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Demonstration of Sustainable Upland Agroforestry Systems in Chinese Taipei

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ABSTRACT

Taiwan is a mountainous island with lush and diverse forests which occupied 58.5% of the island area. Upland area is vulnerable and unstable, especially huge landslides and debris flow disaster happened in upland area frequently in recently decades. However, agricultural practices in upland areas are continuously implemented for livelihood. In Chinese Taipei, one of the present research priorities has been focused on carbon sink effect in afforestation and reforestation. This project will provide more knowledge and technology in this field. Furthermore, agroforestry management systems that encourage the farmers to interplant trees on their farmlands can be a solution to harmonize the land use types in these areas.

The major goal of this project is to develop and demonstrate the sustainable agroforestry systems adaptable in upland areas of Chinese Taipei. Not only at least 2 agroforestry management systems but also the criteria and indicators for evaluating the sustainability will be developed. The ability of soil and water conservation of these agroforestry systems will be verified. Moreover, several farmers' technical teams from upland villages will be fostered to assisting technology dissemination. Taiwan Forestry Research Institute, the executing agency, will cooperate with two agencies, Taiwan Forestry Bureau and Chinese Forestry Association to carry out this project. Farmers who provide their farms as experimental plots, farmers' communities, and industries interested in forest products also play an important role in this project.

Study sites are selected in north, east and center Taiwan, respectively. They vary in elevation and in crop species. Although most population is living in the downstream plain areas, the upland areas are in the upstream and environmentally closely related to the downstream cities. However, the major activity for livelihood in upland villages (including aboriginal areas) is agricultural productions, such as betel nuts, tea, fruits and vegetables. Surface erosion problems might be serious on these cultivated uplands. Therefore, appropriate agroforestry management system(s) in these areas will be able to balance different interests among different parties.

KEY WORDS: Agroforestry, Sustainability, Upland area, Demonstration site.

BACKGROUND

Taiwan is a mountainous island with lush and diverse forests. The total area of Taiwan island is only 3.6 million ha. Forest area is 2.1 million ha which occupied 58.5％ of the island (Forestry Bureau, 1995). About 20% (420,000 ha) of the forest area, is plantation, 7% is bamboo forest, and the remaining 73％ is classified as natural forest. With more than 260 mountain peaks over 3,000 meters in elevation, the island of Taiwan supports a diverse flora of over 4,000 vascular plant species and a spectrum of six forest types ranging from tropical rain forest to sub-alpine tundra.

Since the mid 1990s, huge landslides and debris flow disaster occurred frequently due to unusual climate change and occasional earthquake. However, the agricultural practices in upland areas are continuously implemented as a consequence of gaining relatively high revenues comparing to those of plain areas. Many landowners even cut trees on their land and planted high revenue agricultural crops instead. Their behaviors not only violate the forest regulations, but also result in soil erosion and water pollution. As a result, how to balance landowners' profit and land sustainability policy is very important now.

An agroforestry management system that encourage the farmers to interplant trees on their farmlands can be a solution to harmonize the land use types in the upland areas. Upland area is vulnerable and unstable due to its rugged topography. Yet the communities around the mountain villages rely heavily on the production of agriculture such as fruits, tea, and other cash crops for their livelihood. As it usually takes several years or decades in most cases for a planted tree ready for harvest, most farmers/landowners are not willing to change their farms into tree plantations due to lack of income for a long period of time. Moreover, domestic timber market is not sound because over 99% timbers in Chinese Taipei are imported. Therefore, combining partial agricultural crop production for short-term income and partial planted trees for long-term forestation as an agroforestry system should be practical.

Although the Chinese Taipei administration has encouraged private individuals, aboriginal people and/or organizations to plant trees by providing free seedlings, rewards, and long-term low interest loans, there are usually not many landowners being qualified to receive the rewards. For example, no agricultural crops on forestland are allowed if landowners want to apply for reforestation rewards. In other words, agroforestry systems are still not encouraged in the Chinese Taipei forestry policy.

In other cases, agroforestry can make it easier for farmers to transit from one type of crop to another as market demand for their products changes. As many upland landowners are getting older while most their children are working in urban areas, they would like to change their intensive-managed farmland into a low input and labor system, such as forestation. Agroforestry systems will be a good choice during the transition period.

In spite of the advantages of conducting agroforestry systems in upland areas, land management under agroforestry system is still very rare in Taiwan. Related researches in agroforestry in Taiwan are not enough and outdated (Lo and Lin, 1993). More updated technologies in silviculture and plantation management, soil and water conservation, and system evaluation investigations are urgent. Only after we have adequate research results, proper and practical forest policies can be made.

PROJECT OBJECTIVES

1. To develop several different agroforestry management systems to cope with different demands of crop planting and afforestation: According to the choice of crop and tree species, the purpose of land owners and the natural condition of the area, various agroforestry systems and management strategies are developed in this study. A good agroforestry system should not only achieve sustainability in land use, but also fulfill the needs of the local people.

2. To demonstrate the ability of these systems in preventing the destructive landslides and massive surface erosions on cultivated uplands: As huge landslides and massive erosions occurred frequently in upland areas in Taiwan, awareness of the need for soil conservation has arisen. Interplanting trees in farms may control erosion through increasing soil cover, providing hedgerow barriers, stabilizing earth structures and etc.

3. To develop the criteria and indicators for evaluating the sustainability of such agroforestry management systems: One of the most important purposes of developing agroforestry systems in this study is to accomplish a sustainable land-use system. Important criteria and indicators for sustainable include the evaluation on biological diversity, forestry and crop products, healthy ecosystems, soil and water resources, carbon dioxide sequestration and etc.

4. To encourage the communities of mountain villages to participate in the development of new agroforestry system(s) and take part in the dissemination of new technologies: Not only individual farmers and stewards of natural resources execute the new agroforestry system(s), people from mountain villages need to know the system(s) and encourage related people to participate in some workshops that have held in the past

year. Linking individual and communities actions to national concerns and achieving sustainable land use becomes important.

TARGET AREA

The field study and demonstration sites are in aboriginal reserves and private upland farms in Chinese Taipei. The majority of aboriginal reserves are located in upland area. When aboriginal people work on their reserve areas, there are special regulations which are usually more flexible to fit the tribe's traditions. Generally, other people's activities on upland areas are more restricted for natural resources protection reason.

Although most population is living in the downstream plain areas, the upland areas are in the upstream and environmentally closely related to the downstream cities. If soil and water conservation job in the upland areas is not well planned and implemented, disasters (such as landslide and flooding) might occur to the downstream big cities. On the other hand, the major activity for livelihood in upland villages (including aboriginal areas) is agricultural productions, such as betel nuts, tea, fruits and vegetables. Surface erosion problems might be serious on these cultivated uplands. Therefore, appropriate agroforestry management system(s) will be a solution to harmonize the land use in these areas.

Farmlands of betel nut and tea are the main target this study. Firstly, betel nut and tea farms occupy majority of upland agricultural areas. In 2009, betel nut and tea farm areas were 49,093 ha and 14,855 ha, respectively (COA, 2009; TTMA, 2010). Secondly, the prices of both betel nuts and tea are dropping gradually every year since cheap products are imported. As a result, some farmers are considering changing their crops of betel nut or tea to other crop(s) or even planting trees.

PROJECT MAJOR ACTIVITIES

Study site

Several study sites were established in north, east and center Taiwan, respectively (Fig. 1), as weather and soil conditions are varied in the sites. These experimental sites also differ in elevation (200-300m, 500-700m, 1000-1500m) and in crop species (Table 1). Selected tree species, all native species in Chinese Taipei, may offer a wide range of products from timber to non-timber forest products (such as drinks, cleaning products, medical use etc.). For example, *Cinnamomum kanehirae*, interplanted at Pinglin and Yuchi sites, is a unique culture medium for growing a famous and expensive medicinal fungus (*Antrodia cinnamomea*).

In this study, field data, including the growth data of trees and cash crops, and biodiversity indexes are collected for analyses. Environmental factors (e.g. air & soil temperature, rainfall, wind meter, light meter, moisture) are also recorded. Three soil and water conservation demonstration sites were set up to monitor runoff and soil losses.

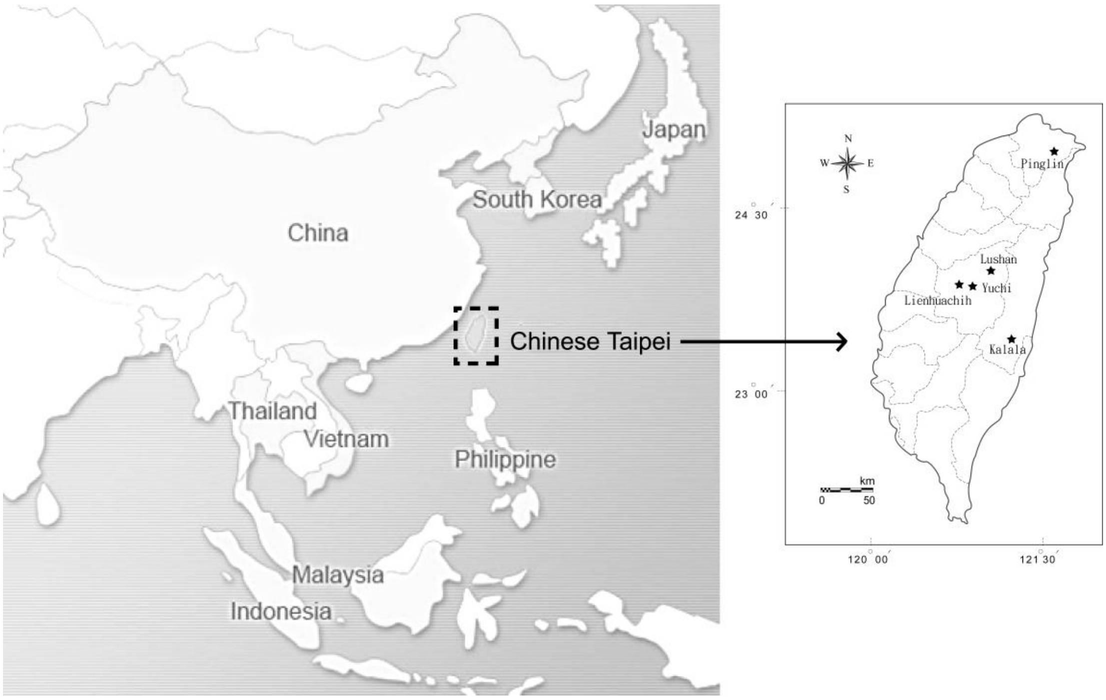

Figure 1. Map of study sites

Table 1. Information of study sites

Site	Crop	Tree species	Area (m^2)	Elevation (m)
Pinglin	Tea	*Cinnamomum kanehirae*	3,800	400-600
Lushan	Tea	*Calocedrus formosana*	10,000	1,460
		Phellodendron amurense var. *wilsonii*	1,200	
		Prunus taiwaniana	1,200	
Lienhu achih	Betel nut	*Calocedrus macrolepis var. formosana*	1,125	700
Yuchi	Betel nut	*Cinnamomum kanehirae*	3,600	650
Kalala	Coffee	*Cinnamomum osmophloeum*	2,800	200
	Betel nut	*Ficus pumila* var. *awkeotsang*		

Agroforestry Promoting

Agroforestry workshops were held in several upland village communities to promote the concept of agroforestry and/or train farmers. Visiting the project study sites is one of the best ways to demonstrate and show people how agroforestry may be put into practice. Trained agroforestry technical teams proudly presented their agroforestry sites to others and encouraged other upland village communities to modify their agriculture land into agroforestry management system. Sharing experiences from participating farmer is very convincing when promoting agroforestry.

A number of industries are interested in developing some particular forest product industry. For example, *Cinnamomum kanehirae* is one of the species that the industry is interested in. They have helped finding suitable upland villages to participate, as well as facilitating the cooperation between research teams and farmers. With the participation of industries, more farmers will have motivation to join agroforestry.

EXPECTED OUTCOMES

Agroforestry management system can be a solution of balancing agriculture for livelihood with sustainability in upland villages in Chinese Taipei.

Under agroforestry system, loss and degradation of agricultural land will be reduced, but resource use efficiency both above and below ground will increase. Moreover, by planting trees we can achieve carbon dioxide reduction. Depending on the tree species interplanted, other advantages of agroforestry systems may include erosion control, soil improvement, windbreak, groundwater management, wildlife habitat, and etc.

The establishment of demonstration sites will encourage other upland village communities to modify their agriculture land into this agroforestry management system. Those trained farmer technical teams will play an important role on helping disseminating the technology.

Furthermore, after providing more updated and relative research results in agroforestry, the Chinese Taipei administration will then be able to make more appropriate and practical forest policy.

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Evaluation for the Implement of Agroforestry in the Experimental Forest, National Taiwan University

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ABSTRACT

Three types contracted forestlands in the Experimental Forest were widely illegally used because of low economic value of bamboo. For increasing income of contracted forestry farmers and also maintaining the forest, in 2012, the Experimental Forest developed the projects of "Investigation of the feasibility of agroforestry implement for the contracted forestlands with existing mixture planting" including four categories of evaluation of feasibility, effects of agroforestry implement, issues of current land use, legality of agroforestry implement. In category "evaluation of feasibility", agroforestry was unsuitable for subjects of soil properties, hydrology and soil physics environment, hydrogeology, mingle of plantations and vegetables, and the supporting measures were suggested for subjects of mingle of plantation and fruit trees and plantation and tea trees. The results of category "effects of agroforestry implement" indicated that soil quality degradation, changes of soil microbial community caused by improper pesticide application and the ecological environment impacts by distribution of pesticide from uphill to downhill were found after agroforestry implementing. Twenty-eight percent (28 %) area of contracted forestlands (6,011.81 ha) was illegally planted high economic crops and occupied. Thus, for agroforestry implement of contracted forestlands, supporting measures were suggested and "Forest Law" will need to be amended for legality of land use in the future.

KEY WORDS: Agroforestry, Contracted forestland, Soil quality, Forestland classification.

INTRODUCTION

Because of low economic value of bamboo, the contracted forestry farmers breached the contracts by planting high economic crops, which affected the ecological environment and soil and water conservation. Contracted forestry farmers anticipate the agroforestry implement could be allowed for increasing their income and meet legality of over land use. Both considering the income of contracted forestry farmers and maintaining the forest, in 2009, Executive Yuan convened a meeting of “Deliberation of crop management in forestlands of the Experimental Forest, Shin-Yi township” and commanded the Experimental Forest to execute the research of the feasibility of implement of agroforestry for the existing forestland utilization of agriculture and forest and to inspect the applicability of impracticable decrees for agroforestry implement. Therefore, a three and half year “agroforestry research project” for solving the problems of contracted forestlands management was developed.

MATERIALS AND METHODS

The Experimental Forest lies in central Taiwan and administratively belongs to Lugu, Shueli, Sinyi townships in Nantou County, covering 32,786 ha. Three contracted forestlands, conservation bamboo forestlands, nursed bamboo forestlands, and cooperative forestlands in the Experimental Forest were contracted with forestry famers for planting bamboo and trees, and 30% area for economic crops planting was restricted in of cooperative forestlands contract. The utilization of 98.9% and 95.26% of forestland areas are legal in conservation bamboo forestlands and nursed bamboo forestlands separately. However, only 40.4% of cooperative forestlands use is legal, and 1,655 ha, over 30%, is extremely illegally used by planting tea trees, fruit trees, betel nut trees, and catch crops (Table 1).

Table 1. Information of vegetation and its area in three types of contracted forestlands

Contracted Forestlands		Threes	Bamboo	Fruit Trees	Tea Trees	Vegetables	Others*	Total area (ha)	Counts
Conservation Bamboo Forestlands	Area (ha)	18.57	1921.17	3.57	7.02	0	9.68	1960.01	980
	Percentage of forestlands (%)	0.95	98	0.18	0.36	0	0.49		
Nursed bamboo Forestlands	Area (ha)	3.75	1359.41	11.87	26.34	0.44	28.71	1430.52	1,093
	Percentage of forestlands (%)	0.26	95	0.83	1.84	0.03	2.00		
Cooperative Forestlands	Area (ha)	643.72	410.16	1190.68	86.23	15.76	264.73	2611.28	3,824
	Percentage of forestlands (%)	24.65	15.7	45.60	3.30	0.60	14		

*Others: betel nut trees, flowers, jelly figs, gravel field, arid field, mushroom, farmyard, and meadow

Study Sites

The altitude and slope of established 16 study sites were ranging from 320 to 1, 500 m and 2 to 45°, and high diversity of vegetation including tea trees, fruit trees, betel-nut trees, and all kind of vegetables were selected. Scientists and experts had participated in agroforestry research projects of cropping, environmental monitoring, forestland classification, insect ecology, and law interpretation. Fourteen projects were divided into four categories, and six goals of agroforestry research projects are as following:

Categories

(1) Evaluation of feasibility; (2) Effects of agroforestry implement; (3) Issues of current land use; (4) Legality of agroforestry implement

Goals

(1) To inspect the relevant laws and policies about management of forestlands; (2) To analyze the current problems of land utilization; (3) To evaluate the feasibility of agroforestry implement for the contracted forestlands in the Experimental Forest, NTU; (4) To evaluate and compare the effects on environment and economic benefits before and after agroforestry implement; (5) To develop the concrete scheme for agroforestry; (6) To propose the concrete conclusions and suggestions in accordance with current circumstance and laws

RESULTS AND DISCISSIONS

The results showed that seven negative evaluations and supporting measures suggestions were found in 14 projects separately, and positive evaluation was not found. According to the results of all research projects, agroforestry is not suitable for the forestlands of the Experimental Forest, otherwise some supporting measures might be needed when necessary. The results of all projects are listed in Table 2.

Four projects of category “evaluation of feasibility” and two projects of category “effects of agroforestry implement” were evaluated to be unsuitable for agroforestry implement, and another four projects of these two categories were suggested that supporting measures would be needed. In category “effects of agroforestry implement”, soil quality degradation, changes of soil microbial community caused by improper pesticide application and the ecological environment impact of pesticide flushed by runoff from uphill to downhill were found after agroforestry implementing. From the perspective of existing laws, the use of forestlands is restrained conditionally. Except amending the laws, contracted forestlands cannot be managed by using agroforestry

Table 2. The evaluations and suggestions of 14 projects for agroforestry research projects

Projects	Subjects	Evaluations	Suggestions
Evaluation of feasibility	Soil properties	╳*	Soil properties and nutrition condition affected and soil quality degraded because of the implement of agroforestry.
	Hydrology and soil physics environment	╳	The slope of most contracted forestlands is steep, and the depth of soil is shallow. The ability of soil water conservation decreased after agroforestry implemented.
	Hydrogeology	╳	The shallow landside areas usually have low forest coverage, steep slope, shallow depth of soil, which is unsuitable for agricultural development. The operation of agricultural development such as irrigation and the forestation trail setting would affect the slope hydrologic condition and slope stability.
	Mingle of plantation and fruit trees	△	Catch crop (such as foliage plants and leafy vegetables) and plantation was suggested.
	Mingle of plantation and tea trees	△	Growth of teas trees and tea quality were not affected by planted konishii tanoak. Thus, tea tree would be considered a proper crop.
	Insect disease prevention	△	High cross infection was found in plantation converted into agroforestry. Choosing the suitable crop deliberately was suggested.
	Mingle of plantation and vegetables	╳	The yield of Sweet potato and *Angelica keiskei* koidzum was highest, and the vegetable fern and bird's-nest were lowest-yield. Tropical violet and madeira vine were not suggested.
Effects of agroforestry implement	Pesticide effects	╳	Pesticide residue was found on the trees nearby farming area, which could be flushed by runoff from uphill to downhill.
	Soil enzymatic activities	╳	Forestry soil organic matter decreased after agroforestry implement, which means that the soil degradation and groundwater contamination could happen.
	Insect disease prevention	△	Choosing crops have lower incidence of insect disease, such as vegetable fern, mustard, and *Angelica keiskei* koidzumi was suggested.
Issues of current land use	Current circumstance of contracted forestlands	△	Regaining the illegally used lease forestlands, increasing the compensation expense, encouraging the contracted forestry farmers to join the “reforestation projects”, and developing “community forestry” were suggested for improving the illegal land utilization.
	Business condition of forestry farmers	△	The decrease of agricultural land would increase the forestation area in Lugu, Shueli, Sinyi townships, Nantou County. The difficulties of forestland management forced the forestry farmers to give up cultivation and join the reforestation projects for gaining the compensation.
Legality of agroforestry implement	Policy	△	The restrain of the laws might cause the illegal behaviors and improper forestlands management. Thus, the supporting measures would be suggested if managing the forestlands by agroforestry.
	Legality	╳	The current “Forest Law” doesn’t allow the implement of agroforestry, and the results of research showed that the development of agroforestry was unsuitable.

*╳ = Unsuitable; △= Supporting measure needed

legally (Lin, 2010). The challenges of agroforestry implement are as follows: 1. Small farming area and production scale, the difficulties of automation, lack of labors, increasing of cost of fertilizer and pesticide cause high production cost and low economic efficiency (Lo and Lin, 1993). 2. Forestry farmers concern more income and compensation instead of national land conservation, soil and water conservation, and biodiversity. The supporting measures need to be provided for farmers who have different requirements for increasing the economic incentive (Wang, 2012). 3. Law restraint: “Forest Law” will need to be amended for legality of land use. 4. Technical guide proving for forestry farmers.

CONCLUSIONS

The legality and environmental impacts of agroforestry implement of 3.5 years research results showed that agroforestry is not suitable for the forestlands of the Experimental Forest currently. It is expected that the circumstance would be changed after “Forest Law” and relevant laws are amended. A mid- and a long-term solution are proposed for dealing with the current condition. The mid-term solution is：(1) to gain more funding from government for regaining lease forestlands, (2) to encourage the contracted forestry farmers to join the “reforestation projects” and “national land conservation projects” for gaining the compensation, (3) to develop and to promote “community forestry” and “reforestation projects” to decrease illegally overuse. The long-term solution is to develop supporting measures and implement agroforestry by stages or regionally for diminishing the impact, after “Forest Law” and the relevant laws amended.

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Effect of Agroforest Planting on Soil Losses on Betel Palm Farm

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ABSTRACT

The planting betel palm on slopeland played an important role in soil erosion and conservation questions. The purpose of this project was constructing mixed plantation plots with clear-cutting, reserved, and thinned betel palm treatments to monitor agroforestry management effect on surface runoff and soil losses for extension and demonstration in the future.

Based on runoff and soil erosion experiments of agroforest planting in betel palm farm at Jianana, the rainfall amount of 19 events was 577.0 mm. Surface runoff amounts of clear-cutting, reserved and thinned were 38.9 mm, 92.0 mm and 88.8 mm, respectively. Runoff rate of clear-cutting, reserved and thinned were 6.7 %, 15.9 % and 15.4 %, respectively. Soil erosion of clear-cutting, reserved and thinned were very few and their amounts were 6.3 kg (0.285 t/ha), 14.1 kg (0.630 t/ha) and 9.6 kg (0.428 t/ha), respectively. The forest interception would consume water which was evaporated back to atmosphere. Basically, adding forest planting area in agroforestry would increase the consumption of evaporation and could contribute to reduce runoff and surface erosion.

KEY WORDS: Agroforest, Betel palm, Rainfall, Runoff, Sediment, Soil losses.

INTRODUCTION

In recent years, many fruit trees and forests on slopeland have been converted to betel palm plantations. The total area of betel palm plantation has increased over the past 30 years, reaching a peak of 56,542 ha in 1997. (DAFTPG, 1998). Slopeland affected by rainfall, topography, geology, soil, slope, slope length, vegetation cover, and soil conservation treatments, was the sensitive areas of soil erosion and sediment transportation. Betel palm plantation on slopeland caused easily soil erosion. The public and conservation groups frequently expressed great concern over the potential negative hydrological impacts of betel palm plantations on steep slopes (Lin, 1999a, 1999b). Based on protection of soil and water resources, planting native plants and efficient land use on slopeland, agroforestry management in betel palm plantation had become an important thinking. The Universal Soil Loss Equation (USLE) was a widely used mathematical model that described soil erosion processes (Hudson, 1993; Wischmeier, 1960, 1971, 1978). The purpose of this project was constructing mixed plantation plots with clear-cutting, reserved, and thinned betel palm treatments to monitor agroforestry management effect on surface runoff and soil losses for extension and demonstration in the future.

CONSTRUCTING MONITORING PLOTS

The monitoring plot situated at Jianana aboriginal clan, Ruisui Township, Hualian County, Eastern Taiwan, and was a private slopeland with slope 20°~25°, in which betel palm had been planted more than 20 years old and 15 m high. Due to influence by Northeastern monsoon and Pacific Ocean current, annual rainfall in Hualien was between 1,348.5 mm and 2,777.0 mm, and average annual rainfall was 2,165.4 mm during 2003-2012. Monthly average rainfall was between 57.1 mm and 364.8 mm, and 75% of annual rainfall occurred from May to September. Annual average temperature was between 23.08 ℃ and 23.88 ℃. The higher temperature took place from May to September, the lowest temperature was 17.9 ℃ in January, and the highest temperature was 28.6 ℃in July (Table 1).

Table 1. Water balance at Hualien area

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Set.	Aug.	Oct.	Dec.	Nov.	Total
Avg. monthly rainfall(mm)	57.1	72.9	83.3	68.0	175.3	182.1	243.0	298.7	364.8	359.4	175.7	85.1	2165.4
Avg. temp.(℃)	17.9	19.2	19.8	22.5	25.3	27.0	28.6	28.4	27.1	24.9	22.5	19.2	23.5
Potential ET(mm)	41.3	48.3	61.1	90.9	138.6	164.9	200.1	189.0	150.2	113.9	78.6	50.0	1327.1
Soil moisture change (mm)	15.8	24.6	22.2	-22.9	36.7	17.2	42.9	109.7	214.5	245.6	97.0	35.1	
Soil moisture content(mm)	120	120	120	97.1	120	120	120	120	120	120	120	120	
Actual ET(mm)	41.3	48.3	61.1	68.0	138.6	164.9	200.1	189.0	150.2	113.9	78.6	50.0	1304.0
Deficit water amount (mm)	0.0	0.0	0.0	22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.9
Surplus water amount (mm)	15.8	24.6	22.2	0.0	36.7	17.2	42.9	109.7	214.6	245.5	97.1	35.1	861.4

The observation subplots in design were clear-cutting, reserved and thinning to measure the effect of agroforest planting on runoff and soil losses in betel palm farm. The subplots would follow the specifications of Universal Soil Loss Equation (USLE), and would be set up with slope length of 22.3 m, width of 10 m, and area of 223 m^2 (Figure1). The subplots were fenced with steel plates that directly inserted into soil depth of 15 cm and out soil surface of 15 cm. The lower reach of each subplot would be set up a surface runoff collection trough to collect the surface runoff and sediment. Each subplot would be installed with a pressure-type stage gauge to record the water stage and turbidity gauge to record the changes of water turbidity during a rainy time.

CHARACTERISTICS OF BETEL PALM

The crown of betel palm, as illustrated in Figure 2, had six leaves with total leaf area of 8.47 m^2. The leaf area index (LAI) of betel palm was 1.36 which was rather low as compared to 9 of the LAI of natural hardwood forests and 8.4 of the LAI of 30-year old China fir forests (Lin, 1995). This gave reasons for lower LAI and lower crown closure of betel palm plantations in comparison to China fir and natural hardwood plots. The tall, single-layer and wide spacing canopy between planted betel palms led to lower interception losses, higher mixed throughfall and stem flow, and higher net rainfall. Plots planted with betel palms had lower infiltration, higher surface runoff and higher erosion than forested sites (Cheng, 2008). These hydrological characteristics were related to factors such as crown cover, soil organic content and soil porosity in betel palm plantations. The crown characteristics of betel palm were rather different from those of fruit trees and China fir.

RUNOFF AND SEDIMENT MORNITORING

The result of estimating potential evapotranspiration with Thornthwaite's empirical formula was as table 1. In rainy season, monthly rainfall was usually greater than potential evapotranspiration, and actual evapotranspiration was equal to potential evapotranspiration. Annual potential evapotranspiration in Hualien area was estimated 1,327.1 mm, and annual calculated actual evapotranspiration was 1,304.8 mm. The deficit water amount was 22.9 mm; the surplus water amount was 861.4 mm. The runoff percentage was the ratio of surplus and rainfall amounts, and equal to 39.78%.

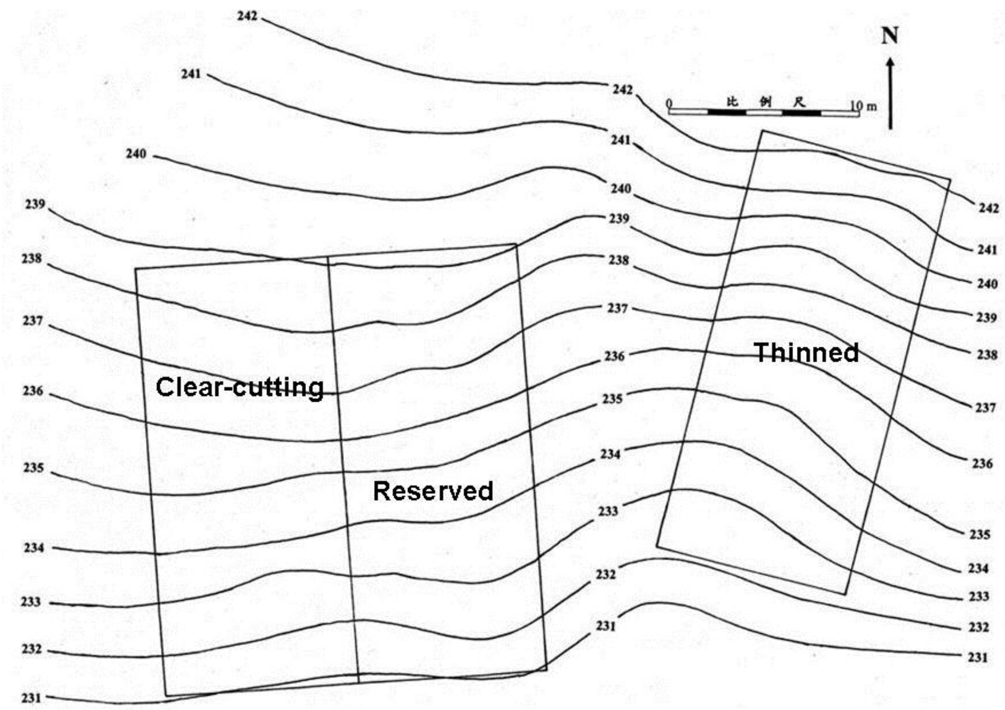

Figure 1. Site of agroforest planting to measure soil losses in betel palm farm.

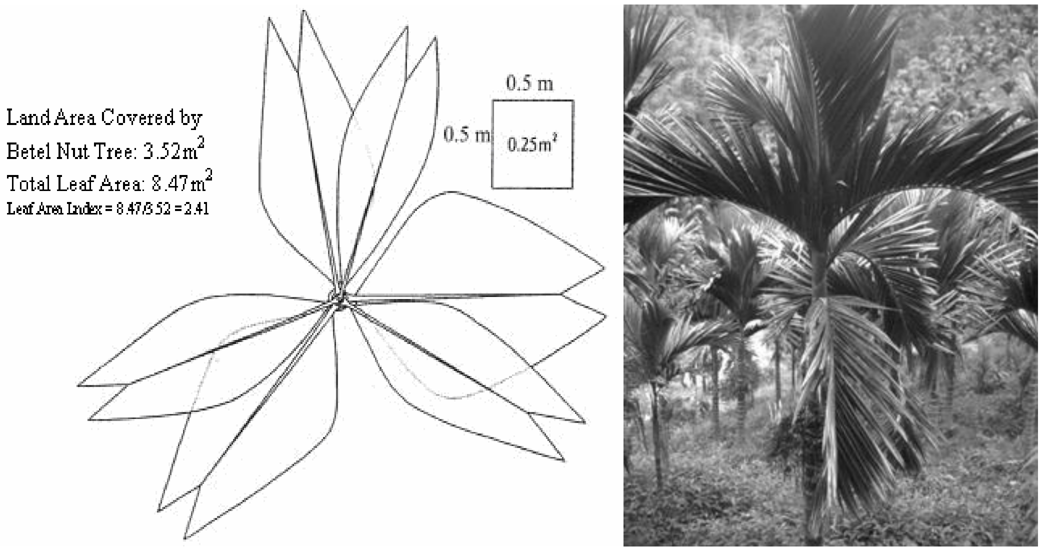

Figure2. Bird's-eye view of a typical betel palm crown (left) and betel palm plantation (right).

Most rainfalls in spring were rare about 45~80mm during the dry season from January to March in Taiwan. In this period, the soil would be dry and all the rainfall would be absorbed in soil except occasionally heavy rainfalls to produce rainfall excess converting into surface runoff. During rainy days last year, surface runoff and turbidity were measured by 19 events. Surface runoff and turbidity was calculated (Table 2). The total rainfall amount of 19 events was 577.0 mm. Surface runoff amounts of clear-cutting, reserved and thinned were 38.9 mm, 92.0 mm and 88.8 mm, respectively. Runoff rate of clear-cutting, reserved and thinned were 6.7 %, 15.9 % and 15.4 %, respectively.

The occurrence of soil erosion resulted from the shear force of surface runoff. Shear force took place due to the surface runoff flowing on the soil surface. If the soil erosion resistance was smaller than the shear force of surface runoff, then the sheet erosion took place. Otherwise, the soil erosion would not take place on the soil surface. Soil erosion of clear-cutting, reserved and thinned were very few and their amounts were 6.3 kg (0.285 t/ha), 14.1 kg (0.630 t/ha) and 9.6 kg (0.428 t/ha), respectively. The surface runoff and soil erosion amounts of clear-cutting and thinned were obviously lower than those of reserved. Perhaps soil disturbance in establishing plots and their slope gradient difference affected surface runoff and soil erosion.

Table 2. Rainfall, surface runoff and soil losses calculation of each storm event.

Date	Rainfall (mm)	Runoff (mm)			Soil losses (kg)		
		Clear-cutting	Reserved	Thinned	Clear-cutting	Reserved	Thinned
3/19 14:38~4/19 16:18	38	6.582	14.173	0.032	414.395	2510.503	5.068
4/1612:34~4/19 08:00	8	0.812	0.823	1.328	48.124	162.432	111.639
4/26 06:10~4/27 00:48	13	1.207	0.960	0.959	213.723	226.955	208.602
6/07 14:46~6/07 15:24	7	0.246	0.290	0.845	43.801	69.747	205.206
7/21 23:20~7/25 11:28	58	2.056	2.321	2.390	395.590	320.590	315.097
7/22 15:06~7/24 03:24	12.5	0.518	0.530	0.489	100.631	77.527	64.935
7/24 16:02~7/25 11:28	17.0	0.413	0.669	0.227	78.827	92.465	24.245
7/25 18:58~7/27 07:58	19.5	0.394	0.981	2.055	76.839	148.448	205.169
7/25 20:30~7/25 23:28	14	0.340	0.728	1.716	64.589	110.967	159.703
7/26 18:32~7/26 22:20	5.0	0.072	0.255	0.089	14.168	31.405	16.931
7/28 03:00~7/2/ 18:00	44.0	2.315	8.924	11.822	446.398	1297.178	792.174
7/30 12:26~8/03 05:58	112.5	4.456	9.350	13.087	837.751	1256.950	1228.229
8/15 00:00~8/18 22:00	38.0	1.781	4.555	2.814	429.398	751.719	504.563
8/15 06:10~8/16 07:58	35.0	1.757	5.543	5.244	424.322	829.184	742.367
8/18 03:30~8/16 07:58	2.0	0.056	0.067	0.104	13.553	11.407	19.336
8/23 11:00~8/24 05:14	66.5	5.922	12.528	11.952	1001.671	2036.243	1056.905
8/27 18:00~8/28 12:20	67.5	5.388	25.083	19.903	707.735	3327.531	1441.432
9/14 21:40~9/29 06:52	12.5	2.680	1.589	12.108	583.926	288.133	2123.486
10/23 18:16~10/24 05:26	7.0	1.861	2.613	1.647	450.253	506.591	329.959
Total	577	38.855	91.982	88.810	6345.696	14055.975	9555.047

CONCLUSIONS

When no rainfall was for a long time, the soil would be dry and all the rainfall would be absorbed in soil except occasionally heavy rainfall to produce rainfall excess converting into surface runoff. The occurrence of soil erosion resulted from the shear force of surface runoff. Shear force took place due to the surface runoff flowing on the soil surface. If the soil erosion resistance was smaller than the shear force of surface runoff, then the sheet erosion took place. Otherwise, the soil erosion would not take place in the soil surface. Based on runoff and soil erosion experiments of agroforest planting in betel palm farm at Jianana, the rainfall amount of 19 events was 577.0 mm. Surface runoff amounts of clear-cutting, reserved and thinned were 38.9 mm, 92.0 mm and 88.8 mm, respectively. Runoff rate of clear-cutting, reserved and thinned were 6.7 %, 15.9 % and 15.4 %, respectively. Soil erosion of clear-cutting, reserved and thinned were very few and their amounts were 6.3 kg (0.285 t/ha), 14.1 kg (0.630 t/ha) and 9.6 kg (0.428 t/ha), respectively.

The tall, single-layer and wide spacing canopy between planted betel palms led to lower interception losses, higher mixed throughfall and stem flow, and higher net rainfall. Plots planted with betel palms had lower infiltration, higher surface runoff and higher erosion than forested sites (Cheng, 2008). These hydrological characteristics were related to factors such as crown cover, soil organic content and soil porosity in betel palm plantations. The crown characteristics of betel palm were rather different from those of fruit trees and China fir. The forest interception would consume water which was evaporated back to atmosphere. Basically, adding forest planting area in agroforestry would increase the consumption of evaporation and could contribute to reduce runoff and surface erosion.

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Traditional Working Woodlands "*Satoyama*": Its History and Future

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KEY WORDS: *Satoyama*, Landscape, Fuelwood.

SATOYAMA BEFORE MODERN ERA

Japan *Satoyama Satoumi* Assessment (JSSA, 2010) described *satoyama* as follows.

"*Satoyama* is a Japanese term for a mosaic of different ecosystem types—secondary forests, farm lands, irrigation ponds, and grasslands — along with human settlements, which has been managed to produce bundles of ecosystem services for human well-being."

Satoyama was an indispensable place for daily life of rural area of Japan before modern ages to obtain various resources and materials. The main energy to take cooking and heating was firewood, brushwood and charcoal from *satoyama* forest. Manure to maintain soil fertility for paddy field or arable land was *karishiki*, made from woody shoot and grasses like compost. Grassland embedded into *satoyama* land-mosaic was necessary for breeding of domestic animals such as cows and horses that had borne important labor for cultivation. Materials of foods like wild vegetables, mushrooms and nuts, fiber for clothing, and house building materials were also provided from *satoyama* woodlands in self-sufficiency way.

Though there is strongly a self sufficient image in *satoyama* that linked with life of agriculture and rural community, it was the realities that not only self supported usage but also a large amount of firewood, charcoal or mown grass were sold commercially, if the *satoyama* connected urban or industrial area. Consequently, there existed lot of regions where the bare land had extended around granite region like western Honshu Island. On the other hand, there were woodlands like pine forests or underwoods, and grasslands where the harvesting could be repeated without becoming a bare land by some regulations or restriction by governance of community or various power (for instance, the shogunate and feudal clans). In addition, special demands from urban culture such as charcoals of Daiba-Kunugi (*Quercus acutissima*) for tea ceremony invented systems ensuring sustainable wood productions.

CHANGES IN PRESENT *SATOYAMA*

Since modern ages, utilization of *satoyama* woodlands had been declining gradually along with energy revolution. Especially, values of *satoyama* had almost lost at the high economic growth period (after 1960’s).

From the latter half of the 1980's, citizens and local people living close to suburban area rediscovered novel meanings such as biodiversity and recreational values in *satoyama* landscapes and they began to try to manage it by their own. About four half a century has passed from such early movement, various new changes that could not be imaginable in the days, came to threaten *satoyama* environment.

Aged *Quercus* woodlands without appropriate management have easily get Japanese oak wilt disease. In addition, aged *satoyama* broadleaved woodlands hardly sprout after trees felled. Traditional reproduction way of woodland is becoming difficult. *Satoyama* woodlands left unmanaged became secure routes for wild animals like wild boar or deer to invade village’s arable land. Rapid increasing of deer population came to obstruct reproduction of *satoyama* woodlands greatly. Rapid population declining in rural communities caused difficulties in succeeding to traditional techniques and skills to acquire kinds of benefit from *satoyama* woodlands.

Thus, in the situation of such uncertainty, what sort of direction is requested for citizens who want to start to re-utilize *satoyama* woodlands, and for administrators who want to support these movements?

DIRECTION OF THE FUTURE OF *SATOYAMA*

To maintain *satoyama* woodlands is not to leave without changing appearance of the woods. It is to maintain relationships between people and woodlands. In other words, it is important to reproduce motive to utilize resources from *satoyama* woodlands continuously.

For instance, using woody biomass as fuelwood came to be shown in some regions as an attempt to re-utilize resources from *satoyama* woodlands in daily life. Our institute also tries a social experiment to establish a modern management technique of *satoyama* woodlands by small scale clear cutting that holds *satoyama* woodlands healthy with utilization of fuelwood by wood stoves. As a result, re-utilizing fuelwood by wood stoves brought users a high satisfaction in quality of life. And local people involved this social experiment came to recognize that *satoyama* woodlands should not be left uselessly, and they comprehended that *satoyama* woodlands should be alternative recyclable resources with additional enjoyment in their lifestyles. *Satoyama* resource utilization by firewood that adds better quality to lifestyle will become one effective choice for *satoyama* woodlands management by citizens, local people and local government in the future.

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Agroforestry an Integrated Land-Use System to Meet Agricultural Production and Environmental Protection in the United States

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ABSTRACT

Agroforestry practices have long been part of the heritage of North American peoples. Native Americans and European pioneers practiced subsistence lifestyles and integrated land-use strategies that were similar in principle to the agroforestry being practiced by indigenous populations in today's developing countries. The widespread use of these strategies, however, largely disappeared during the last century with the concurrent development of separate agricultural and forestry research and management infrastructure. Major problems that can be addressed through agroforestry today in the United States include wind and water erosion and water pollution from agricultural run-off. Agroforestry practices can also be used to help protect animals and crops from severe winter temperatures, generate additional income through the integration of trees into farms, reduce economic risk, and provide ways to sequester carbon and mitigate the effects of climate change. Agroforestry practices used today include alley cropping, riparian buffers to address water pollution, silvopasture for economic production, and wind breaks to protect against water and wind erosion, as well as forest farming for mushrooms, ginning, floral greenery, and other non-timber forest products such as juniper berries. Opportunities for agroforestry development include changing policy, regulations, and incentives to favor sustainable resources management; improving education and research; and providing demonstrations projects that will speed the adoption of agroforestry practices.

KEY WORDS: Agroforestry practices, Integrated land use, Sustainable land use, Agroecosystems, Policy regulation and incentives.

INTRODUCTION

Agroforestry practices have long been part of the heritage of North American peoples. Native Americans and European pioneers practiced subsistence lifestyles and integrated land-use strategies that were similar in principle to the agroforestry being practiced by indigenous populations in today's developing countries (King, 1987; Lassoie and Buck, 2000). Native peoples gathered nuts, roots, seeds, and berries; hunted rabbits and deer; and caught fish. They were skilled in the use of fire, hunted and kept animals, selected and planted seeds from annual and perennial crops including tree crops, and commonly transplanted trees and shrubs. In most areas, they relied on tree crops for much of their sustenance, primarily oaks, mesquites, and pines. These crops provided not only food, but medicine, building materials, craft materials, and fertilizer (Bainbridge, 1994).

Indian agroforestry practices have been used for millennia; Karl Davies (1994) describes how these traditional agroforestry systems were sustainable and, in many cases, integrated animal husbandry, crop rotations, and fallow periods. In the Willamette Valley, Oregon, the Kalapuya managed oak savannas, vast woody huckleberry shrubs, and forests while also managing crops alongside them (Goodness, 2011). The coastal tribes in Oregon also managed the land in a harmonious way so that the land fertility was not greatly diminished or overly stressed. They gathered food and supplies in a rotational approach so that a location would not be over harvested. This well-managed process, enforced by tribal leaders (Petrie, 2012), was conducted by skilled and knowledgeable applied ecologists who actively managed the land (Bainbridge, 1994).

The complex polyculture of native peoples was replaced by resource extraction with a much narrower focus, for example, intensive trapping, grazing, logging, market hunting, fuelwood extraction, mining, and agriculture. Many of these were initially combined, i.e., fuelwood cutting on grazing lands, fishing, and timber harvest, and would fit under an agroforestry definition; however, most were not concerned with sustainability **(**Lassoie and Buck, 2000). A few agroforestry practices survived into the mid-20th century in association with long-established organizations (e.g., Northern Nut Growers Association) or as culturally acceptable complements to traditional farming enterprises, such as maple syrup production (Laesoue and Buck, 2000).

Since the 1940s, agriculture has become more specialized and dependent on purchased off-farm inputs. Technology has facilitated specialization and constantly increasing yields, with fewer, larger farms producing more food than ever before (Alternative Agriculture, 1989). Despite great progress in agricultural productivity in the past half-century, and with crop and livestock productivity strongly driven by the increased use of fertilizers, irrigation water, agricultural machinery, pesticides, and areas of land, it would be over-optimistic to assume that these relationships will remain linear in the future. New approaches are needed that will integrate biological and ecological processes into food production, minimize the use of those non-renewable inputs that cause harm to the environment or the health of farmers and consumers, and make productive use of the knowledge and skills of farmers (Pretty, 2007).

Periodic agricultural disasters have stimulated unique forestry and agriculture activities that can also be considered agroforestry practices. In the 1930s, the Great Depression combined with the drought-induced "Dust Bowl" in the central United States set off economic and environmental alarms throughout the agricultural community and the nation. The formation of the Civilian Conservation Corps promoted many conservation activities, including the planting of millions of trees as windbreaks and plantations to help protect eroding farm lands (Garrett et al., 1994; Lassoie and Buck, 2000). Such ecological problems also stimulated interest in the use of nut trees to reclaim and promote production from lands marginal for conventional farming practices.

The 1980s marked a time of change in U.S. agriculture. The financial viability of many farms and communities declined during the mid-1980s as crop prices and land values fell, and more than 200,000 farmers went bankrupt. The farm crisis of the 1980s was less dramatic on a large scale than the Dust Bowl, but it had devastating economic and social impacts on many rural communities (Alternative Agriculture, 1989). The environmental consequences of farming have also become increasingly important to policy makers, farmers, and the public. The Environmental Protection Agency has identified agriculture as the largest nonpoint source of water pollution. Pesticides and nitrates from fertilizers and manures have been found in the groundwater of most states. The issue of pesticides and antibiotics in food remains unresolved. Soil erosion, salinization, and the depletion of aquifers for irrigation are significant problems in some regions. Some congressional actions taken in response to these problems include the establishment of alternative agricultural programs such as the Conservation Reserve Program (CRP), low-input sustainable agriculture (LISA), and integrated pest management (IPM) (Alternative Agriculture, 1989).

The growing environmental consciousness on the part of the American public in the 1950s and 1960s has promoted alternative land-use practices, often involving unique mixes of trees, crops, and livestock by nontraditional rural landowners. During the 1960s, more people became interested in integrated land-use practices with low input forms of agriculture and forestry, leading to the development of such organizations as The Land Institute, the Rodale Institute Research Center, the Permaculture Research Institute, and the International Tree Crops Institute USA (Lassoie and Buck, 2000). Beginning largely in the 1980s, many farmers took steps to reduce the costs and adverse environmental effects of their operations. Some improved conventional techniques and others adopted alternatives. Many farmers have tried alternatives; farmers who have adopted alternatives try to take greater advantage of natural processes and beneficial on-farm biological interactions, reduce off-farm input use, and improve the efficiency of their operations (Alternative Agriculture, 1989).

In recent years the effects of inappropriate agricultural, pastoral, and silvicultural practices throughout the world have become increasingly apparent. Soil erosion, the loss of soil fertility, and the consequent deterioration of rural economies have lead many agriculturists, animal scientists, and foresters to search for more sustainable food, fiber, and fuelwood production systems. The terms agroforestry and agro-ecosystem have gained currency in describing food, fiber, and fuelwood production systems that offer the prospect of sustainability and productivity (Davies, 1994).

The past 20 years have witnessed a growing understanding of the potential usefulness of agroforestry practices in addressing today's concerns over the economic and environmental sustainability of forest- and farm land uses (Garrett et al., 1994; Lassoie and Buck, 2000; Pretty, 2007). The list of potential agroforestry practices has been expanded to include (1) riparian management systems, (2) windbreaks, and (3) forest farming (Garrett et al., 1994; Schultz et al., 1995), (4) silvopasture, and multiple cropping of valuable hardwoods with agricultural crops, alley cropping.

AGROFORESTRY PRACTICES IN THE UNITED STATES

Most of the agroforestry development in the United States has occurred since 1994 (Rietveld, 1996); the great stimulus for such development was the Resource Conservation Act (RCA) assessment for agroforestry, which came in February 1994. Agroforestry in the United States is defined as intensive land-use management that optimizes the benefits (physical, biological, ecological, economic, and/or social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or livestock (Association for Temperate Agroforestry (AFTA), 2000). For example, agri-horticulture is an agroforestry system wherein fruit trees and crops are integrated in order to provide food and nutrition security while conserving the agro ecosystems. Agroforestry also helps in the more efficient use of sunlight, moisture, and plant nutrients than is generally possible either by agriculture alone or forestry exclusively.

As the U.S. population continues to increase by three million each year, forestry and agriculture will both face increasing demands for goods, as well as for an expanding array of services, such as clean water, recreation, and wildlife habitat. More importantly, as the population increases, society will have to meet its needs with fixed or shrinking land base (AFTA, 2000). Ultimately the challenge will be to find ways to sustain the provision of goods and services derived from forests and agriculture in ways "that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN WCED, 1987). Properly designed and implemented, agroforestry practices can increase crop production, diversify products and farm income, improve soil quality and reduce soil erosion, improve water quality and reduce damage due to flooding, enhance wildlife habitat and improve biodiversity, and reduce pest management inputs.

Agroforestry practices used in the United States include **alley cropping** to increase income diversity, **riparian buffers** to address water pollution, **silvopasture** for economic production, and **wind breaks** to protect against water and wind erosion, as well as **forest farming** for mushrooms, floral greenery, and other non-timber forest products such as juniper berries.

Alley Cropping

Alley cropping is the planting of trees and/or shrubs in single or multiple tree rows at a relatively wide spacing, and with a companion crop grown in the alleyways between the tree rows. High-value hardwoods such as oak, walnut, and ash are typically grown in alley-cropping systems. Short-rotation biomass species can also be incorporated into the design. The cost of waiting for a financial return on the long-term investment in trees is offset by the annual income provided from the rows of crops in the alleys and fruits (nuts) from the trees. The benefits realized from alley-cropping practices include increased income diversity and biological diversity, improved aesthetics, and reduced negative environmental impacts. Thus far, alley cropping is mostly practiced in the Midwest, and there is the potential for its use on an area of 17.9 million hectares.

Riparian buffers

Riparian buffers consist of perennial vegetation alongside streams, lakes, wetlands, ponds, and drainage ditches. They serve as protective barriers against the negative impacts of activities originating from adjacent land-use practices (agriculture, urban, industrial). Riparian buffer strips may also be designed to process water carried by field drainage tile systems. They can stabilize stream banks and protect floodplains, reduce nonpoint-source pollution, enhance aquatic and terrestrial habitat, improve landscape appearances, provide harvestable products, and function as windbreaks in some situations. Buffer strips are designed to meet landowner objectives; plant materials composition, width, and maintenance activities may be adjusted so that buffers perform the desired functions. Riparian and upland buffers are used in all regions of the United States; there is the potential for their use on 1.69 million hectares.

Silvopasture

Silvopasture deliberately combines trees with forage and livestock production in an intensively managed practice. Under this system, the overstory tree component creates favorable microclimate conditions for growing forage (pasture or hay), while growing a tree crop at the same time. Letting cows graze in a natural woodland area without any type of tree or forage management is not considered a silvopastural practice. This system is different from traditional forest or range management because it is intentionally created and intensively managed. Although currently practiced mostly in the southern and western United States, integrated tree/livestock systems are gaining interest everywhere because both economic production and environmental protection can be optimized. Silvopasture is practiced in all regions of the United States and there is a potential for its use on 77.7 million hectares.

Windbreaks

Windbreaks utilize a single or multiple rows of trees and/or shrubs that are integrated into an agricultural system. Windbreaks enhance crop production and protect livestock. Windbreak technologies are also applied to protect outdoor work areas from cold winds, protect roads from dangerous cross winds and blowing snow, provide buffers in the rural/urban interface, and provide protection and buffers within communities. As buffer zones, they reduce noise and dust and reduce energy consumption for heating and cooling. Landowners may want windbreaks to provide timber, create travel lanes, provide habitat for wildlife, or serve as living fences. The intended function of a windbreak will dictate its placement and design parameters. Windbreaks are mostly practiced in the Great Plains of the United States, and there is a potential for their use on 8.95 million hectares.

Forest Farming

Forest farming is a unique practice in which existing forest stands are managed to create an appropriate environment for growing potentially high-value understory crops. The key factors are that production systems must be intentionally created and intensively managed. Examples include maple syrup production, medicinal plants (ginseng is probably the best known and most valuable), craft materials (grasses, branches, pine cones, seed pods, and evergreen cuttings), mushrooms, native fruits (persimmon, paw-paw), and nuts (black walnut, hazelnut). Removal of some trees may be necessary in order to create the appropriate shade conditions for crops to be grown in the understory. Forest farming is practiced in all regions of the United States, and there is the potential for its use on an area of 37.35 million hectares.

AGROFORESTRY FOR ECOSYSTEM SREVICES

Concern for environmental issues including nonpoint-source pollution, loss of wildlife habitat, and climate change has resulted in a wide array of mitigation efforts. Riparian and upland buffers and windbreaks are agroforestry practices that are widely known for their positive environmental impacts; however, when all five agroforestry practices are properly implemented, they directly address each of these major environmental issues (Jose, 2012)

Biodiversity

Agroforestry practices often diversify agricultural productivity. Diversified systems, which tend to be more stable and resilient, reduce finical risk and provide a hedge against drought, pest infestation, or other natural factors that may limit production. Diversification can also reduce economic pressures from price increases for pesticides, fertilizers, and other inputs; drops in commodity prices; regulatory actions affecting the availability of certain products; and pest resistance to pesticides (Alternative Agriculture, 1989).

Water Quality Enhancement

More than three decades after the implementation of the Clean Water Act in the 1970s, nonpoint-source pollution from agricultural watersheds continues to impact the nation's water bodies. Despite the adoption of conservation practices, managed fertilizer application, and crop rotations, large losses of nutrients still occur in runoff. In addition to farm chemicals, livestock manure also constitutes a major nonpoint source of pollution in the United States. Through the process of supplying livestock products, farmers in the United States annually generate more than 350 million tons of manure that must be disposed of in some manner (Jose, 2012). A well-designed riparian or upland buffer is recognized as one of the most cost-effective approaches to mitigate nonpoint-source pollution (Schultz et al., 2009). Enhanced infiltration, trapping efficiency due to flow resistance, root safety nets, water use by buffer vegetation, and denitrification are major mitigation processes by which particulate and dissolved nutrients and herbicides transported in surface and subsurface flow are intercepted (Schultz et al., 2009; Udawatta et al., 2011).

Carbon sequestration

Carbon sequestration involves the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, vegetation, or soils) through physical and biological processes. The incorporation of trees or shrubs in agroforestry systems can increase the amount of C sequestered compared with a monoculture field of crop plants or pasture (Sharrow and Ismail, 2004). In addition to the significant amount of C stored in aboveground biomass, agroforestry systems can also store C belowground. Carbon sequestered in agroforestry systems could be sold in carbon credits markets where such opportunities exist. The greatest quantity and most permanent form of carbon may be sequestered by increasing the rotation age of trees and/or shrubs and by manufacturing durable products from them upon harvesting.

Because agroforestry is a hybridization of agriculture and forestry conservation and production technologies, landowners need to be able to evaluate the economic performance of an agroforestry practice against traditional forestry and agricultural cropping alternatives. In most instances, there remains a need for a better characterization of the economic cost for the establishment and maintenance of an agroforestry practice and its economic return. This must include considerations of financial risk and operational complexity. Region-specific economic analyses are needed that present information in ways that natural resource professionals and landowners can understand. In many areas, landowners are seeking advice on how to form cooperatives in order to harvest and market new products (AFTA, 2000).

CHALLENGES AND OPPORTUNJTIES

There is a great interest in agroforestry, both domestically and globally. This interest is expected to grow as increasing emphasis is placed on land stewardship and environmental protection in agroecosytems. The potential of agroforestry to simultaneously provide economic, environmental, conservation and social benefits is rapidly being recognized by federal and state agencies, universities, and conservation organizations. Despite its potential, however, numerous barriers have impeded the development and application of agroforestry. The challenging circumstance surrounding agroforestry are that it is unconventional, lacks recognition, and cuts across agencies and disciplines. Current agroforestry research and development and related extension activities are limited, disconnected, and minimally funded in relation to the need and interest.

In response to these challenges, the community of interest for agroforestry has come together and is unified nationwide to support agroforestry development and implementation in the United States. More emphasis is needed on technology development, systems integration, application and decision support tools, technology transfer to agriculture and natural resource professionals, and technical assistance to landowners. A focused effort is needed to accelerate the development and application of agroforestry practices. The immediate need, however, is to get agroforestry on the ground. This can best be achieved through a concerted effort to put into practice what is already known.

Improved technologies and information are only part of the challenges. A determined effort is needed to strengthen partnerships and cooperation among federal agencies and form alliances among federal, state and university, and private sectors to develop, disseminate, and apply agroforestry technologies. There is a need to overcome barriers and build bridges. Agroforestry offers an unprecedented opportunity for interagency cooperation. Closer linkages are required between ongoing agricultural systems and natural resources R&D and extension programs in order to be successful and effective. Establishing agroforestry working groups in each U.S. region will help the development and application of agroforestry technologies on the ground, and will help remove barriers between agencies and universities and create cooperation between scientists, natural resources professionals, and landowners.

The opportunities for the application of agroforestry technologies are unlimited. Currently, millions of acres of economically marginal or environmentally sensitive cropland and pastureland in the United States could potentially be put into sustainable use through agroforestry technologies (Rietveld, 1996). There are millions more acres of productive agricultural lands that could also benefit from the implementation of agroforestry practices. Agroforestry can contribute greatly to creating integrated agricultural and community systems that maintain productivity, protect natural resources, minimize environmental impacts, and provide for people's economic and social needs.

The USDA agencies are committed to developing an ecosystem-based approach for planning and implementing programs at farm, watershed and landscape scales. Agroforestry is part of the infrastructure of sustainable land-use systems; thus, foresters, wildlife biologists, agronomists, and other natural resources and agriculture professionals are needed to develop an approach to sustainable development in agroecosystems on large and small scales. Partnerships and teamwork between the natural resources and agricultural disciplines are essential in order to successfully address complex and critical issues associated with attaining sustainable development. Agroforestry is beneficial and effective whether it is implemented on an individual property or throughout the entire watershed.

In view of environmental problems confronting modern agriculture, and the emphasis being placed on the development of sustainable agricultural and natural resource systems, agroforestry can have lasting economic, environmental, and social impacts. As part of an ecologically based land-management system, agroforestry practices can contribute substantially to improving ecosystem diversity and generating processes important to long-term sustainability. At farm, watershed, and landscape scales, the integration of agroforestry practices can transform U.S. agricultural lands into stable, resilient, diverse, aesthetic, and sustainable agricultural land-use systems. By enhancing the production capabilities of rural lands, agroforestry can help revitalize rural communities that have become socially depressed due to recent economic downturns.

Changing policy, regulations, and incentives to favor sustainable resources management, improving education and research, and providing demonstration projects will speed the adoption of agroforestry practices. To this end, the U.S. Department of Agriculture (USDA, 2011) has developed the Agroforestry Strategic Framework, Fiscal Year 2011-2016 in order to increase awareness of and support for agroforestry. This strategic framework brings together the ideas and resources of five USDA agencies and two partners, as well as a diverse group of stakeholders. It also creates a roadmap for advancing the science, practice, and application of agroforestry as a means of enhancing America's agricultural landscapes, watersheds, and rural communities (USDA, 2011).

In February 2013, the USDA issued a new Policy for Agroforestry. This regulation sets forth the policy of the United States Department of Agriculture on agroforestry, based on the USDA Agroforestry Strategic Framework, Fiscal Year 2011-2016 (approved by Secretary Thomas J. Vilsack, May 2011). The Department of Agriculture further acknowledged that agroforestry practices improve the health and sustainability of agricultural systems and also recognized agroforestry as a unique land-management approach that provides opportunities to integrate productivity and profitability with environmental stewardship. In order to provide knowledge, tools, and assistance in combining agriculture and forestry for the benefit of landowners, communities, and the nation, the Strategic Framework identifies three goals: (a) Increase use of agroforestry by landowners and communities; (b) Advance the understanding of, and tools for, applying agroforestry; and (c) Incorporate agroforestry into an all-lands approach to conservation and economic development.

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The Effects of Agricultural Use on Chemical, Biological and Enzymatic Activities of Soils in the Experimental Forest of National Taiwan University

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ABSTRACT

The objectives of this study were to investigate the effects of agricultural cultivation on the chemical, biological, and enzymatic activities of some forest soils of the Experimental Forest of National Taiwan University. Ten soil samples from five Tracts that cultivated agricultural crops and three soil samples from forest were selected for the study. The five Tracts were Neimaopu, Shueili, Heshe, Qingshuigou and Duigaoyue. The soils were sampled to the 15 cm depth. The chemical properties, biological properties and enzymatic activities of soils were analyzed. The results showed that there were great differences in the chemical properties, biological properties and enzymatic activities of soils compared with the forest soils. It is supposed that application of agro-chemical and tillage not only resulted in changes in soil chemical properties but also biological properties. The soil organic matter contents of soils of agricultural uses were one-third less than that of forest soil. In summary, agricultural cultivation had a strong impact on the chemical properties, microbial biomass, and enzymatic activities of soils, likely through soil acidification and fertilizer application.

KEY WORDS: Soil organic matter, Soil respiration, Soil biomass carbon, Soil biomass nitrogen, Soil enzyme, Soil acidity.

INTRODUCTION

Conversion of forest soil to agricultural use or grassland resulted in a great impact on soil properties (Lal, 2009). These impacts include significant decrease in organic matter, nitrogen, phosphorus and microbial biomass of soils (Srivastava and Singh, 1991). Thses effects are due to soil leaching and increase in soil organic matter oxdation

(Schnitzer, 1991; Turner and Lambert, 2000). In addition, the amount and quality of organic matter return to soils are different from natural ecosystems (Lugo and Brown, 1993). Some forest soils of the Experimental Forest of National Taiwan University have been used in agricultural cultivation for a long time. The changes in soil microbial abundance and community structure affect nutrient cycling, C-sequestration and long-term sustainability. The objectives of this study were to investigate impacts of land-use change on chemical and biological properties of soils.

MATERIALS AND METHODS

Five Tracts were chosen for studying, i.e. Neimaopu, Shueili, Heshe, Qingshuigou and Duigaoyue. The soils were sampled to the 15 cm depth. The chemical properties, biological properties, and enzymatic activities of soils were analyzed. The soil enzyme studied included dehydrogenase, β-glucosidase, uease, arylsuphatase, acid phosphatase and alkaline phosphatase.

RESULTS AND DISCUSSION

Chemical properties

Compared with the forest soils the soils of agricultural use had a higher pH. The pHs of soils also depended on the kinds of crops cultivated (Table 1). Application of lime is a common practice to neutralize the acidity of soils and resulted in a higher soil pH in agricultural land. Nourbakhsh (2007) showed that deforestation resulted in significant decrease in soil organic matter content. In this study, the soil organic matter contents of agricultural use lands were significantly less than that of forest soils.

Biological properties

Soil respiration is an indicator of soil biological activity. Table 2 shows that forest soils have the greatest soil respiration. The decrease in soil basal respiration of deforestration was great (Nourbakhsh, 2007). Most of soil respiration is microbial respiration. This result indicated that agricultural cultivation resulted in decrease in microbial activity, which was also showed in the other study (Gupta and Germida, 1988).

Enzymatic properties

Miralles et al. (2012) indicated that deforestration resulted in decrease in soil enzymatic activities. Table 3 shows that there were great differences in soil enzymatic activities between forest and agricultural used soils. The decrease in soil enzymatic activities was highly correlated with decrease in soil organic matter content.

Table 1. Soil chemical properties of studied fields

Study site	pH (1: 1)	EC (sat.)*, dS m^{-1}	Org-C**, g kg^{-1}	Total N, g kg^{-1}	Mehlich-III P, mg kg^{-1}	Mehlich-III K, mg kg^{-1}
10-811	3.23 ± .04	0.83 ± 0.13	8.7 ± 1.1	1.12 ± 0.15	158 ± 25#	84 ± 17
12-44	3.44 ± 0.09	1.16 ± 0.20	53.6 ± 2.7	4.84 ± 0.52	194 ± 81#	300 ± 101
15-298A	5.76 ± 0.32	0.52 ± 0.09	33.9 ± 5.3	7.30 ± 0.95	183 ± 121	359 ± 103
15-298B	4.97 ± 0.44	0.32 ± 0.11	24.2 ± 4.3	6.79 ± 0.57	69 ± 50	153 ± 71
18-310A	6.36 ± 0.19	0.48 ± 0.13	34.7 ±10.8	9.23 ± 0.35	91 ± 22	582 ± 154
18-310B	6.30 ± 0.10	0.39 ± 0.10	15.0 ± 2.6	5.92 ± 0.84	18 ± 7	280 ± 90
18-310C	6.60 ± 0.36	0.52 ± 0.09	23.7 ± 3.2	7.64 ± 3.75	46 ± 17	374 ± 17
21-322A	5.11 ± 0.30	0.50 ± 0.11	49.6 ± 4.6	7.19 ± 0.80	405 ± 199	173 ± 41
21-322B	4.61 ± 0.48	0.67 ± 0.28	62.5 ± 9.0	8.05 ± 1.21	641 ± 262	280 ± 63
21-322C	4.85 ± 0.33	0.83 ± 0.20	61.8 ± 6.1	9.09 ± 0.79	742 ± 141	328 ± 59
21-322D	4.46 ± 0.43	0.79 ± 0.26	65.9 ± 12.4	8.61 ± 2.20	705 ± 197	195 ± 29
21-322E	5.43 ± 0.59	0.58 ± 0.16	53.5 ± 10.6	9.11 ± 2.71	711 ± 399	278 ± 99
Forest-A	5.55 ± 0.10	0.43 ± 0.06	82.4 ± 27.1	9.64 ±1.18	12 ± 3	153 ± 28
29-40A	5.97 ± 0.96	0.25 ± 0.12	54.5 ± 14.5	4.2 ± 1.4	503 ± 189	122 ± 31
29-40B	5.51 ± 0.31	0.16 ± 0.02	42.9 ± 5.2	3.1 ± 0.3	439 ± 199	29 ±7.1
29-47	6.17 ± 0.27	0.23 ± 0.07	86.4 ± 24.9	5.2 ± 1.1	14.4 ± 8.9	108 ± 36.5
27-66A	6.61 ± 0.21	0.30 ± 0.06	31.9 ± 7.3	3.6 ± 0.6	130 ± 56	492 ± 103
27-66B	5.25 ± 0.40	0.28 ± 0.06	26.3 ± 3.7	2.6 ± 0.4	98 ± 20	395 ± 69
Forest-B	6.24 ± 0.20	0.32 ± 0.04	38.9 ± 5.8	3.7 ± 0.6	7.7 ±1.7	251 ± 96
27-354	6.23 ± 0.37	0.71 ± 0.05	36.6 ± 3.2	3.5 ± 0.6	416 ± 97	441 ± 93
Forest-C	5.10 ± 0.26	0.27 ± 0.05	54.7 ± 6.4	4.4 ± 0.2	93 ± 39	142 ± 32
27-306	6.54 ± 0.21	0.30 ± 0.05	26.9 ± 5.8	2.5 ± 0.6	784 ± 205	307 ± 199

* : Electric conductivity of saturation extract.

**: Organic carbon.

: Bray -1 P.

Table 2. Soil biological activities

Study site	CO_2-respiration, mg C kg^{-1} h^{-1}	Biomass-C, mg C kg^{-1}	Biomass-N, mg N kg^{-1}	Biomass-C/ biomass-N	Biomass C/soil organic C, %
15-298A	10.3 ± 1.8	470 ± 65.3	74.1 ± 8.8	6.4 ± 1.4	1.40 ± 0.21
15-298B	4.7 ± 1.4	162± 66.8	31.5 ± 18.3	8.2 ± 2.5	0.64 ± 0.19
18-310A	11.4 ± 6.3	483 ± 150.2	96.0 ± 32.6	5.1 ± 0.4	1.28 ± 0.07
18-310B	9.1 ± 2.5	334 ± 50.4	39.4 ± 24.7	8.5 ± 2.3	2.25 ± 0.03
21-322A	6.7 ± 1.4	291 ± 68.0	35.9 ± 1.7	8.0 ± 1.5	0.59 ± 0.16
21-322B	7.7 ± 2.3	256 ± 121.8	42.7 ± 17.0	5.9 ± 0.6	0.40 ± 0.15
21-322C	8.4 ± 2.3	289 ± 72.8	40.9 ± 12.3	7.2 ± 0.7	0.46 ± 0.08
21-322D	10.4 ± 3.9	356 ± 147.3	44.4 ± 19.2	8.3 ± 1.6	0.53 ± 0.15
21-322E	10.5 ± 3.5	380 ± 158.0	52.2 ± 20.3	7.2 ± 0.8	0.69 ± 0.22
Forest-A	34.2 ± 8.5	1040 ± 293.1	207 ± 39.0	5.0 ± 0.6	1.29 ± 0.17
29-40A	7.39 ± 4.34	623 ± 293	67.0 ± 22.4	9.2 ± 2.8	1.10 ± 0.26
29-40B	4.52 ± 0.47	454 ± 127	43.4 ± 9.0	10.4 ± 1.3	1.06 ± 0.21
29-47	10.79 ± 5.07	1150 ± 434	105.6 ± 40.6	11.0 ± 1.3	1.32 ± 0.18

Table 3. Soil enzymatic activities

Study site	dHase[a], mg TPF kg^{-1} h^{-1}	Gase, mg PNF kg^{-1} h^{-1}	Urease, mg NH_4^+ kg h^{-1}	aSas, mg PNF kg^{-1} h^{-1}	aPase, mg PNF kg^{-1} h^{-1}	Pase, mg PNF kg^{-1} h^{-1}
15-298A	74 ± 9	152 ± 51	197 ± 46	262 ± 32	702 ± 195	82 ± 30
15-298B	32 ± 18	56 ± 29	117 ± 31	143 ± 51	324 ± 64	38 ± 40
18-310A	96 ± 33	273 ± 81	460 ± 146	357 ± 79	651 ± 141	443 ± 96
18-310B	39 ± 25	199 ± 55	145 ± 19	231 ± 25	460 ± 85	223 ± 66
21-322A	51.0 ± 12.7	137 ± 39	243 ± 81	135 ± 20	699 ± 61	61 ± 11
21-322B	56.2 ± 43.5	170 ± 73	187 ± 128	131 ± 67	844 ± 165	92 ± 47
21-322C	59.2 ± 34.4	220 ± 59	306 ± 208	111 ± 55	818 ± 191	101 ± 59
21-322D	44.3 ± 23.6	225 ± 107	115 ± 26	59 ± 30	877 ± 317	105 ± 48
21-322E	87.8 ± 43.0	242 ± 87	124 ± 51	153 ± 84	769 ± 220	194 ± 130
Forest-A	414.6 ± 128	731 ± 183	432 ± 110	1300 ± 293	1800 ± 391	575 ± 184
29-40A	86 ± 53	101 ± 19	15.7 ± 7.1	252 ± 70	581 ± 104	388 ± 44
29-40B	47 ± 15	84 ± 14	12.6 ± 4.1	186 ± 34	524 ± 60	237 ± 17
29-47	325 ± 197	140 ± 71	27.7 ± 11.3	375 ± 134	738 ± 230	415 ± 43
27-66A	345 ± 93	103 ± 13	17.6 ± 3.9	156 ± 55	476 ± 53	390 ± 107
27-66B	48 ± 19	83 ± 23	13.3 ± 4.5	164 ± 30	527 ± 131	237 ± 46
Forest-B	204 ± 70	99 ± 18	39.8 ± 7.1	494 ± 80	638 ± 45	555 ± 122
27-354	173 ± 33	166 ± 9	18.1 ± 0.9	218 ± 17	860 ± 118	423 ± 40
Forest-C	100 ± 32	96 ± 35	18.8 ± 3.6	482 ± 59	1070 ±151	562 ± 108
27-306	66 ± 41	89 ± 32	13.0 ± 2.9	142 ± 45	478 ± 144	420 ± 141

[a]:dHase: dehydrogenase; Gase: β-glucosidase; aSase: arylsulphatase; aPase: acid phosphatase; Pase: alkaline phosphatase.

CONCLUSIONS

Agricultural cultivation had strong impacts on the chemical, microbial biomass, and enzymatic activities soil, likely through soil acidification and fertilizer application. In addition, soil organic matter content decreased significantly after conversion from forest into agricultural use.

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Saproxylic Beetles Community Structure of Agroforestry in the NTU Experiment Forest

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ABSTRACT

Agroforestry has been seen as a feasible solution of the conflict about crop production and biodiversity conservation in developing countries. But it still has doubts about introducing agroforestry into the rugged mountain of Taiwan, where used to be forest plantation. This study set up 3 groups of sample site, depend on different altitude, in the NTU Experiment Forest, to compare the diversity and the community structure of saproxylic beetles under the environment of agroforestry and forest plantation. And discussed the ability of environment factor influence the saproxylic beetles, through the orientation technique, canonical correspondence analysis (CCA). From September 2011 to September 2012, 4697 individuals of coleopteran insect, belong to 554＋species and 63 families, were collected from six sample site, including 18 emergence traps. Every sites other than low-medium altitude, both diversity and richness were higher in the agroforest one, but lower in evenness. The results of cluster analysis shown the species composition was well depend on the geographical distance. In the CCA, altitude and canopy on axis 1 and forest age and the utilize on axis 2 were the environment variables that best explained about 37.2% of the variance in saproxylic beetle assemblage on the first two axes.

KEY WORDS: Agroforestry, Saproxylic Coleoptera, Biodiversity, Coarse wood debris, Canonical correspondence analysis.

INTRODUCTION

The Agroforestry system has been proved to have at least four major ecosystem services of environment benefits: (1) carbon sequestration, (2) biodiversity conservation, (3) soil enrichment and (4) air and water quality (Jose, 2009). But all of them were observed under the circumstances of comparing the agroforestry system and the monoculture system. The agroforestry literatures lacked of evidence for maintaining those benefits while introducing agroforestry system into the land used to be forest or forest plantation, which believed to play an important role in providing all the ecosystem services above. This research focus on the service of conserving biodiversity, we want to know what environment variable had been changed under the system of agroforestry, and how these changes of factor influenced the organisms living in that system.

Saproxylic beetles, being the most abundant group of coleopteran (Koler, 2000; Hammond et al., 1996), might be the group have the most number of species in any forest ecosystem. The limited ability of migrate and great sensitivity to the microhabitat changes mad them became the highest priority group when seeking for the indicator to the agroforestry ecosystem.

Three group of sample sites were set up in the NTU Experiment Forest (central Taiwan) along three different altitude, each group had one agroforestry site (1A, 2A, 3A), and a forest plantation site (1B, 2B, 3B) as control site. Three emergence traps were filled up with all the coarse wood debris collected from their sample site, separated by three different decay degree, to collect beetles feathered from those dead wood. Cluster analysis was used to examine the similarity of beetle assemblage in different sample sites. Environment variables including altitude, timber volume of dead wood, surface area of timber, canopy, slope, age of forest (roughly represented with maximum tree DBH), decay degree, and usage were recorded to analyzed their correlation with the beetle's community through the ordination techniques, canonical correspondence analysis (CCA) (Jonsell et al., 2004; Hsu and Yang, 2005).

CONCLUSIONS

From September 2011 to September 2012, 4697 individuals of coleopteran insect, belong to 554＋species and 63 families were collected. Family Staphylinidae had the most abundant number of species, with 192 taxons；Subfamily Scolytinae had 1849 individuals, were the most abundant group. Species richness and biodiversity index were higher in the agroforestry sites than their control site in medium and low altitudes, and were opposite in the site of low-medium altitude. The results of cluster analysis shown in Figure 1, all the species composition of agroforestry sites were most similar to their own control site. This result was also supported by CCA, in all environment variables, altitude got the highest correlation with canonical axis 1 (0.9715; Figure 2 and Table 1). Since high richness and diversity of saproxylic beetles can hardly self-generated in a system that just introduced, and beetles assemblage well depend on the geographic feature, the hypothesis of most of the saproxylic beetles of agroforestry sites came from the forest surrounded it was true. In the perspective of pest management, many saproxylic species were seem as serious forest pest (Scolytinae, Bostrichidae, and Platypodidae), Introducing agroforestry into forest plantation will attract more pest species and numbers than into monoculture land, increase the cost of pest control.

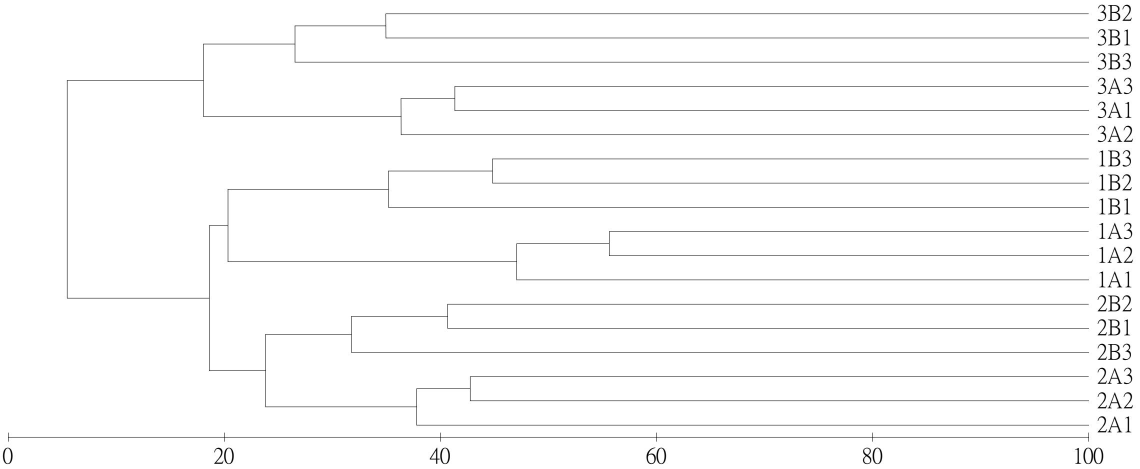

Figure 1. Cluster analysis of saproxylic beetle community structure in NTU Experiment Forest. (Sep. 2011 – Sep.2012).

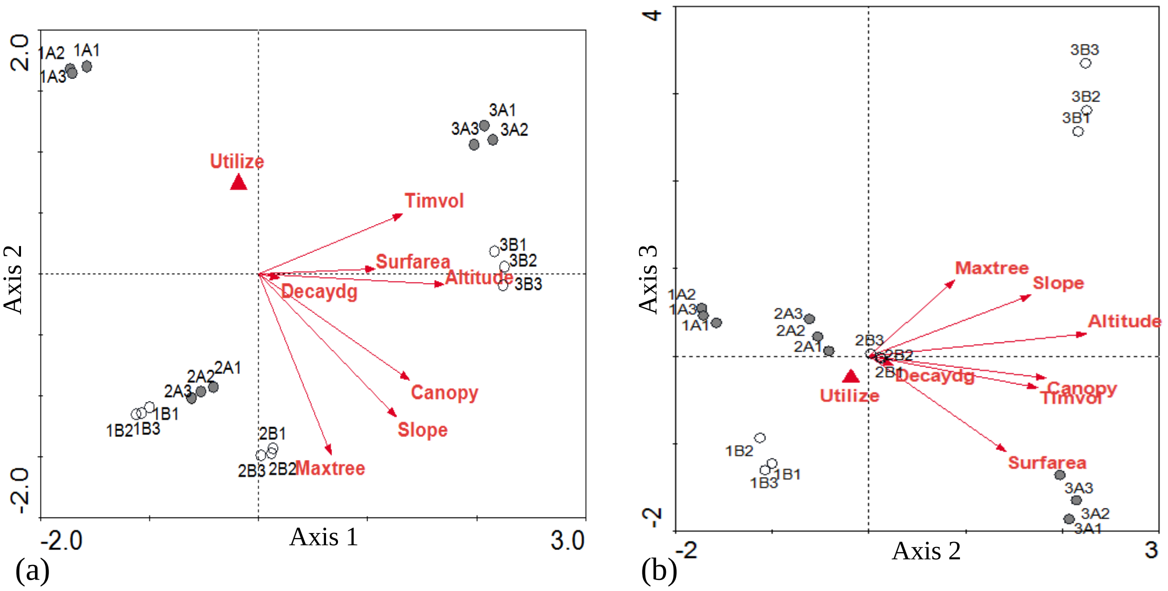

Figure 2. The 18 samples plotted on the first three axes of the CCA ordination: (a) axes 1 and 2; (b) axes 2 and 3. The effect of the environment variables are indicated by arrows. Correlations between axes and environment variables are shown in Table 1.

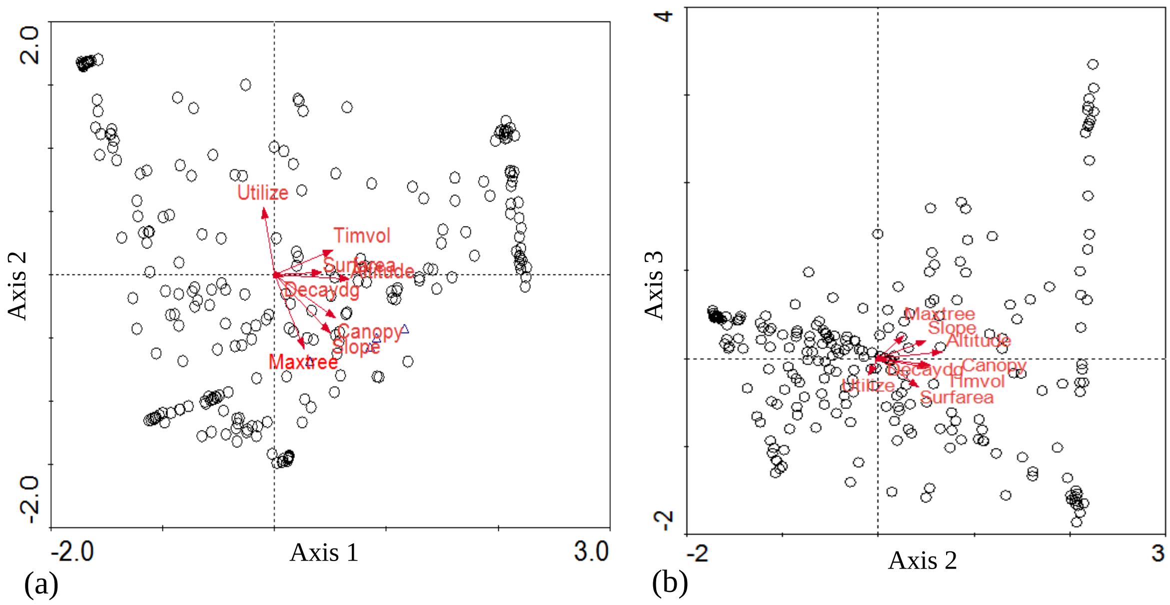

Figure 3. Species found in all emergence traps (except rare species) plotted on the first three axes of the CCA ordination: (a) axes 1 and 2; (b) axes 2 and 3. The effect of the environment variables are indicated by arrows.

Table 1. Correlations between the environmental variables and the canonical axes in the CCA analyses

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.527	0.377	0.362	0.323
Species-environment correlations	0.998	0.998	0.997	0.999
Cumulative percentage variance of species data	13.1	22.5	31.5	39.5
Cumulative percentage variance of species-environment relation	21.7	37.2	52	65.3
Altitude	0.9715	-0.0438	0.0946	-0.1995
Canopy	0.791	-0.4341	-0.094	0.2776
Maxtree	0.3808	-0.7413	0.3228	0.4403
Slope	0.723	-0.585	0.2586	0.2348
Decaydg	0.1103	-0.0175	-0.0399	0.0965
Timvol	0.7536	0.2427	-0.1345	0.1974
Surfarea	0.6109	0.0205	-0.4059	0.0988
Utilize	-0.1481	0.6728	-0.2277	-0.6081

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The Adaptation of Traditional Agroforestry Systems for Sustainable Community Forests Management– A Case of Alder-based Rotation and Inter-cropping Systems in Yunnan, China

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ABSTRACT

Alder (*Alnus* spp.) is a native tree species widely distributed in the Himalayan Region. It grows rapidly, coppices profusely, fixes nitrogen and produces huge quantities of high quality leaf litter leading to soil enrichment. Local people in Yunnan apply the leaf of alder as organic manure. The improvement of fast growing alder tree cover also means the increase in carbon sequestration capacity of hill ecosystems. This paper deals with the most widespread traditional alder-based rotation and inter-cropping system and its variants evolved in response to the changing socio-economic and policy conditions in Yunnan.

KEY WORDS: Agroforestry, Alder, inter-cropping system, Yunnan.

INTRODUCTION

Yunnan, a remote mountainous province in China, is a complex and diverse socio-ecological system of national, regional and global significance. This region shares borders with Vietnam, Laos PDR and Burma and covers the upper reaches of Lanchang-Mekong River, Red River and Salween River, flowing through south-east Asia. It is widely recognised as a biodiversity hotspot in the world with 17,000 species of vascular plants which is 62.9% of total in China and 1,737 species of vertebrates. Yunnan is also very rich in cultural diversity; it is home to 25 ethnic groups, the highest diversity of ethnicity in China.

With its unique topography, diverse climates, great ecological and cultural complexity and regional significance, indigenous innovations together with outside influences have given rise to a variety of upland agricultural systems such as home garden system, upland agroforestry system, silvi-pastoral system, terraced paddy field system, and shifting cultivation systems interspersed among the natural ecosystems.

THE TRADITIONAL ALDER BASED ROTATION AND INTER-CROPPING SYSTEM

The alder based rotation system seems to have become a major upland rice production system since Ming Dynasty about 600 years ago and continued in its traditional form till 1990s. In the traditional system, soon after the beginning of the Lunar New Year (Chinese New Year), the qualified alder forests with ages about 8-10 year old or diameter about 10 cm are cleared, usually trees are cut at no more than 10 cm above the soil surface, the slash is allowed to dry for 3 months and burned in the month of April before the raining is coming and once they missed the timing for burning they were not able to cultivate dry rice that year. Immediately after the first showers in the month of May, upland rice seeds are broadcasted. After a period of 30 days when rice plants have established and attained a height of about 3 to 5 cm, alder seeds are broadcasted in June. The majority of the farmers exchanged labour with each other ranging from employing 1 person up to 10 people depending on the size of the farm land, farming season and the weather.

After rice crop is harvested during September or October, alder seedlings are left to grow for next cutting until 8-10 years after while the diameter reach 10 cm, before next cutting, they also used the fallen leaves of alder as organic compost for their paddy rice field. The exact timing and execution of each procedure is different from place to place and year to year, local farmer remove all the alder trees by clean cutting in winter/dry season, and the main stem of alder was taken home mainly used as firewood while few was used as timber for furniture making, the remains, such as branched and leaves thus left on the ground for drying before burned and a new cycle of slash-burn-broadcast will then starts again. Most farmer household divided their 1-1.5 hectare of rotational land to seven to eight plots, and burnt one plot of land every year to manage yearly output of dry rice.

Collection of alder seeds, alder clearing, land preparation, seed broadcasting, upland rice harvesting are all very labour intensive tasks and carried out traditionally in groups. Farmers usually kept the seeds of dry rice only for next cultivation by themselves, because dry rice seemed to have a seed degeneration problem. Villagers usually solved the problem by obtaining the seed from other villages, which was located at a higher altitude. Farmers believed that the seeds coming from the colder climate were stronger where as other farmers said that the dry rice could be kept healthy by changing its environment. Most of the farmers seemed to exchange the seed every 2 to 3 years; there was 20% increase in yield after exchanging the seed.

THE CHANGING PRACTICES: ADAPTATIONS/REPLACEMENT OF TRADITIONAL LAND USE

In the past, farmers undoubtedly valued alder for its ability to rejuvenate fallowed lands, providing sustained yield of food staples and an abundant supply of firewood by removing wood at the time of burning the field before cropping as well as green manure they used to lop branches when the site was fallowed. Growing staple food crops so as to achieve local production based food security was core objective behind strengthening alder tree in swidden system.

With the introduction and extension of high yield's paddy varieties from the government since 1990's, area under irrigated paddy lands increased. This change was also coupled with a change in terms of increasing influence of market on the otherwise subsistence farmers. Farmers started paying attention to cash-generating opportunities if the staple food requirement was met from irrigated paddy fields. Under such circumstances, they are likely to replace paddy by annual cash crops and/or of *Alnus* spp. by timber trees like *Betula alnoides, Cunninghamia lanceolata* and *Taiwania flousiala* with comparative advantages in the mountains. The annual cropping phase is now considered as a means to accomplish a standing crop of high-value timber.

The New Tree-crop Intercropping Combinations

Local farmers have started practicing new tree-crop combinations and rotations such as *Pinus armandi* rotation with upland rice and buckwheat, establishing alder as shade trees in tea plantations and rotation as well as inter-cropping of annual crops and high value conifer trees *Cunninghamia lanceolata* (Chinese fir) and *Taiwania flousiala.* As Chinese fir is valued on the market, farmers also mix Chinese fir in alder stands. Pine (*Pinus yunnanebsis*)-pineapple intercropping system in tropical areas is another emerging model of traditional alder based system.

The alder-tea system provides an attractive combination of economic and ecological benefits. While tea is the main economic product in this system, alders provide firewood for processing tea leaves and timber (available from thinning of trees when canopy cover is > 40%) used for making of tea boxes and as s substrate for mushroom cultivation. Alders reportedly distracts pests from tea. Much of the former swidden land has been converted into long-term alder-tea plantation. In some cases, Chinese cardamom is planted under the shade of the alder trees.

Many households manage fallows as plantation forests, unhealthy trees are culled for firewood, while the healthy ones are maintained for timber. Farmers regularly harvest the side branches from the alder trees for use as green manure in paddy fields. In case of alder population regenerated on communal lands, almost all above-ground biomass is harvested leading to a bushy growth commonly grazed by free-ranging cattle/buffalo.

If irrigated paddy land is scarce and food security is a serious concern, farmers sometimes also inter-crop maize and beans with the tea/alder. If market is easily accessible, farmers also intercrop vegetable crops with alders.

Perennial Cash Crops (Non-forest Species) Plantations

A substantial swidden area has been converted into pure plantations of tobacco, sugar cane and rape. The soil restoring function of fallow became redundant with use of inorganic fertilizers. Horticultural crops such as plums, peaches, apples and pears are expanding, particular in fields adjacent to the farmhouse where theft can be better controlled. These fruit orchards are also established through *inter-cropping* approach – but intercropping of annual food crops may continue over a long period of time.

Selective Protection of Natural Regeneration of Alder Based System

A variant of this traditional system in Yunnan where farmers plant alder (*Alnus* spp.) is the practice of selective protection of natural regeneration of alder observed in some isolated pockets in the north-eastern Himalayan region of India. It is conjectured that systematic planting of this nitrogen fixing fast growing species with high quality leaf litter evolved as an adaptive mechanism enabling swidden system where nutrient stress was severe, natural regeneration capacity was poor and land available for swidden was extremely scarce. Isolation and poor communication between local communities in the mountains because of terrain, linguistic and cultural barriers lead to selection of different plant species for achieving the same objective, i.e., using trees to create microenvironment suitable for food crops.

THE FACTORS CONTRIBUTING TO THE DECLINE OF TRADITIONAL ALDER BASED ROTATIONAL SYSTEM

Population Growth

Population growth reduces per capita land availability. Added to this, land closure for nature reserves and conversion of farmland for housing and other land uses, and getting forests back on sloping farmlands further aggravate land scarcity. Thus, the changes in population together with changes in land use have been such that farmers were forced to modify or replace the traditional swidden system.

Land Use Policy

With implementation of the Household Contract Responsibility System in 1982, a system of individual household management of small farms has replaced the system of collective management of large farms. The new forest policy including reforestation on wasteland, protection of natural forests and conversion of sloping fields back to forests, has enforced preservation of the young alder trees and has prohibited clearing of mature alder forests for growing upland rice. The current land zoning separates reforestation from agricultural production in the landscape, neglecting the benefits of alder-crop rotation. The extension programs actually encourage farmers to introduce alien species such as Chinese fir. While the area under the traditional alder-upland rice rotation has decreasing significantly, the sustainability of new land use systems is also becoming a matter of concern.

Social and Economic Development

After the land was distributed to individual households, uses of modern productivity-enhancing inputs such as high-yield varieties (particularly of rice and maize), chemical fertilizers, pesticides have dramatically increased. Area under irrigation has also increased. Application of chemical fertilizers is setting aside the importance of biological nitrogen fixation by *Alnus*. Rice yield has drastically increased, from 150kg/mu in the traditional alder-rice rotation system to the level of 600 kg/mu at present as a result of use of modern agricultural inputs. In many ethnic areas of Yunnan, people also make compost by used the fallen leaves of broadleaves trees as organic compost for their paddy rice field.

CONCLUSIONS

Population pressure, policy and social-economic factors seem to have induced the process of replacement of traditional upland rice – alder rotation by the modified systems. Yunnan remains among the poorest areas in China, though several government programs have been increasingly implemented to push economic development in the region. Coexisting with the economic development programs are the actions for conservation of resource-rich but fragile ecosystems in Yunnan. The challenge is how to adapt and integrate traditional rotational systems to the fast changing economic and policy conditions. An integrated analysis of ecological, economic, social and policy processes is required for identifying strategic actions to build the capacity of local communities in evolving and practicing land use systems that are environmentally sound as well as meet their requirements. Left to themselves, the indigenous farmers adapted to subsistence economy over generations may, under the influence of market forces, adopt practices which may not serve their long term sustainability interests and may also cause significant environmental degradation.