Research article

Evaluation on Agro-forestry System in Salt Affected and Non-salt Affected Areas

JEERANUCH SAKKHAMDUANG
Institute of Environmental Rehabilitation and Conservation, Southeast Asia Office, Thailand
Email: j.sakkhamduang@gmail.com

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan /
Institute of Environmental Rehabilitation and Conservation, Tokyo, Japan

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Abstract Low economical return is the main constraint that makes farmers not grow more trees in salt affected areas. So, the research interest was paid to the applicable agro-forestry system combining advantages of trees and crops for rehabilitating salt affected soils and increasing local farmers' income. Accordingly, existing agro-forestry systems in salt affected and non-salt affected areas in Khon Kaen province were investigated and evaluated. For the evaluation, the plant profile of each system was described in the investigation plot at 20m x 20m. In addition, Simpson and Shannon indexes were used to evaluate plant diversity of each investigation plot. Agro-forestry systems on salt affected areas could be categorized into five types: patch forests in farmlands, trees on paddy bunds, tree plantations associated with animal husbandry, home gardens, and trees in vegetable gardens. On the other hand, agro-forestry systems in non-salt affected areas could be categorized into seven types: trees in farm boundaries, trees on paddy bunds, tree plantations associated with animal husbandry, trees in home gardens, trees in vegetable gardens, trees in fruit orchards, and trees and aquaculture. The results of the two indexes revealed that the diversity of plants in agro-forestry systems in non-salt affected areas was higher than that in salt affected areas, except in the systems of tree plantations associated with animal husbandry and of trees in home gardens. It was considered that as the plant diversity in salt affected areas was lower than that in non-salt affected areas due to soil salinity; local people in salt affected areas kept higher plant diversity in the systems of tree plantations associated with animal husbandry and of trees in home gardens for their livelihoods.

Keywords agro-forestry system, salt affected and non-salt affected areas, Simpson diversity index, Shannon diversity index

INTRODUCTION

Reforestation by fast growing trees for lowering saline groundwater level is one of practices that can be applied by local people for rehabilitating salt affected soil in northeast, Thailand (Yamklee et al, 1995; Wada, 1998; Yuwaniyama, 2011). Several organizations in Thailand and overseas introduced the utilization of salt-tolerant trees and plants to solve or to mitigate salinization problem. However, local farmers have not adapted planting trees, as it takes long time to gain the profit (Vittayakorn et al., 1994). Thus, the applicable practice that combines the advantage of growing trees for mitigating salt affected soils along with generating income should be considered to introduce to local people.

Agro-forestry is an interface between agriculture and forestry and encompassed mixed land use practices. Agro-forestry practices are ranging from simple forms of shifting cultivation to complex hedgerow intercropping systems. All agro-forestry systems have the purposeful growing trees with

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crops and/or animals for multiple products or benefits from the same management unit. Agro-forestry also has three attributes: productivity, sustainability, and adoptability (Nair, 1993).

Agro-forestry systems for rehabilitating salt affected soils are widely applied in several countries such as Australia, Bangladesh, and China, and India (Singh et al., 2002; Zang et al., 2004; Ahmed, 1991; Eastham et al., 1993).

Agro-forestry in Thailand has been practiced for a long time since the Forest Village Scheme was introduced by the Forest Industries Organisation of Thailand (FIO) in 1967 as an attempt to stop further spreading of the fast shifting cultivation and deforestation in the country (Boonkird et al., 1984). In Nakorn Ratchasima province, Im-Erb et al. (2004) reported that an agro-forestry system being promoted in recharge area of the province for mitigating salt affected soils was well accepted by farmers according to their additional income. In 2007, Ruaysoongern studied about agro-forestry systems in the northeast of Thailand and categorized into 25 systems.

While there were some researches regarding agro-forestry systems in Thailand, there were a few investigations focusing on agro-forestry practices in salt affected areas. The objectives of this study were to categorize and evaluate the existing agro-forestry systems in salt affected and non-salt affected areas in Khon Kaen province.

Salt affected and non-salt affected areas are defined by the salinity level of soils. Salinity level in Thailand is defined by percentage of salt crust on soil surface in dry season. The area that salt crust covers more than 50% is defined as very severely affected class, and the salt crust covers 10-50% is defined as severely affected class, and for the 1-10% as moderately affected class and non-salt crust is defined as non-salt affected area (Arunin, 1998).

METHODOLOGY

Field investigation on existing agro-forestry practices in salt affected areas and non-salt affected area were conducted in September, 2009 and March 2013 in Khon Kaen province, Thailand. Aerial maps were used for identifying the land utilization. After the land utilization was identified, agro-forestry practices were categorized based on the studies of Ruaysoonngern (2007) and Nair (1993). The sampling plots of 20m x 20m were made for observing plant profiles of each practice. For the comparison of agro-forestry in salt affected and non-salt affected areas, Simpson diversity index and Shannon diversity index were employed in this research. The Simpson diversity index is the probability of any two individuals drawn at random from an infinitely large community belonging to same species. The Shannon diversity index assumes that individuals are randomly sampled from an indefinitely large population and also assumes that all species are represented in the sample.

Simpson diversity index (1949)

$$D = \sum_{i=1}^{s} (Pi^2) \quad (1)$$

where D = Value of Simpson's diversity index
Pi = proportion of individuals in the ith species
s = number of species

and Shannon's index (1949)

$$H' = -\sum_{i=1}^{s} \{(\frac{n_i}{N}) \cdot \ln(\frac{n_i}{N})\} \quad (2)$$

where H' = Value of Shannon's diversity index
Pi = proportion of individuals in the i^{th} species
ln = natural logarithm
s = number of species in community

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The indexes were used for calculating diversity index of each sampling plot. Moreover, hearing survey to farmers regarding their land utilization were also conducted.

Research Sites

Salt affected areas: Phra Yun district is one of the salt affected areas of Khon Kaen province. According to Regional Environment Office 10, Khon Kaen reported that salt affected areas cover 6,095 hectare or around 35 percent of the district area (REO 10, 2003). Agriculture is the main occupation of people in the district while paddy rice and sugarcane are the main agricultural products (Phra Yun Community Development Office, 2012).

Non-salt affected areas: Nong Rue district is one of the non-salt affected areas of Khon Kaen province. Agriculture is the main occupation of the people in the district while paddy rice, cassava, veg etable, and sugarcane are main agricultural products (Nong Rue Community Development Office, 201 2).

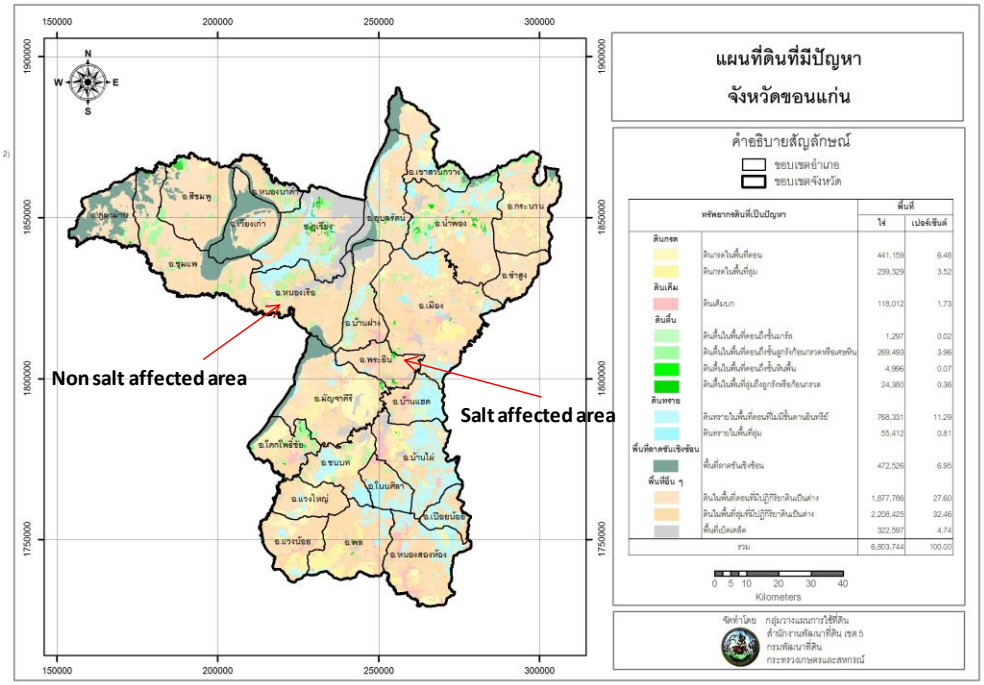

Fig. 1 Study areas

RESULTS AND DISCUSSION

Salt Affected Areas

Land uses in the salt affected areas were classified into paddy field, upland field, patch forest along the stream, settlement area, and bare area. Five agro-forestry systems were found in salt affected areas. Patch forest in farmland was a small area of natural forest surrounded by naked land or farmland, as the natural Dipterocarp trees were kept in farmland for collecting fuelwood and being source of timber, as well as food such as leaves, flowers, shoots, and mushrooms. The samples of tree from patch forests were *Sindora siamensis*, *Dipterocarpus obtusifolius*, *Xylia xylocarpa*, and *Lannea coromandelica*.

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Farmers in the northeast of Thailand preferred to keep trees in their paddy bunds for multipurposes. Trees found in the paddy bunds were considered important due to their commercial value. *Shorea obtusa* was the dominant tree found in the paddy bunds. Farmers with large areas planted trees and let their cows graze in the plantation for weed control. The cows also provided natural fertilizer for trees in the plantations. The samples of trees from the plantation were *Eucalyptus camaldulensis*, *Tectona grandis*, and *Pterocarpus macrocarpus*.

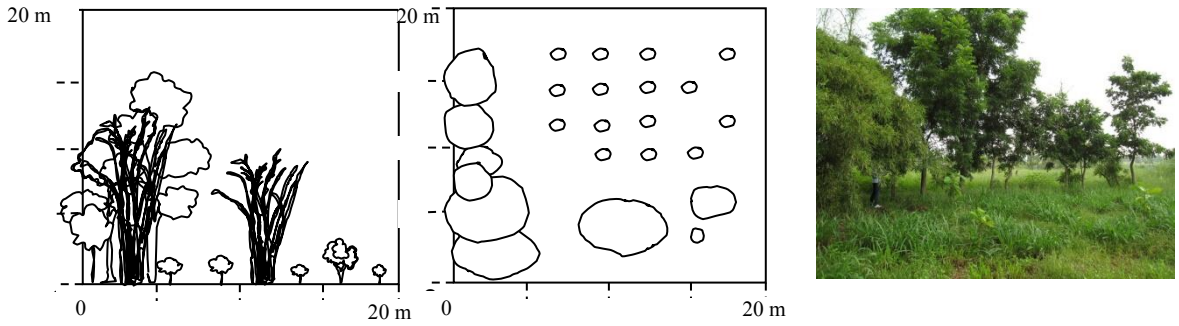

Fig. 2 Trees in home gardens

As shown in Fig. 3, farmers planted several kinds of tree in their home garden. The examples of tree in the home gardens were *Bambusa bambos*, and *Thyrsostachys siamensis*, *S. siamensis* and *Azadirachta indica*. Fast-growing *Anthocephalus chinensis* was found to be used for temporary construction materials and *Pennisetum purpureum* for fodder. In vegetable gardens, farmers planted several kinds of tree together with vegetables. The trees of *Mangifera indica*, *Cocos nucifera*, *Musa sapientum*,and *Anthocephalus chinensis* were used as edible fruits and temporary construction materials.

Non-salt Affected Areas

Land uses in the non-salt affected areas were classified into paddy field, upland field, trees plantation, water bodies, fruit orchards, and settlement area. Agro-forestry systems in non-salt affected area could be categorized into seven types.

Farmers often grew trees for indicating farm boundary because it was cheaper than construct farm fence. Trees that mainly grew for indicating farm boundary were valuable trees or fast growing ones such as *E. camaldulensis*, *A. indica*, and *Bambusa* sp. In the sampling plot, *P. marcrocarpus* were grown for indicating boundary of sugarcane farm.

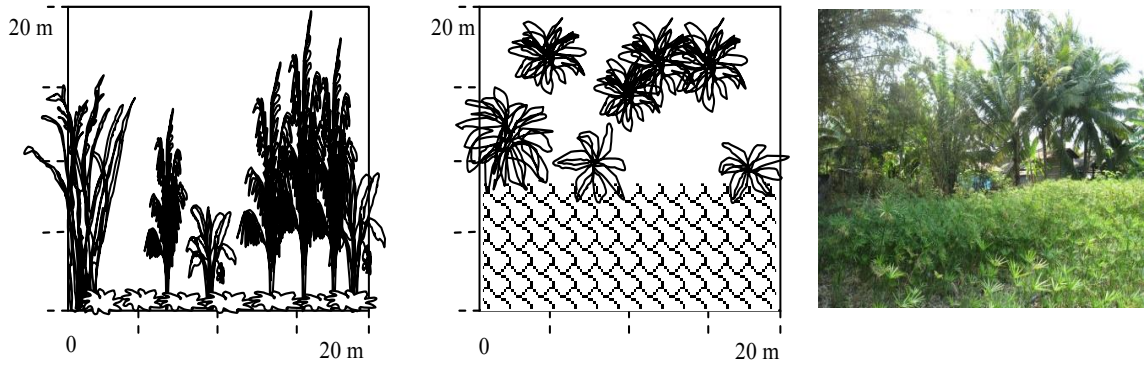

Fig. 3 Trees in home garden

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Trees on paddy bunds were kept for several purposes. Aside from natural trees, in non-salt affected area farmers also grew fast growing trees for economical purpose. In the sampling plot, *E. camaldulensis* and *A. indica* were grown on the paddy bund for economical purpose. Farmers who had enough farmland grew commercial trees in large area and let their cows graze in the plantation for weed control. Besides weed control, cows also provided natural fertilizer for the trees in the plantations. The sample of the tree from the plantation was *E. camaldulensis*.

As shown in Fig. 3, home gardens consisted of various kinds of tree for foods, construction materials, fuel wood, and material for handicraft. The samples of trees in the home gardens were *B. bambos* for construction and handicraft, garden fences; *Cocos nuciferus* and *Musa sapientum* for food; and *Cyperus alternifolius* for weaving mat. In vegetable gardens, several kinds of trees were planted together with vegetables. For this agro-forestry practice, 18 species of plants were found included trees such as fruits trees and timber trees for construction materials.

Farmers grew trees and mixed them with fruit trees for several purposes. In fruit orchard, trees were grown and resulted in multi-storey pattern, the highest tree *P. macrocarpus* and *Tamarindus indica* provided shade to *Annona squamosa* and *Dimocarpus longan* while *B. bambos* was the middle storey. Two of agro-forestry practices that commonly applied in non-salt affected areas were trees and aquaculture. In this practice, several kinds of trees were grown around fish pond for fruit, construction material, and shadow. Moreover, trees around fish pond also provided shade that decreased evaporation. Trees found in this practice included; *P. macrocarpus*, *Mangifera indica*, *A. indica*, *Borassus flabellifer*, *Leucaena leucocephala* and *Erythophleum succirubrum*.

Trees found on the paddy bund in salt affected areas were the trees surviving from the forest while trees found on paddy bund in non-salt affected area were domesticated or new introduced trees. The result was similar to Vityakon (1993) finding that surviving trees were once a part of dry Dipterocarp forest while the domesticated or new introduced trees were grown intentionally.

Comparison of Agro-forestry System in Salt Affected and Non-salt Affected Areas

The results of the field investigation of agro-forestry systems in salt affected and non-salt affected areas in Khon Kaen province indicated that the agro-forestry systems as well as plant varieties in salt affected areas had a lower variety than that in non-salt affected areas.

Table 1 Simpson and Shannon diversity indexes of plant species found in each agro-forestry system in salt affected and non-salt affected area

Salt affected area			Non-salt affected area		
Practice	**1/D**	**Shannon Diversity index**	**Practice**	**1/D**	**Shannon Diversity index**
1. Patch forests in farmland	2.666	1.165	1. Patch forests in farmland	non observed	non observed
2. Trees on farm boundary	non observed	non observed	2. Trees on farm boundary	1.04	0.097
3. Trees on paddy bunds	1.001	0.004	3. Trees on paddy bund	1.002	0.01
4. Tree plantation associated with animal husbandry	1.134	0.279	4. Tree plantation associated with animal husbandry	1	0
5. Trees in home garden	2.909	1.098	5. Trees in home garden	1.006	0.024
6. Trees in vegetable garden	3.111	1.174	6. Trees in vegetable garden	34.735	0.512
7. Trees in fruit orchard	non observed	non observed	7. Trees in fruit orchard	3.459	1.284
8. Trees and aquarculture	non observed	non observed	8. Trees and aquarculture	9.142	1.126

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Moreover, total plant species, as well as plant numbers that were found in agro-forestry systems in salt affected area were lower than that in non-salt affected area. The results of Simpson diversity index and Shannon's index revealed that the diversity of plants in agro-forestry systems in non-salt affected area were higher than that of in salt affected area except in the practices of tree plantation associate with animal husbandry and trees in home garden (Tables 1).

CONCLUSION

The agro-forestry systems found in salt affected areas consisted of five practices while in non-salt affected areas consisted of seven practices. Simpson diversity index and Shannon's index revealed that the diversity of plants in agro-forestry systems in non-salt affected area were higher than that of in salt affected area except in the systems of tree plantation associate with animal husbandry and trees in home garden. Based on the investigated results, it was suggested that the suitable agro-forestry system with higher varieties of plant be introduced in salt affected area.

It was suggested that farmers in salt affected area increase the diversity of tree species especially salt tolerant tree together with salt tolerant or halophyte vegetable or field crop in each agro-forestry practice in salt affected areas for increasing plants diversity and income, as well as rehabilitating salt affected soil.

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