Evaluation of the effectiveness of community development on naturally mychorrhizal mushroom cultivation technology for forest restoration and community food bank at Northern, Thailand

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Abstract: Forests in Northern Thailand have been changed to intensive farming that growing high yield crops, using fertilizers and pesticides leading to human being a harmful effect on the environment. The effectiveness community development on naturally mycorrhiza mushroom cultivation technology for forest restoration and community food bank were recorded. The community participation with knowledge transfer workshop on naturally mycorrhiza mushroom cultivation technology was in vestigated. As the result, people registered to get the knowledge around 355 but attend the workshop about 253 samples (71.27%) from 10 communities at Phrae province. Most of them were the farmers and averaged age 56.23 years old. Result found that top five of trees were *Citrus reticulata* Blanco., *Hopea odorata* Roxb., *Gymnema inodorum* (Lour.) Decne, *Spondias pinnata* (L.f.) Kurz, and *Melientha suavis* Pierre respectively. Naturally mycorrhizal mushroom cultivation were *Astraeus hygrometricus* 159 samples (62.8%) and *Thaeogyroporus porentosus* 152 samples (60.1%) that become food supply at community. Farmers will plant the seedling average 9 trees/person at home garden because they it will easy to get mushroom about 131 samples (51.8%) and easy to take care trees about 129 samples (51%). On the otherhand, farmers will plant the seedling average 22 trees/person at farm because it will be a business about 126 samples (49.8%) and develop farm to a business about 118 samples (46.6%). However, at the community forest, farmers will plant the seedling average 34 trees/person because they will want to build the food supply and want to restore forest. Thus, the forest restoration then to build the food security from forest at Northern, Thailand as have to do a cooperative at community.

Keywords: food security, seedling, Astraeus hygrometricus, Thaeogyroporus porentosus

Introduction

The situation of forests in Thailand is in crisis. In 2018 forest areas in Thai national reserve forest that has been invaded 17,269.26 ha, and 5,697.25 ha of conservation forests. During last 10 years (2008-2018), it was found that the forest areas has been increasingly invaded (Royal Forest Department, 2019). This illustrates that agriculture is still the main driver of deforestation. It is estimated that forest loss is due to conversion to agriculture (FAO, 2018). One of the main factors is increased in population that increased in forest resource utilization, especially the farming encourages much forest invasion. Royal Forest Department issued 3 strategies to protect the existing forest and reforestation (Royal Forest Department, 2018) including the existing forests protection by integrating participation from all sectors to prevent forest areas invasion, reforestation by restoring the invaded and destroyed forest areas, and people's participation in community forest preservation. It created a sense of ownership of forest resource. However, reforestation has long term goals in restoring and increasing forest areas in Thailand to be fertile natural resource that can be used for living and food chain for human and wildlife. Moreover, sustainable forest management should be included for sustainable effects. The purpose of sustainable forest management (SFM) defined by the United Nations General Assembly is to maintain and enhance the economic, social and environmental values of forests, for the benefit of present and future generations. SFM is rooted in two main premises that 1) ecosystems have the potential to renew themselves, and 2) economic activities and social perceptions define human interaction with the environment that can be changed to ensure the long term productivity and health of the ecosystem (HLPE, 2017). Survey should be done to study the kinds of native species that exist in the areas and native plants should be grown in private or public areas without planting alien species. Phrae province is an origin of Yom river, the main river of Chao Phraya river in Thailand, has been faced with forest invasion problem that the peoples occupied for farming (Thairath, 2019). The researchers are interested to promote reforestation in the area of Phrae province by using technology and related research to provide suitable reforestation. Therefore, an experiment of Mychorrhizal mushroom cultivation in seedlings was conducted. A training program was developed to transfer Mychorrhizal mushroom cultivation to villagers who would obtain knowledge, understanding, and able to cultivate Mychorrhizal

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mushroom in tree. Therefore, the objectives were to evaluate effectiveness of technology transfer, and to synthesize knowledge for developing and planning suitable reforestation pattern for each community.

Materials and methods

Study area consisted of 5 districts at Phrae province: Rongkwang, Song, Wangchin, Muang, and Nongmoungkhai. Scope of this study was to evaluate the effectiveness of community development on naturally Mychorrhizal mushroom cultivation for reforestation and community food bank creation.

Samples were registered villagers to attend and practice in the project. There were 253 samples at Phrae province. Research instrument was a questionnaire based on factors for evaluation. Efficiency indicator included in 1) ration of the expected mushroom products between cost and expense, 2) prediction of mushroom production in period 1-2 years for waiting tree growth, 3) prediction of outcome for knowledge transfer from researchers, and 4) length of services of the project. Effectiveness indicator included in 1) level of goal attainment that people can do by themselves, 2) level of standard criteria attainment of planning seedling with mushroom spawn, 3) level of people's participation in attending the project, and 4) level of risk that mushrooms are unable to grow. Adequacy indicator was level of adequacy of resources applied in planting trees with mushroom spawn. Satisfaction indicator included in level of satisfaction in attending project to receive the knowledge and technology transfer, and level of satisfaction in taking action by themselves. Equity indicator included in all interested people have an opportunity to attend the project, and all people have an opportunity or select seedlings for mushroom cultivation. Progress indicator was mushroom productions that compare to goal, activity, natural resources, and times. Sustainability indicator included in 1) economics ability for community form project, 2) possibility in extending the project outcome to villagers, and 3) possibility in extending the project outcome to nearby villagers. Externality indicator included in impact of environment, economic, and social.

Data were collected by using questionnaire and interviewing the participants. Data were analysed by using CIPP (Context, Input, Process and Product) evaluation model. CIPP evaluation model requires the evaluation of context, input, process and product in judging a programme's value. CIPP is a decision focused approach to evaluate and emphasize the systematic provision of information for programme emanagement and operation. Data were surveyed and collected on environment, economic and social factors of project participants. The aspects of economic, social and environmental evaluation were analysed and data on efficiency and effectiveness were synthesized.

Results

As the result, 174 informants were female (68.8%), the average age was 56.23 years old, 134 informants graduated from primary (53%), their average income was 136.75 USD per month. Their land holdings included rice field 0.75 ha, orchard 1.04 ha and backyard garden 0.19 ha. The tree planting sites were as followed: 9 trees in their house area, 22 trees in their farmland, 34 trees in community forest, and 19 trees in community public place. Top 5 tree species selected for reforestation were *Citrus reticulata* Blanco., *Hopea odorata* Roxb., *Gymnema inodorum* (Lour.) Decne, *Spondias pinnata* (L.f.) Kurz, and *Melientha suavis* Pierre. This revealed their ability in increasing green area by planting more trees in their own places as well as in public place. As the samples selected native plants that were appropriate for the location's specific climate. This would enhance the reforestation as well. Mushroom spawn was puff ball (*Astraeus hygrometricus*) that was able to grow on the root of Dipterocarpaceae such as *Dipterocarpus* alatus Roxb., *Dipterocarpus obtusifolius* Teijsm. ex Miq., *Dipterocarpus tuberculatus* Roxb., *Shorea obtusa* Wall. ex Blume., *Shorea siamensis* Miq., *Shorea roxburghii* G. Don, and *Afzelia xylocarpa* (Kruz) Craib, king bolete mushroom (*Thaeogyroporus porentosus*) that was able to grow on the root of fruit trees, and other plants such as jackfruit, cork wood tree, rose apple, hog plum, longan, Burmese grape, dwarf poinciana, and royal Poinciana. Mushroom spawn preparation in scientific laboratory by bringing king bolete mushroom (*Thaeogyroporus porentosus*) or fresh puff ball mushroom (*Astraeus hygrometricus*) to separate the spawn in laboratory. Mushroom spawn is cultivated in Potato Dextrose Agar; PDA. A. After the spawn propagated the PDA, it is transferred to cultivate in Potato Dextrose Broth; PDB. The mushroom spawn bottles are placed over a shaker. The bottles are shaken continually for 10-15 days to stimulate mycelial growth. King bolete mushroom spawn can be transferred from PDA into cereal grain in order to increase the mushroom spawn. As this method has to be conducted by the experts in laboratory, it costs higher expense. However, it gives more spawn for cultivation throughout the year. The mushroom spawn has a high concentration, so small amount of spawn is used for cultivating mushroom on tree. Preparing mushroom spawn form fresh mushroom by taking mushroom portion and portions of clean water without chlorine. Put mushroom and water into a blender, then mix them well. This method is easy, but lots of mushrooms are needed. And this can be done only the season that naturally mushrooms are at their peak. Techniques for cultivating Mychorrhizal mushroom in seedlings.

Mychorrhizal mushroom can be cultivated in the seedlings that have been planted in pot in or bag for 45-60 days. The amount of mushroom spawn depends on the height of seedlings for example, 10 mm. of mushroom spawn for the seedlings that are 10 cm. high. Cultivating mushroom in young and perfect seedlings stimulates faster mycelial growth. Before inoculating mushroom spawn in seedlings, the soil should be wet, but not saturated. Mushroom spawn should be inoculated 2 times on 15 and 30 days after inoculation. Caring for seedlings after inoculated with mushroom spawn. Before planting, the seedlings should be placed indoor. Do not water the seedlings during first 2-3 days after inoculation to allow full mycelial growth. Water the seedlings in a gentle manner to keep the soil but not soggy. Place the seedlings indoor for 1 month before transplanting them into the ground.

Satisfaction in knowledge transfer and reasons to plant trees

In the aspect of satisfaction in knowledge transferring on Naturally Mychorrhizal mushroom cultivation technology, it was found that the informants' satisfaction was at the highest level as king bolete mushroom and puff ball mushroom were popular edible mushrooms, they were in high demand and profitable. The seedlings inoculated with Mychorrhizal mushroom spawn were planted over different sites included backyard, farmland, public place, or community forest. 131 samples (51.8%) planted the seedlings in their backyard because they could pick mushroom easily. 126 samples (49.8%) planted the seedlings in their farmland as the larger area for tree planting, the more mushroom production they would get. 12 samples (4.7%) who planted the seedlings in community forest and public place revealed that these were for future reforestation and next community generations. Regarding the perception and understanding in Mychorrhizal mushroom cultivation technology transfer, 103 samples (40.7%) could inoculate mushroom spawn in each procedure correctly. 251 seedlings (99.2%) were taken care of by the samples correctly. 118 samples (46.6%) were able to transfer knowledge to other people (**Table 1.**).

Table 1. Satisfaction in knowledge transfer and reasons to plant trees

Items	Number	Percentage
Satisfaction in puff ball mushroom technology transfer at the highest level	159	62.8
Satisfaction in king bolete mushroom technology transfer at the highest level	152	60.1
Reason to plant trees in house area because it was easy for mushroom picking	131	51.8
Reason to plant trees in farmland because more trees led to more mushrooms production	126	49.8
Reason to plant trees in community forest / public place because this reforestation was for future generations	12	4.7
Perception and understanding in each procedure of Mychorrhizal mushroom cultivation technology transfer at a high level.	103	40.7
Correct seedlings care after the inoculation	251	99.2
Ability to transfer knowledge to other community at a high level	118	46.6

Food security and the happiness of community

After the training on Mychorrhizal mushroom cultivation technology transfer, 125 samples (49.5%) expected for mushroom production for household consuming. 117 samples (46.2%) revealed that mushroom production was not only for household consuming but they also generated income through local trade. 251 samples (99.2%) perceived that planting trees inoculated with mushroom spawn contributed to future food security. 126 samples (49.8%) were happy from future prospect of mushroom production quantity and expected income. These reflected the confidence in technology transfer method and qualified mushroom spawn received as well as correct seedlings care that strengthen them to be ready for transplanting in the ground in the beginning of rainy season (**Table 2.**).

Table 2. Food security and happiness of community

Items	Number	Percentage
Expected mushroom productions for household consumption	125	49.5
Expected mushroom production for consumption and trade	117	46.2
Food security planting trees inoculated with mushroom spawn	251	99.2
Happiness with future prospect of mushroom production and expected income at the highest level	126	49.8

Project evaluation for decision-making by using Context-Input-Process-Product (CIPP Model). The CIPP model considers 4 aspects. Context Evaluation (C), context evaluation was conducted before the project execution to consider rationale for the project, obstacle, and appropriateness of project goal. Forest area was so important for people ways of life especially rural communities in Phrae province. Mushrooms and forest foods were used for household consumption and for selling. Villagers were dependent on forest resources for their livelihoods. In rainy season, there were abundance of forest products especially wild mushrooms that mostly were Micorrhiza mushrooms such as *Astraeus hygrometricus* (puff ball mushroom), *Amanita citrine* var. *citrine, Russula virescens* Fr*., Russula emetica* (Schaeff. Ex Fr.), *Russula alborealata Hongo, Russula densifolia* (Sevr.) Gill. Wild mushroom products were uncertain and depended on natural environmental factor. Low naturally mushroom production caused food insecurity, income insecurity, and weak economic development. Forest resources were utilized without sustainable conservation. Context evaluation revealed that the project was able to contribute to household food security as the project focused on solving problem by increasing mushroom production and in long term period the project could increase green space through forestation or reforestation in each community (4,783 trees) which responded to UN Sustainable Development Goals (SDGs), goal 1 no poverty, goal 2 zero hunger, goal 13 climate action and goal 15 life on land. The selected communities had central area or community forest, and agricultural water resources that were suitable for participating in the project. This showed an awareness in developing community food resources for community food security including income generating in the future.

Input Evaluation (I), input evaluation was to consider the possibility, appropriateness and availability of project. Area for study the diversity and Micorrhizal mushroom database as well as ecology of mushroom covered Phrae province. Area for transferring Micorrhizal mushroom cultivation technology covered 10 communities in Phrae province. Budget for the project implementation 176,455 USD. Research staff that included 17 researchers and 4 assistant researchers. Four activites in nine months were 1) survey and data management of GIS for biodiversity of naturally mychorrhizal mushroom 2) development of naturally mychorrhizal mushroom propagation 3) tree phenology study, and 4) transfer on naturally mychorrhizal mushroom cultivation technology for forest restoration and sustainable community food bank. According to input evaluation, it was found that at the first year of project operation involved in basic investment and knowledge development for various utilization, including preparing villagers and areas for reforestation and creating sustainable community bank through mychorrhizal mushroom cultivation.

Process Evaluation (P), process evaluation was conducted to find the weakness of the project. The data obtained would be used for future development and improvement for more efficient operation. The strength and weakness of the project. Strength: project staff knew the area geographic so they could access the area for solving problem suitably. The area selected was suitable and villagers were interested in the technology transfer. As the community model had public places and community forest, the reforestation responded community's need. The project participants had suitable places for tree planting that contributed to income earning in the future. Strong and perfect mushroom spawn that used in technology transferring could attach themselves well to plant roots. Process and order of knowledge transfer were appropriate and understandable. The participants received knowledge, took care of trees, and were able to plant trees correctly. Weakness, most participants were interested in receiving technology transfer and desired to reforest and cultivate mushroom. However, the area was limited to plant many wild trees or fruit trees so, they could only plant those trees in their backyard.

Product Evluation (P), product evaluation was to compare the outcome with the project goals by considering economic, social and environmental impacts from project operation on communities. Environment, more green spaces increased as the result of 4,783 trees that villagers selected and 4,880 seedlings in the nursery. There were totally 9,663 trees. Economic, mushroom yield a substantial addition to villagers' income and provided future income source for the participants. Society, created happiness during technology transfer. 126 informants (49.8%) were happy at the highest level. Created food security from project participation. Awareness in forming group for reforestation for future generations.

Discussion

Community development through mychorrhizal mushroom cultivation technology for reforestation and creating sustainable community food bank in northern Thailand was efficient and effective in the first year of project according to CIPP model. In economic aspect, participants expected to grow plants inoculated with mychorrhizal mushroom for selling because the seedlings led to higher price for example an ordinary seedling costed 1 USD, whereas the seedling inoculated with mychorrhizal mushroom spawn costed 2-3 USD. The efficiency happened as the increase of green space through planting 9,663 trees and mushroom product yielded from fully mature trees were average 2-3 kg. As 28,989 kilograms of expected mushroom product, which costed 6 USD/kg. would create income at 173,934 USD/year. Prediction of outcome for knowledge transfer was efficient that participants obtained knowledge from the transfer and could be able to take good care of their trees. As the transfer had finished before the rainy season, so the seedlings inoculated with mychorrhizal mushroom were transplanted in the ground in the rainy season of year 2019. The result conforms to forest in Banpong royal at Chiangmai province initiated development project, provided non-timber forest products such as mushrooms, bamboo shoots and vegetables (Somboonchai, 2002). Total value of all products was 76,386.07 USD. The usage for household consumption had valued of 40,431.51 USD (53.46%) and the usage for trading had valued of 35,205.74 USD (46.54%). The net total value was 100.55 USD/year/household, that contributed a substantial addition to villagers' income. This is in accordance with the study on mushrooms and edible plants in Sakaerat forest (Kosol, 2006) that found 30 species, 9 families of mushrooms, and 62 species, 35 families of edible plants. Value of mushroom picking at Wangnamkhiao village was 253.12 USD/year/household, and value of edible plants was 14.44 USD/year/household. The value of mushrooms around Sakaerat forest obtained was 104,454 USD/year. In northern Thailand, there is a survey of wild edible mushroom in Nan province of Kullamal and Sinunta (2011). The high price of wild mushrooms, approximately upper than 6 USD/kg. This research revealed that people got benefits and more income from non-timber forest products. Wild mushrooms as *Astraeus hygrometricus, Amanita princeps* and *Russula virescens* (schaeff) fr. were one of expensive non-timber forest products that motivated people to pick mushroom. However, forest utilization had affected forest biodiversity as well as forest restoration.

Regarding social aspect, farmers were interested in cultivating mushroom for household consumption. When they planted trees in their house area, they could pick mushroom easily and comfortably. Strong community leaders supported and encouraged villagers to get new knowledge to enhance their occupations and food security for their future generations. Farmers collectively prepared seedlings as well as restored the exploited areas to reduce global warming, create green space in community. The effectiveness resulted was able to solve food shortage problem. As the project focused on the increase of mushroom production and create green space through reforestation in each community (totally 9,663 trees). Happiness creation during technology transfer was at a high level (49.8%). This result was in accordance with the findings of the study on benefits from using forest resources of people in the Maeon Conservation Forest at Chiangmai province of Komonrut (2005) in different manners such as utilization of water, land, forest, local herbal plants, and community food bank which were necessary for their ways of life. This helped maintain agricultural production system, custom and tradition, ritual ceremony, belief, social relationship in community on the basis of rich natural resources. In the aspect of local intellectual that community people were trying to conserve biodiversity of Saensuk (2017). In the area of Khaokradong Volcano Forest Park, Buriramp province there were 25 species, 10 families of mushrooms. The most popular mushroom was in Russulaceae family. Regarding a study on local intellectual and utilization guidelines for people, it was found that people had got various intellectual related to mushroom and community ways of life. Most community people collect mushroom for trade and consumption. However, community forest utilization impacted habitat utilization of wildlife. A case study of Kaenkrachan National Park (Polphan, 2009) revealed that most local people collected forest products (69.3%) within the national park's boundaries. Mushrooms were the most forest products that people collected (50.5%). The average distance from home was 2.23 km. and the time spent was about 1.36 hours/day. October was usually the peak period for collecting mushroom. Most people realized that forest product collection disturbed wildlife but they stated that it was necessary for their livelihood.

In environmental aspect, natural resources are appropriate for mushroom cultivation. There are river sand village reservoirs which nourish this fertile area. The integration between several sectors supports the progress of technology transfer including encourage the participants to practice their knowledge correctly. The sustainability comprised of survival of trees, and the desire to expand the project outcome to nearby villages. Positive impact on environment is the increase of trees and long-term effect of reforestation is environmental balance. Development of spatial and temporal modelling platforms based on empirical models of structural and functional outcomes of reforestation is essential for deciding how to reconfigure agricultural regions. To build such platforms, we must quantify, the influence of previous land uses, establishment methods, species mixes and interactions with adjacent land uses on environmental (particularly biodiversity) outcomes of reforestation (Cunningham *et al.*, 2015). The outcome of good taking care of forest was the variety of mushroom found in the area of Nanthawan forest temple at Nakhonratchasima province (Chunechob *et al.*, 2017), where 44 species, 6 orders, 13 families, 21 genus of mushroom were found. There were 27 species of edible mushroom, 17 species of inedible mushroom. Russulaceae was a very common mushroom family found in that area. There were 12 species included *Rusuula emetic* (Schaeff. & Fr.) S.F. Gray, *R. alboareolata Hongo., R. japonica Fr., R. delica Fr., R. virescens Fr., R. densifolia (Secr.) Gill., R. nigricans (Bull.) Fr., R. Cyanoxantha, R. fragrantissima Romagn., R. vinosa Lindbl., Lactarius corrugis Fr., and Lactarius volemus Fr*. Regarding to the diversity of plants and forest product utilization in Khokyai community forest at Mahasarakham province (Bookaew *et al.*, 2009), tree species with the highest value were found that included *Dipterocarpus obtusifolius* Teijsm. 42 species of wild mushroom were utilized for consumption and trade approximately 22,582.70 kg./year.

Efficiency in economic, society and environment aspects led to a conclusion that an acceptable and suitable method for reforestation. Effectiveness was a well care of trees in order to pick tree-dwelling mushroom. This promoted effective reforestation that was suitable for ways of life of people in Northern Thailand. Moreover, this model for reforestation project could be applied to other areas where villagers prefer to consume mushroom.

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