvement, and/or creation of specific forests and/or specific forest functions and services (Sunderlin et al., 2005). Forest conservation can provide the motivation to protect, improve, and/or create functions and services that benefit people living in or near a given forest or far from them.

The FD initiated a revegetation project as part of their program. The FD included 1000 ha of encroached forest land, to be planted with local tree species of timber, fruit, fodder, and so on (Table 7). The participants would received 45% of the income generated from the project for 10 years (the FD would also receive 45% and the remaining 10% would go toward future tree farm management funds). To reduce dependency on forests for fuel wood, timber, and other resources, the project supplied 200 tree species (e.g., timber, firewood and fruit species) to every participant and 5500 forest-dependent families. The study observed that about 52.5% trees have survived after 5 years in their homestead premises, when the participants started benefiting. Most of the participants collected firewood, either from their homestead or market, rather than from the forest.

The real causes of destruction of Madhupur forest have

Table 7 Revegetation scheme of the Madhupur Sal Forest

Year	Tree type/use	Area (ha)	No. of Trees	Tree species
1st	Native timber, fuel wood and fruit	150	375000	Blackberry (*Sytzygium cumini*), Bohera (*Terminalia belerica*), Chickrosi (*Chukrassia tabularis*), Dhakijam (*Syzygium grande*), Gamar (*Gmelina arborea*), Garjan (*Dipterocarpus turbinatus*), Jackfruit (*Artocarpus heterophyllus*), Kadom (*Neolamarckia cadamba*), Mahogany (*Swietenia macrophylla*), Neem (*Azadirachta indica*), Sal (*Shorea robusta*), Star apple (*Syzygium samarengense*)
	Native fodder	10	16000	
2nd	Native timber, fuel wood and fruit	600	1500000	
3rd	Native timber, fuel wood and fruit	250	625000	
	Native fodder	10	16000	
1st & 2nd	Local fruit, timber and fuel wood	Homestead	1100000	

Source: BFD (1016)

not been rightly diagnosed in the past. Only those who felled trees in the forest have been blamed for the forest destruction. The Madhupur forest office have been filed huge cases in court against the tree loggers. The new policy has been able to lessen the gap between local ethnic and non ethnic community and build up confidence. Positive attitude has been developed among people of Madhupur. As a result, forest offenses such as illegal logging, land encroachment and other illegal activities were gradually reduced during the project period. In 2008–2009 and 2009–2010, there were 361 and 376 offenses, respectively. In 2010–2011, there were only 23. There were no offenses in 2011–2012, 2012–2013, or 2013–2014 (Fig. 5). Forest disturbances by anthropogenic activities had decreased due to decrease in forest offences, cattle grazing, and forest product collection. The absence of anthropogenic disturbances has had an important impact on the natural regeneration of the forest floor. A number of young tree species of timber, fruit, medicinal, shrub, climber etc. were found naturally regenerated in the forest floor opined by participants (Table 8). In addition, they also put their opinion about wildlife increases (Table 9). More than 50% participants were agreed with raises of deer, cock and monkey in compare with the period before program launched.

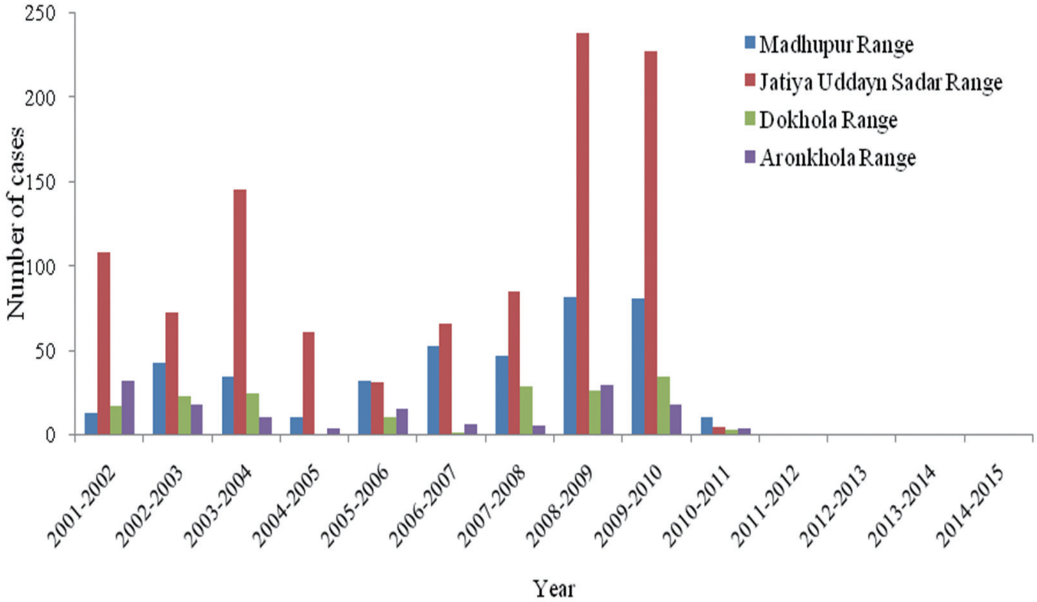

Fig. 5 Trend of offences in Madhupur Sal forest over time (Source: IUCN, 2014)

Table 8 Tree species naturally regenerated in forest floor opined by participants

Unit	Frequency	Percent (%)
Timber Trees		
Sal (*Shorea robusta*)	98	49
Gandhi gajari (*Miliusa velutina*)	78	39
Koroi (*Albigia procera*)	62	31
Ajuli (*Dillenia pentagyna*)	42	21
Shida (*Lagerstroemia parvifloraRoxb*)	29	14.5
Kaika (*Adima cordifolia*)	17	8.5
Shiris (*Albiria sp.*)	16	8
Segun (*Tectona grandis*)	15	7.5
Giza (*Odina Older*)	12	6
Others (Jarul, Arjun, Bot, Sonalu etc.)	34	17
Fruit trees		
Black berry (*Syzygium cumini*)	143	71.5
Anaigota (*Ziziphus rugosa*)	104	52
Ban Alu (*Dioscorea bulbifera*)	48	24
Pahari banana (*Musa textilis*)	32	16
Neor (*Bursera serrata*)	27	13.5
Jaina (*Schleichera oleosa*)	42	21
Medicinal Plants		
Amloki (*Phyllanthus emblica*)	108	54
Bohera (*Tenninalia arjuna*)	103	51.5
Haritaki (*Terminalia belerica*)	53	26.5
Undergrowth and climbers		
Bet (*Calamus spp.*)	18	9
Monkata (*Randia dumentorum*)	15	7.5

Table 9 Increased wildlife's availability in the forest opined by respondents

Unit	Frequency	Percent (%)
Deer	165	82.5
Cock	155	77.5
Monkey	116	58
Birds	96	48
Mukhpora Hanuman	51	25.1
Pig	42	21
Snake	38	17
Cat	29	14.5
Porcupine	27	13.5
Fox	23	11.5
Rabbit	21	10.5

Finally, we asked participants about their willingness to extend the project. All respondents expressed a firm intention to continue with the project. When asked why, most cited economic benefits and protection of the forest, and very few did not respond.

DISCUSSION

The present study attempted to highlight protecting forests, sharing resource management and ensuring secure livelihoods for those dependent on forest through a forestry project. Participation in this project "Revegetation of Madhupur Forest through Rehabilitation of Forest-Dependent Local and Ethnic Communities," had a positive influence on livelihood development and forestry management. The development program was built around a vision for human empowerment, advancement, and welfare, with the fullest range of available natural resources being available (Mbie et al., 2005). Our results revealed the existence of strong relationships among FD staff and participants, despite the fact that most participants were illegal loggers before the project was initiated.

The participants knew each other quite well and a strong, collaborative attitude was built among them. Previously, most of the participants were dependent on the forest for their livelihoods. They earned subsistence money, either by engaging in illegal logging activities or collecting forest products, thus accelerating forest degradation. After starting the project, however, they stopped stealing timber from the forests and became crop producers or engaged in other income-generating activities.

The success of the FD program involved people radically departing from their roles of tree destroyers to forest protectors. They benefited from their participation in the project, which discouraged them from further involvement in activities destructive to the forest and encouraged them to engage in the conservation process. The intensive training and motivation, as well as the monetary incentives, changed the attitudes of the community.

Ezebilo (2011) reported that local people residing in the vicinity of the Cross River National Park in Nigeria highly preferred collaborative management of local resources that combined biodiversity, conservation, and community development. Islam et al. (2013) reported that a rehabilitation project for Sal forest dependents in Bangladesh resulted in a high participation rate among encroachers and forest dependents, resulting in capacity building, social relationship development, and the use of natural assets and human capital through alternative livelihood strategies that have provided security and improved livelihoods. According to Yadav et al. (2003), natural resources in most regions of Nepal deteriorated before the introduction of community forestry, but the forests improved where community forestry was well-established.

In the present study, we also observed some shortcomings of the project. For example, the FD made most decisions regarding project implementation; hence, while participants were empowered by the project they were not in control of most aspects. We also found that while participants protected the forest, some owners of saw mill and brick field tried to influence them to cut trees illegally. Finally, after the project concluded, and wages and incentives from the FD were terminated, the participants again considered pursuing illegal logging.

Improved human capital

The development of human capital improved the capability of individuals to secure their well-being. In this study, human capital included training, as well as refresher courses. Specialized training was also built on awareness of these issues in the community. Training could enhance skills, which might have a significant impact on the participants' attitudes, as well as on forest conservation (Islam et al., 2012). In this study, participants were highly inspired in response to the training program that focused on conserving Sal forest. Moreover, acquired skills and knowledge affect social capital, such as building relationships and encouraging self-sufficiency within participating groups.

An important finding from this study was the change in attitude of the FD staff toward the participants and local people. Muhammad et al. (2008) claimed that, as for the implementing agency of any project, the staff included in his study played a role in the failure of the project. They did not seek active participation of genuinely poor people and other direct stakeholders in the forestry projects. Tole (2010) also mentioned that state officials entrusted with the design and implementation of co-management projects in many developing countries often have negative attitudes about community empowerment, which impedes the full realization of the project goals. This did not occur in our study.

Improved physical capital

Most participants improved their houses after being involved in the project. In a case study in Bangladesh, Islam and Sato (2012) found a similar trend for non-ethnic groups but ethnic participants showed negative attitudes after being involved in a participatory forestry program.

Animal husbandry is an important livelihood activity in the study area. Animals are reared for milk, manure, meat, and farming activities. All of the participants were given a ruminant from the project, but in general the average number of livestock decreased due to a lack of grazing land and shortage of fodder in the study area. A similar trend was reported by Islam and Sato (2012).

The participants had previously allowed open grazing of their livestock in the forest. After the project, open grazing was restricted and human entrance as well. Good communication and transportation is a prerequisite for community development. However, improvements to roads and other public goods were beyond the scope of this project. We did find that access to and use of some expensive appliances such as televisions, CD players, and solar panels increased among the participants after the project.

Improved natural capital

Natural capital was one of the main income sources for participants. Most participants produced crops that generated income. Moreover, agro-forestry practices in the participatory forestry plots provided additional income. Muhammad et al. (2008) also identified agro-forestry as being the most beneficial practice among different land-use patterns for public-oriented forestry in the Tangail Forest Division of Bangladesh.

Participants used their financial capital to cover household expenses and partially sustain their livelihoods. Livelihoods and natural resources are closely interrelated, where the decline of one puts additional pressure on the other (Rigg, 2006). Community forests are natural capital. Access to forest resources, particularly firewood, was restricted. In the study area, wood was the main energy source for cooking. Before the project, the majority of participants were dependent on forests as a source of firewood. The project helped to minimize their firewood demand, by establishing homestead forestry, but some of the local poor people still depend on the forests for this resource.

Improved financial capital

Financial assets denote disposable income from various sources. Adequate financial resources help to overcome external risks. The major source of cash income of the participants was associated with farming. The trained participants worked on farms, which provided a good source of seasonal income. The participants received wages from the project as well, which provided regular income. Moreover, loans from different sources were obtained to support their livelihoods.

Participants spent their money on household items, appliances, and agricultural inputs. Some also invested in education and health care for their children. Hence, the extra financial capital helped to partially sustain their livelihoods. In the event of family crises, the sale of natural resources such as trees and livestock generated enough to meet their emergency financial needs. Therefore, the project helped to boost their financial capital, but their livelihoods depended on all types of capital.

Improved social capital

Social capital plays an important role in the management of natural resources and improvement of livelihoods, particularly in remote, rural areas (Nath and Inoue, 2010). The benefits of the creation of social capital depend on the participation of households and individuals in local institutions and enhanced knowledge of rights and duties involved in securing a livelihood. Knowledge, skills, and motivation have a strong impact on social capital, which builds positive relationships and capabilities.

In our study, intensive training and CFW activities helped to create good social networks. Participants developed social relationships among themselves and with the project staff and neighbors. In the past, locals had not been satisfied with the FD or their own community. These relationships improved throughout the project. Muhammad et al. (2008) reported similar results.

The project also improved most participants' satisfaction with their annual diet, clothing, health care, education, and entertainment (Table 8).

Progress related to women's rights were also improved. In rural Bangladesh, women are usually deprived of their status and respect, both in the family and in society (Subhani, 2008), although it is generally recognized that women play an important role in resource management because of their knowledge, skills, and experience. In this study, officials encouraged women to actively participate in the project activities and this reduced mental and physical harassment and also improved their empowerment both in the family and in society. Subhani (2008) also reported improvements in skills, knowledge, decision-making power, and respect in females who participated in co-management projects in Lawachara National Park, Bangladesh.

Improved forest condition

The project reduced dependency on forest resources and thus improved the preservation of biodiversity and the socioeconomic development of the local communities. The community-based projects improved the living conditions of local residents, alleviated pressures on resources, and reduced conflicts between community members and forest managers (Blaint, 2006).

Sawhney et al. (2007) reported that participation in such projects improves when adequate incentives are offered and the roles of participants are clearly defined. The Sal project achieved these objectives, and both the community and the forest benefited.

Table 10 Improvements in household expenditures

Unit	Participants' opinions (%)							
	Before joining the project				After joining of the project			
	Highly satisfied	Satisfied	Less satisfied	Not satisfied	Highly satisfied	Satisfied	Less satisfied	Not satisfied
Food	–	34.3	65.7	–	11.9	83.6	4.5	–
Cloths	1.5	26.9	58.2	13.4	14.9	62.7	22.4	–
Health	–	13.4	79.1	7.5	11.9	71.6	16.4	–
Education	3	12.1	80.3	4.5	16.7	72.7	10.6	–
Amusement	–	7.6	59.1	33.3	9.1	36.4	42.4	12.1

More specifically, incentives for livelihood improvement and inspirational development of various socio-cultural parameters of the community were the basis for sound forest management. The participants became highly motivated during training and were committed to conserving the forest. This was achieved through protection (patrolling by CFWs) of forests from illegal tree felling, livestock grazing outside of the forest, and a reduction in the extraction of forest products. These reductions in external pressures probably keep the forest undisturbed and promoted the natural regeneration of the forest floor, which increased canopy cover. The natural regeneration of vegetation is a dynamic process by which life recolonises land when the vegetation has been partially or totally destroyed. Life recovers the lost ground through the mechanism of the succession of species. The most evident way to restore vegetative cover is to protect it from the causes for degradation mostly exploitation which can spread naturally, but the process is often slow. The species were naturally regenerated because seeds were fallen from surrounding trees to forest floor of stumped sprouts and root suckers developed from them, but it is necessary to understand the strategy for survival of each tree species. Jayakumar and Nair (2013) reported that tree regeneration was higher in species rich vegetation type with no sign of human disturbances in Tropical Forests of the Western Ghats, India. Putul et al. (2003) reported about 55, 68 and 52% species were found to be regenerating in the undisturbed, mildly disturbed, moderately disturbed stand, and there were no species found in highly disturbed stands in tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. They also stated that variation in species richness, distribution pattern and regeneration potential is related to human interference and the need for forest conservation is emphasized. On the other hand, the vegetation is providing important resources for nesting, food and protection for a variety of wildlife, resulting, and their increases in the forest. Saara et al. (2003) reported that changes in tropical forest structure and species composition that occur during regeneration following land abandonment may have important consequences for wildlife populations.

In addition, the participants attempted to resuscitate degraded forest lands. Plantations can play an important role in biodiversity conservation and restoration of forest species, particularly when management aims to balance environmental and economic goals (Hartley, 2002; Brockerhoff et al., 2008). Leah and Kathleen (2010) suggested that plantations are most likely to contribute to biodiversity when established on degraded lands rather than replacing natural ecosystems, such as forests, grasslands, and shrublands, and when indigenous tree species are used rather than exotic species. The plots given out for planting trees adjacent to the Madhupur Sal forest may eventually become a part of the natural forest canopy, increasing overall tree cover. Faruq et al. (2016) reported an increase in natural forest cover of Madhupur Sal forests in Bangladesh. Zaman and Katoh (2011) found significant increases in forest cover in areas protected by local governments and private owners. They also observed conversion of some croplands into closed and opened forest tracts in the Thakurgaon Forest in northern Bangladesh. Islam et al. (2013) reported that re-vegetation activities have proceeded in Sal forest area of Bangladesh, even as authorities ignore many of the illegal activities of forest-dependent people. The net effect is that there has been a significant improvement in the vegetation.

In our study, at the start of the program, participants who were most dependent on the forest were in conflict with the program, particularly in the initial stages. Firewood sellers, in particular, complained bitterly about the restrictions on collecting firewood, although their firewood needs were still accommodated, at least to some extent. They were also encouraged to pursue other alternative income-generating activities, including farming, nursery production, and the rearing of livestock and poultry. These alternatives eventually contributed considerably to their family incomes and also reduced their dependency on forest for resource collection. Mukul and Quazi (2008) also reported a collaborative management project that combined biodiversity conservation and community development and the project almost eliminated illegal logging and the use of forest trees for firewood. Shubani (2008) also reported that a majority of female members involved in a similar project in Satchari National Park, Bangladesh abandoned firewood collection to become involved in more sustainable activities.

For people dependent on forests, it is difficult to reduce the collection of forest trees for firewood, especially for cooking. Thus, in the study area, to reduce dependence on the forest for timber and firewood, all participants were provided different tree species to cultivate in their homestead premises and in plots given to them for this purpose. The participants were also given improved cooking stoves to save firewood and they were experienced to save fuel using the stove. IAP (2008) reported that a one mouth portable improved cocking stove can save 50% of fuel and 25% more effective compare with a traditional mud stove.

CONCLUSION

In this study, co-management of a Sal forest in Bangladesh greatly improved the livelihoods of the people dependent on the forest and enhanced the forest's conservation. Recognizing the interrelationships between community livelihoods and forest resource conservation, the rehabilitation project involved both the local community and local government officials. This project might be a model for Bangladesh's forestry sector.

The results of this study have potential implications for the broader context of co-management in Bangladesh and other developing countries. Among other factors, social capital played an important role in achieving project objectives. The project developed good relationships between local communities and the FD.

The program enhanced various types of livelihood capital, and improved access to livelihood opportunities. The project properly addressed community needs and problems, and developed capacity building through intensive training and by providing alternatives for new occupations. The project reduced illegal logging and encouraged the planting of native species by project participants. Therefore, attempts to conserve the Sal forest were successful.

To prevent further destruction of this forest, and further develop the livelihoods of those who depend it, the FD should consider continued conservation and livelihood strategies for locals; the forest should be protected through coordination among the FD, police, and the justice department; and all brick fields and sawmills in the forest area should be monitored and their owners strongly motivated to not use Sal timber illegally.

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Article

The Differences of the Light Environment Established in 20 Years between the Monolayered Sowing Slope and the Multilayered Mixed-species Plantation Slope

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ABSTRACT

To restore a broadleaved forest, two techniques were introduced 20 years ago on a slope at the Akandana Parking lot, Japan: a mixed-species plantation method using six species and a seed sowing method using seven species. The mixed-species plantation slope is a multilayer forest, whereas the sowing slope is a monolayer forest. Seedling density and forest floor coverage also differ between these two techniques: 3.2 individuals/m^2 seedlings and 23.6% coverage on the mixed-species plantation slope versus 0.1 individuals/m^2 seedlings and 71.3% coverage on the sowing slope. The purpose of this study is to assess differences in light environment between the two slopes and discuss the relationships between community structure and forest floor vegetation. We established 36 plots (5 m × 5 m) and took hemispherical photographs from the midpoint at heights of 2.5 and 0.5 m. The mean value of the sky factor (proportion of open sky area seen from within the forest; %) at the mixed-species plantation slope was 11.2% at 2.5 m and 7.7% at 0.5 m. This environment may promote the emergence of seedlings. In contrast, at the sowing slope, the mean value of the sky factor was 19.0% at 2.5 m and 18.0% at 0.5 m. In this environment, the high coverage by herbaceous species hinders the emergence of seedlings. These results suggest that the light environment caused by vertical stratification influences the forest floor vegetation. To clarify this, surveys of the light environment at varied heights, including the forest floor, should be conducted.

keyword: forest floor vegetation, light environment, mixed-species plantation, vertical stratification

INTRODUCTION

In recent years, reforestation has become an important issue in forest management, because it is expected to fulfill several roles, such as preserving the ecosystem and landscape and preventing disasters. Seed sowing or plantation techniques using tree species are generally used to reforest a slope. In many cases, one or a few species are used, and the distribution of the seeds or the saplings is either random or uniform (Miyawaki et al., 1993; Takada, 1999; Nakagawa et al., 2011; Corbin and Holl, 2012). Therefore, a monolayer forest tends to be established owing to simultaneous growth (Takada, 1999; Corbin and Holl, 2012; Shimada et al., 2015), often resulting in low biodiversity and poor health as a forest (Hirata et al., 2006; Suzuki, 2007).

Under such circumstances, in this study, we investigated a method of mixed-species plantation wherein different seral-stage saplings suitable to the site conditions are planted to restore a natural forest composed of many species with a multilayer vertical forest structure in a short period (Takada, 1999; Shimada et al., 2013). The distribution of the saplings in this case would be neither random nor uniform, because when combinations of the saplings based on species characteristics are considered, individuals of some species are clumped together whereas others are dispersed (Shimada et al., 2013) (Fig. 1).

There is a similar method called applied nucleation, in which trees are planted in small patches to simulate the nucleation model of succession and accelerate natural recovery (Corbin and Holl, 2012; Zahawi et al., 2013). In contrast to this method, the technique we investigated uses a larger variety of tree species, with different growth characteristics and seral-stages, in order to restore the target forest type certainly. However, little has been reported on this technique, and comparing the effects of the different plantation methods is important for future restoration efforts. Considering this, in a previous study (Shimada et al., 2015), we investigated two adjacent slopes where two different reforestation techniques, mixed-species plantation and seed sowing, were introduced 20 years ago. We confirmed that a multilayer forest was established at the mixed-species plantation slope while the sowing slope had a monolayer

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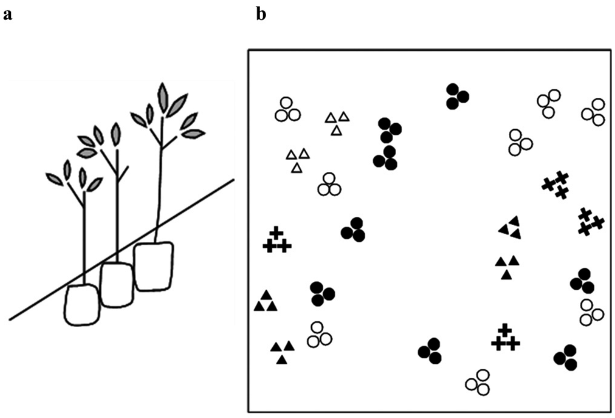

Fig. 1 An example of a planting design and a cross section. ●:*B. ermanii*, *B. platyphylla*, ×: *Q. crispula*, ▲:*S. commixta*, △:*T. cuspidate*, ○:*W. hortensis*. Reprinted from Shimada et al. (2015) by courtesy of the Japanese Society of Revegetation Technology.

forest. In addition, the number of naturally recruited seedlings (hereinafter called seedlings) found at the mixed-species plantation slope was 40 times greater than that found at the sowing slope, but the reason underlying this difference was not determined. Although many conceivable factors may have been implicated, Kato and Komiyama (1999) suggest that the light environment is one of the most important parameters influencing forest floor vegetation. Other studies have also found that forest floor vegetation is affected by the light environment (Machado and Reich, 1999) and that species of plants are varied by it (Canham et al., 1994). Based on these reports, we focused on the light environment in this study.

According to Nakagawa et al. (2009), a forest where one species is dominant has more light than a forest composed of several species. In addition, another study found that if the dominant species at the overstory transmits a lot of light, overgrowth of the understory vegetation will be more advanced (Messier et al., 1998). Furthermore, herbaceous species have been reported to become dominant under higher light levels (Mizui et al., 1979; Kikuzawa et al., 1980). Based on these reports, we speculate that the monolayered sowing slope, where herbaceous species are dominant (Shimada et al., 2015), receives more light than the multilayered mixed-species plantation slope. To our knowledge, a light environment survey has never been conducted at a forest established by the mixed-species plantation method such as the one in this study. Therefore, the purpose of the present study was to clarify differences in light environment between the two slopes and discuss the relationships between community structure and forest floor vegetation.

MATERIALS AND METHODS

Study Area

The study took place on a slope of the Akandana parking lot (1,300 m a.s.l) in Takayama City, Gifu prefecture, Japan (Fig. 2). Average temperature (from data covering 1981–2010) and average precipitation in Takayama city are 11.0℃ and 1,669.5 mm/year (JMA, 2013), respectively; the area is thus snowy and cold. The Akandana parking lot was constructed during development of the surrounding area, and no vegetation remained after construction, even though the area is a part of Chubu-Sangaku National Park. Therefore, it was necessary to restore the natural forest rapidly while also considering the landscape. Hence, the mixed-species plantation was introduced over the entire slope, except in one area where seeds were sown. At the mixed-species plantation slope, the following six species were planted in August to September of 1991 and 1992: *Betula ermanii* Cham, *Betula platyphylla* Sukatchev var. *japonica* (Miq.) Hara, *Quercus crispula* Blume, *Sorbus commixta* Hedl, *Taxus cuspidata* Sieb. et Zucc, and *Weigela hortensis* (Sieb. et Zucc.) K. Koch. More than three saplings of the same species were planted in clumps as a single unit, in order to promote the network development of mycorrhizae and upward growth, and avoid damage due to insects and weather (wind, snow, etc.) (Fig. 1a). At this study area, the unit numbers/100 m^2 of each species were as follows: the sum of 8 for *B. ermanii* and *B. platyphylla*, 4 for *Q. crispula*, 4 for *S. commixta*, 2 for *T. cuspidata* (planting in clumps partly because of the difficulty in obtaining saplings), and 8 for *W. hortensis* (planting in clumps partly because of the size difference) (Fig. 1b). At the sowing slope, seven species were sown in 1990: *Amorpha fruticosa* L., *Alnus hirsuta* Turcz. var. *sibirica* (Fischer) C.K.Schn, *Artemisia princeps* Pamp, *Dactylis glomerata* L., *Lespedeza cuneata* (Dum. Cours.) G. Don, *Phleum pratense* L., and *Torreya nucifera* (L.) Sieb. et Zucc. As the two slopes are adjacent, a comparative study was suitable because the following three conditions were the same: the surrounding vegetation (a primeval forest composed by *Abies homolepis* Sieb. et Zucc, *B. ermanii*, *Cercidiphyllum japonicum* Sieb. et Zucc, *Chamaecyparis pisifera* (Siebold et Zucc.) Endl, *Fagus crenata* Blume, and *T. cuspidata* Sieb. et Zucc, and a coppice forest composed mainly by *Q. crispula* Blume), the direction (southwest), and the slope angle (29 degrees).

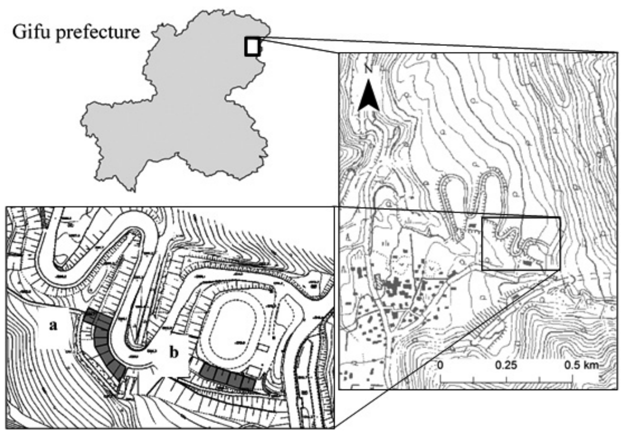

Fig. 2 Study area. (a) mixed-species plantation slope, (b) sowing slope. Modified from Shimada et al. (2015) by courtesy of the Japanese Society of Revegetation Technology.

In our previous study (Shimada et al., 2015), both slope types were investigated from 2012 to 2013, and clear differences were found in the vertical stratification. In the mixed-species plantation slope, several layers were detected; the tree layer composed of *B. ermanii*, *B. platyphylla* and *Q. crispula*, the subtree layer composed mainly of *S. commixta*, and the shrub layer composed mainly of *T. cuspidata* and *W. hortensis*. Thus, these slopes are composed mainly of planted trees with a species distribution pattern preserved from the time of planting (Table 1a, Fig. 3a). In contrast, on the sowing slope, a monolayer, i.e., a tree layer composed of *A. hirsuta* with a random distribution was detected (Fig. 3b). All sown species other than *A. hirsuta* had disappeared from the sowing slope (Table 1b). A difference was also found in the number of seedlings (Table 2): there were 1,606 seedlings (3.2 individuals/m^2) on the mixed-species plantation slope, but only 30 seedlings (0.1 individuals/m^2) on the sowing slope. Finally, a significant difference was noted in the mean forest floor coverage ($P < 0.01$): 23.6% at the mixed-species plantation slope and 71.3% at the sowing slope. The forest floor of the sowing slope was mainly covered by herbaceous species.

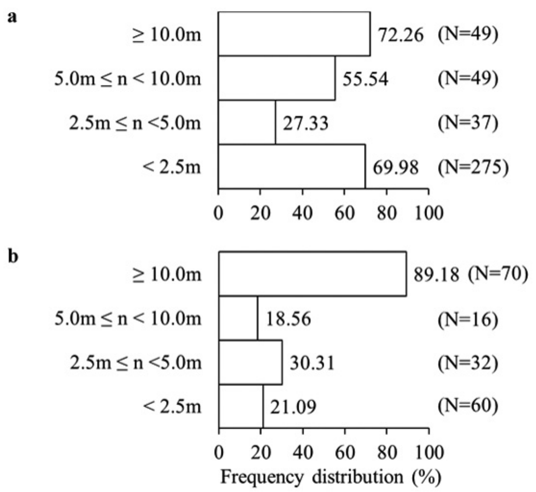

Fig. 3 Frequency distribution of the crown area against the plot area on the basis of height class. (1) a: mixed-species plantation slope, b: sowing slope, (2) Number means the percentage and N means the number of trees.

Data Collection and Analysis

We established 4 plots (three 10 × 10 m plots and one 20 × 10 m plot) on the mixed-species plantation slope and 4 on the sowing slope (all plots were 10 × 10 m). On the mixed-species plantation slope, one plot size was expanded to 20 × 10 m to ensure the plot area was an accurate representation of the slope; however, there was not enough area to do this at the sowing slope. These plots were in the same arrangement as in our previous investigation (Shimada et al., 2015). The light environment survey was conducted in 2013, at the same time as when the vertical stratification survey (Shimada et al., 2015) was done. The seedling data collected in the vertical stratification survey (Shimada et al., 2015) was also used in the following analysis.

To measure the light environment, we divided the plots into 5 × 5 m subplots and took hemispherical photographs (camera: D3200, Nikon, fisheye lens: 10 mm F2.8 EXDC FISHEYE HSM, Sigma) from the midpoint of each subplot at the heights of 2.5 m and 0.5 m. The photos were taken in July 2013, on an overcast day. The shutter speed was on automatic setting and the exposure value was ±0.0, which was identified as the best after testing several values. In total, 72 photographs were taken from 36 photography points. The height at which the photograph was taken was decided based on the vertical stratification survey: 0.5 m and 2.5 m were the highest points of the herb and shrub layers, respectively. Two photographs taken from one of the 36 photography points were excluded because they were out of focus.

To assess differences in light environment between the two slopes and the relationship between community structure and forest floor vegetation, we calculated the sky factor (proportion of open sky area seen from within the forest; %) of each photograph using the free Canopon 2 software (Takenaka, 2009). We then calculated the mean value and the 95% confidence interval of the sky factor at 2.5 m and 0.5 m for each slope with the bootstrap method, resampling 1,000 times, using R software (R development core team, 2006). Following the methods described by Kago et al. (2013) and Washimi et al. (2015), we used the confidence interval as an index of variability and decided that there was a significant difference if the confidence intervals did not overlap. The Spearman's rank correlation coefficient of the following was also calculated for each slope: 1) the sky factor between 2.5 m and 0.5 m, 2) the number of individuals or species of seedlings and the sky factor for each subplot.

RESULTS

The mean value of the sky factor obtained by bootstrap method at the mixed-species plantation slope was 11.2% at 2.5 m and 7.7% at 0.5 m (Fig. 4, Table 3). At the sowing slope, the average was 19.0% at 2.5 m and 18.0% at 0.5 m. Since there was no overlap in confidence intervals between the two slopes (Fig. 4, Table 3), the sky factor of the mixed-species plantation slope was significantly lower than that of the sowing slope at both heights. In addition, the lack of overlap within the mixed-species plantation slope showed that the sky factor at 0.5 m was significantly lower than that at 2.5 m; however, confidence intervals within the sowing slope overlapped, showing that there was no significant difference in sky factor between the two heights in that habitat (Fig. 4, Table 3). Furthermore, the sky factor at 0.5 m in the mixed-species plantation slope showed the least variability between subplots (Fig. 4). Fig. 5 is a scatter plot representing the correlation between sky factors at both heights for each photography point. The correlation coefficient of the sky factor between 2.5 m and 0.5 m was 0.21 ($P = 0.37$) in the mixed-species plantation slope but 0.85 ($P < 0.01$) in the sowing slope. The high value of sky factor shown on Fig. 5 in the mixed-species plantation slope at the height of 2.5 m is a result of the canopy gap.

Fig. 6 shows the relationship between sky factor and number of seedling individuals or species in each subplot. No significant correlation was found between sky factor and the

Table 1 Data of the investigated trees

a: Mixed-species plantation slope

	Species	Number		Height		DBH	
				MAX (m)	min (m)	MAX (cm)	min (cm)
Planted	*Betula ermanii* Cham.	54	(51)	14.2	2.5	18.2	3.4
	Betula platyphylla Sukatchev var. *japonica* (Miq.) Hara.	21	(18)	16.5	2.3	20.7	1.7
	Quercus crispula Blume.	44	(20)	12.1	0.6	17.5	0
	Sorbus commixta Hedl.	39	(29)	8	0.5	6.6	0
	Taxus cuspidate Sieb. et Zucc.	27		2.5	1	4.6	0
	Weigela hortensis (Sieb. et Zucc.) K. Koch.	137		2.8	0.5	3.8	0
Non-planted	*Acer amoenum* Carr. var. *matsumurae* (Koidz.) Ogata.	8		1.1	0.4	0	0
	Acer crataegifolium Sieb. et Zucc.	1		0.8	0.8	0	0
	Acer mono Maxim. var. *marmoratum* f. *dissectum*	1		0.8	0.8	0	0
	Acer rufinerve Sieb. et Zucc.	16		1.5	0.6	0.7	0
	Aesculus turbinata Blume.	20		4.2	0.4	3.6	0
	Carpinus cordata Bl.	4		3.2	0.5	2.3	0
	Cladrastis Platycarpa (Maxim.) Makino.	14		6.2	0.5	4.9	0
	Morus austrails Poir.	1		1.2	1.2	0	0
	Prunus grayana Maxim.	1		0.8	0.8	0	0
	Prunus maximowiczii Ruprecht.	1		0.9	0.9	0	0
	Pterocarya rhoifolia Sieb. et Zucc.	3		1.6	0.5	1.2	0
	Rubus palmatus Thumb. var. *coptophyllus* A.Gray	2		1	1	0	2
	Salix bakko Kimura.	1		4.3	4.3	2.2	2.2
	Salix gilgiana Seemen.	1		8.4	8.4	14.6	14.6
	Swida controversa (Hemsl.) Sojak.	4		10.6	0.8	11.6	0.5
	Tilia japonica (Miq.) Simonkai.	10		1.8	0.5	1.3	0
	Total	410					

The number inside the parenthesis is the number of the planted trees.

Modified from Shimada et al. (2015) by courtesy of the Japanese Society of Revegetation Technology.

b: Sowing slope

	Species	Number		Height		DBH	
				MAX (m)	min (m)	MAX (cm)	min (cm)
Sown	*Alnus hirsuta* Turcz. var. sibirica (Fischer) C.K.Schn.	94	(80)	19.7	0.5	28	0
Non-sown	*Abies homolepis* Sieb. et Zucc.	12		3.2	1	5.3	0
	Acer amoenum Carr. var. *matsumurae* (Koidz.) Ogata.	3		1.6	0.9	0.8	0
	Acer mono Maxim. var. *marmoratum* f. *heterophyllum*.	6		2.7	0.8	1.8	0
	Acer rufinerve Sieb. et Zucc.	9		5.4	1.2	4.5	0
	Aesculus turbinata Blume.	4		4.2	0.8	4.5	0
	Betula ermanii Cham.	10		16.3	1.3	11.5	0.4
	Fraxinus lanuginosa Koidz. f. *serrata* (Nakai) Murata.	3		2.3	1.3	1.3	0.3
	Kalopanax pictus (Thunb.) Nakai.	2		2.2	1.2	1.8	0
	Larix kaempferi (Lamb.) Carriere.	9		5.6	0.7	20.1	0
	Prunus grayana Maxim.	1		0.4	0.4	0	0
	Quercus crispula Blume.	5		2.3	1.1	1.8	0
	Rhus sylvestris Sieb. et Zucc.	5		5.5	2	5.3	1.6
	Salix bakko Kimura.	1		2.9	2.9	2	2
	Swida controversa (Hemsl.) Sojak.	2		4	2.1	5.2	1.1
	Tilia japonica (Miq.) Simonkai.	10		2.6	1	2	0
	Weigela hortensis (Sieb. et Zucc.) K. Koch.	2		1.7	0.8	0.9	0
	Total	178					

The number inside the parenthesis is the number of the sown trees.

Modified from Shimada et al. (2015) by courtesy of the Japanese Society of Revegetation Technology.

Table 2 Species and number of the seedlings

Species	Number	
	MSP slope	Sowing slope
Abies homolepis Sieb. et Zucc.	12	0
Acer amoenum Carr. var. *matsumurae* (Koidz.) Ogata.	29	1
Acer crataegifolium Sieb. et Zucc.	11	0
Acer japonicum Thunb.	25	5
Acer mono Maxim. var. *marmoratum* f. *heterophyllum.*	61	3
Acer rufinerve Sieb. et Zucc.	65	0
Acer sieboldianum Miq.	2	0
Aesculus turbinata Blume.	7	1
Ampelopsis Michaux.	30	0
Betula ermanii Cham.	25	0
Betula platyphylla Sukatchev var. *japonica* (Miq.) Hara.	2	0
Carpinus cordata Bl.	108	0
Cercidiphyllum japonicum Sieb. et Zucc.	2	0
Cladrastis Platycarpa (Maxim.) Makino.	236	1
Euonymus sieboldianus Bl.	0	1
Fagus crenata Blume.	2	0
Magnolia obovata Thunb.	1	0
Prunus L.	23	0
Quercus crispula Blume.	314	6
Rhus trichocarpa Miq.	1	0
Rubus L.	23	5
Sorbus commixta Hedl.	111	0
Swida controversa (Hemsl.) Sojak.	27	0
Taxus cuspidate Sieb. et Zucc.	12	0
Tilia japonica (Miq.) Simonkai.	108	4
Weigela hortensis (Sieb. et Zucc.) K. Koch.	369	3
Total	1,606	30
Forest floor coverage (%)	23.6	71.3

MSP, Mixed-species plantation.

Modified from Shimada et al. (2015) by courtesy of the Japanese Society of Revegetation Technology.

Table 3 Mean value of the sky factor for each slope

	Sky factor (%)			
	MSP slope		Sowing slope	
2.5 m	11.2	(9.1−13.6)	19.0	(16.5−21.1)
0.5 m	7.7	(6.8−8.8)	18.0	(15.5−20.4)

MSP, Mixed−species plantation.

Variables inside the parenthesis is the 95% confident interval.

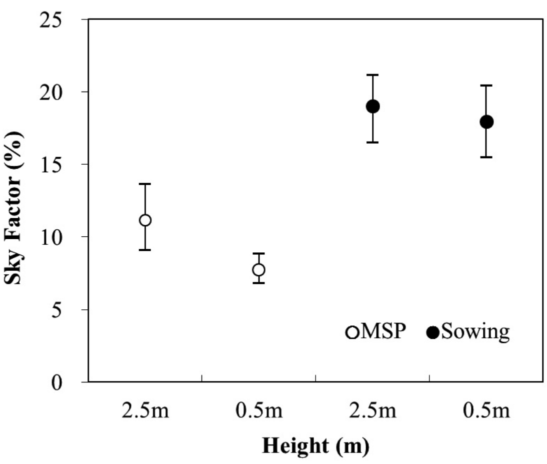

Fig. 4 Mean values and 95% confidence interval of sky factor calculated using bootstrap sampling. MSP, Mixed-species plantation.

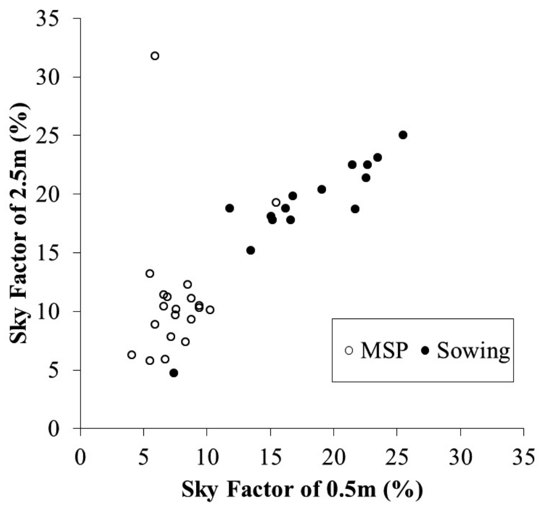

Fig. 5 Scatter plot of sky factor for each photography point. MSP, Mixed-species plantation.

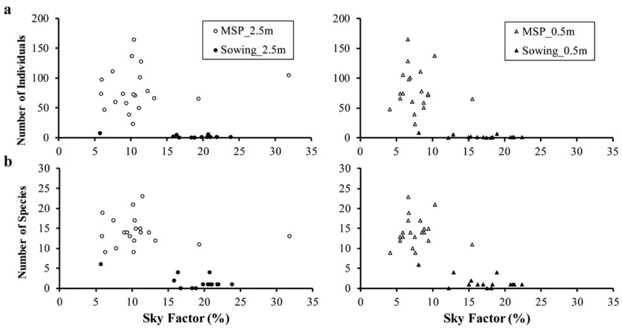

Fig. 6 Relationship between sky factor and the number of a: individuals or b: species of seedlings in each sub-plot. MSP, Mixed-species plantation.

number of individuals or species. At both heights (2.5 m and 0.5 m), the sky factor in the mixed-species plantation slope was lower than in the sowing slope, but the mixed-species plantation slope had a considerably higher number of individuals and species of seedlings, along with higher variability among the subplots, than the sowing slope.

DISCUSSION

In our previous study (Shimada et al., 2015), we identified a difference in the forest floor vegetation between the two slopes: low individual density of seedlings and high coverage by herbaceous species in the sowing slope, and the opposite in the mixed-species plantation slope (Table 2).

In the present study, the sky factor was observed to be significantly higher in the sowing slope than in the mixed-species plantation slope. It is inferred that this difference is caused by the difference in vertical stratification between the two slopes.

In the sowing slope, the results of the bootstrap and a significant correlation of sky factor between 2.5 m and 0.5 m showed that the light environment is similar at both heights; this is because the sowing slope is a monolayered forest. In the sowing slope, coverage by herbaceous species was high, and this may have prevented the emergence of seedlings owing to reduced light intensity. Messier et al. (1998) found that if dominant species at the overstory transmit much light, understory vegetation will overgrow, making the forest floor dark. Furthermore, several studies have reported that overgrowth of understory vegetation, including herbaceous species, made the forest floor dark, which disturbed the emergence of seedlings (Mizui et al., 1979; Shimano et al., 2001; Nakagawa et al., 2009). To verify this effect of the herbaceous species, additional surveys should be conducted on the light environment at the forest floor (0.0 m).

Because the mixed-species plantation slope is a multilayered forest, the sky factor was lower as a consequence of the overlapping canopy (Fig. 3). This is also suggested by the fact that the sky factor at 0.5 m, which showed the least variability, was significantly lower than the value at 2.5 m. This was possibly because almost 70% of the plot area below 2.5 m was covered by shrubs. The sky factor at the canopy gap point also shows the effect of the shrub canopy: the sky factor was 31.8% at 2.5 m, and decreased to 5.9% at 0.5 m. Under the light environment influenced by the overlapping canopy, coverage by herbaceous species was low, and this may have promoted the emergence of seedlings. Shimano et al. (2001) investigated the relationship between the light environment and the forest floor vegetation and found that the number of individuals or species of seedlings was the highest where light, attenuated by the overlapping canopy, reached the forest floor. Therefore, surveys of the light environment at the forest floor (0.0 m) should also be conducted on the mixed-species plantation slope.

On the other hand, no correlation was noted between the sky factor and the number of seedling individuals or species in the mixed-species plantation slope, suggesting a high variability in forest floor vegetation composition between subplots (obvious from Fig. 6); this may indicate the possibility of high spatial diversity in light environment caused by a multilayered forest. Indeed, Baldocchi and Collineau (1994) and Guariguata et al. (1995) have stated that a multilayered forest will lead to high diversity in light environment, and Nagaike (2000) suggested that species with different shade-tolerance are more likely to coexist if fluctuations in amount and quality of the light environment are high. However, it is not possible from this study to conclude whether the light environment on both slopes is highly diverse or not.

Our findings suggest that surveys of the light environment should be conducted not only at the forest floor but also with respect to both vertical and temporal distribution on both slopes. Because the light environment relates heavily to factors such as photosynthesis, evapotranspiration, reproduction, germination, growth, and survivorship (Larcher, 1980), and photosynthetic photon flux density (PPFD) varies along with forest floor vegetation (Messier et al., 1998; Kato and Komiyama, 1999; Ishida, 2000), we should assess the PPFD using precise techniques. Some difficulty has been reported in estimating the PPFD by using hemispherical photography, especially under overlapping canopy (Machado and Reich, 1999; Ishida, 2000; Kunizaki, 2002; Ishida, 2004). Therefore, PPFD measurement using a light sensor should be conducted to get more accurate values. We expect that these surveys might help explain why the forest floor vegetation is so different between the two slopes, and such data would further clarify the relationship between light environment, community structure, and forest floor vegetation.

In conclusion, the main findings of our study are as follows. First, the sky factor of the multilayered mixed-species plantation slope was significantly lower than that of the monolayered sowing slope at both heights (2.5 m and 0.5 m). Second, we found no significant difference in sky factor between the two heights in the sowing slope. Third, the sky factor at 0.5 m in the multilayered mixed-species plantation slope was significantly lower than that at 2.5 m and showed the least variability, probably due to the overlapping canopy. Finally, we suggest that the light environment caused by the vertical stratification influences the forest floor vegetation, but determining this will require an additional survey of the light environment at varied heights, including at the forest floor level.

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* The English titles are tentative translations by the authors of this paper from original Japanese titles.

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