THAI NGUYEN UNIVERSITY
INTERNATIONAL COOPERATION CENTER

Adaptive Research on Rice/Potato Rotation Model (Applying SRI for Rice and Minimum Tillage Method for Potato) in Paddy Land in Phu Binh District, Thai Nguyen Province*

Assoc. Prof. Dr. Hoang Van Phu
M.Sc. Nguyen Trong Hung
International Cooperation Center– Thai Nguyen University
Le Hong Hanh, International school – Thai Nguyen University
Email: phuhv@tnu.edu.vn

Thái Nguyên, Vietnam
2018

**This stuty is supported by the ALiSEA's Small Grant Program, 2017-2018*

Table of Contents

LIST OF TABLE

1. Statement of problem

System of Rice Intensification (SRI) and Growing Potatoes using the Minimum Tillage Method (GPM) has been recognized by the Vietnamese Government as new technical advances from 2007 to 2012. SRI helps farmers save 70-90% of seeds, 50% of labor for transplants, 70% of cost of plant protection (pesticides and labor), 40 - 50% cost of water, increase rice yield from 13-29%, increase the efficiency of rice production by 33-35%. So far, SRI has been adopted by about 2 million farmers on nearly half a million hectares and about 5,000 farmers are applying GPM (Hoàng Văn Phụ, 2005, 2012, 2016, 2017; Nguyễn Thị Thu, 2014; Ngô Tiến Dũng, 2016).

SRI is an ecological agriculture approach based on five principles: transplanted young seedlings, transplanted suitable sparse, restricting the use of herbicides/pesticides, proper water management, minimize the use of chemical fertilizers and increase organic fertilizers.

GPM is also a solution for growing winter potatoes by Vietnamese farmers. Instead of traditional tillage and use many chemical fertilizers, people use the minimum tillage method and use the rice straws as mulching to grow potatoes. GPM helps farmers save 40% and 70% of labor to prepare the land and of the harvest respectively, productivity increased 8.3%, profit increased by 31% (Ngô Tiến Dũng, 2016). Besides, GPM encourage farmers not to burn straws but uses it as mulching and compost.

Therefore, both SRI and GPM encourage farmers to cultivate towards reducing chemical inputs, organic enhancement, improve the nutrition of the soil, increase productivity and economic efficiency. Besides, these two farming methods help to motivate farmers to work in groups and development assistance in rural society. However, SRI and GPM are still only implemented individually by the farmers, there is no SRI-GPM combined rotational cultivation model in the rice cultivation system as well as the lack of scientific evidences of its benefits compared with conventional rice cultivation in monoculture. Therefore, we studied ***"Adaptive Research on Rice/Potato Rotation Model (Applying SRI for Rice and Minimum Tillage Method for Potato) in Paddy Land in Phu Binh District, Thai Nguyen Province, Vietnam***".

Objectives of the study

- To building a model rotational SRI-GPM in the paddy field of farmers with the participation of the people and the cooperation of partners that known in Vietnamese as "***Lien ket 4 nha***" (farmers - scientists – private business sector - local government)
- To holisticly analize of the model on aspects: economics, environmental protection and social aspect.
- To promote closedly cooperation to raise the added-value of the model, encouraging the conversion of conventional rice cultivation towards sustainable ecological agriculture.

2. Literature review

2.1 The concept of ecological agriculture

"Eco-agriculture" is a reasonable and selective combination of the positive aspects of two agricultural societies: chemical agriculture and organic agriculture; aiming to satisfy current needs

without causing any harms to the needs of future generations (sustainable agriculture), to meet the increasing demand of people for agricultural products: high productivity, good agricultural quality with low material investment and high economic efficiency "(Lê Văn Khoa et al., 1999, Nguyễn Thị Thu Hà, 2013).

According to FAO, 2018a "*Agroecology" is a scientific discipline, a set of practices and a social movement. As a science, it studies how different components of the agroecosystem interact. As a set of practices, it seeks sustainable farming systems that optimize and stabilize yields. As a social movement, it pursues multifunctional roles for agriculture, promotes social justice, nurtures identity and culture, and strengthens the economic viability of rural areas*".

In another way, ecological agriculture is a production management system that produces high quality agricultural products while limiting the use of chemicals such as chemical fertilizers, pesticides, and preservatives, limiting the technical measures that are not suitable for the ecological environment in order to preserve the ecological system, including circulation and biological cycles. The ecological agricultural production will help solve three problems, including: not causing ecological imbalance in the field, not affecting badly to the environment, and creating clean products that cannot be guaranteed if being produced in the direction of using a lot of fertilizers and pesticides (Hoàng Văn Phụ et al, 2016).

It can be seen that the concept of ecological agriculture is a multi-dimensional concept that can be understood in a variety of ways, based on the foundations and experience of one person (Castella and Kibler, 2015). For the application of agro-ecological farming, the key principles that are important, five historical principles have been pointed out by Miguel Altieri (Castella and Kibler, 2015) include:

1. Enhanced recycling of biomass, optimising nutrient availability and balancing nutrient flows.

2. Securing favourable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity.

3. Minimising losses due to flows of solar radiation, air and waterby way of microclimate management, water harvesting and soil management through increased soil cover.

4. Species and genetic diversifcation of the agro-ecosystem intime and space.

5. Enhanced benefcial biological interactions and synergismsamong agro-biodiversity components thus resulting in thepromotion of key ecological processes and services

Until recently, in order to expand the scope of ecological agriculture, Stassart et al., 2012 (cited by Castella and Kibler, 2015) has added a number of principles for ecological agriculture:

1. Valorise agro-biodiversity as an entry point for the (re)conception of agriculture and food systems guaranteeing autonomy of farmers and food sovereignty.

2. Valorise knowledge diversity (local/traditional know-how and practices, layman knowledge and expert knowledge) in the definition of research problems, the defnition of people concerned, and in fnding solutions.

3. Work on agro-ecosystems with a perspective of fostering agro-ecological transition in the long term, giving importance to properties of adaptability and resilience.

4. Promote participatory research driven by the needs of society and practitioners, while at the same time guaranteeing scientifc rigor.

Currently, some eco-agricultural practices have been applied in several countries around the world such as organic agriculture, integrated crop management (IPM), integrated farming/home garden/VAC, system of rice intensification (SRI), conservation agriculture, and agro-forestry (Castella and Kibler, 2015).

2.2 Transformation of traditional rice cultivation into ecological agriculture in the world and in Vietnam

China

In China, land degradation, soil erosion, grassland degradation, and water shortages are seriously threatening biodiversity, so ecological agriculture is considered as an important reform to be implemented, to maintain a sustainable environment combined with economic development. China is a country that has a long history of traditional farming. At present, farms in China have developed farming systems in the direction of ecological agriculture. Some typical ecological farming practices in China include intercropping and rotational cultivations, organic fertilization, integrated form of growing rice and farming fish (rice-fish); simulteneously developing science and technology to promote effective ecological farming practices to conserve and control water consumption; reduce and eliminate the use of synthetic fertilizers and pesticides; and the use of animal wastes such as organic fertilizer. An example of the application of the rice-fish model in southern China shows that fish and ducks eat insects, weeds and algae appear in rice fields, helping to reduce diseases for rice and guarantee the development of rice. Their excrement is used as a nutrient for rice. Another example is that straw after harvesting rice in China is used to grow potatoes, reducing the use of chemical fertilizers, and reducing greenhouse gas emissions from burning rice (FAO, 2017).

In addition, rice-lotus intercropping has been applied in China, resulting in an increase of rice yield of 786 kg / ha (24.5%) compared to that of rice monoculture, also creating an increase of lotus yield of 7.568 kg/ha (17.5%) compared to that of lotus monoculture. People's income increased by 15,000 yuan/ha compared to the previous monoculture method (Nong and Meng, 2010).

Comparison between rice monoculture and rice-duck model showed that when applying this model, income will increase by more than 70%, the rice yield of this model is 2.7% higher than that of rice monoculture (Yu Shengmiao, 2008). Deploying this model can help reduce 90% of weed quantity (Zhang et al., 2009b), over 70% of insect pests (Zhang et al., 2009a), nearly 100% of small yellow snails (*Pomacea canaliculata*) and about 40% with adult (*Pomacea canaliculata)* (Liang

Kaiming et al., 2013). Wang and Yang's study, 2015, also shows that applying the rice - duck production model, net income is ten times more than that of traditional monoculture, which motivates almost all farmers. Farmers have then conversed from traditional rice monoculture to rice - duck model. Moreover, in China, the rice - frog model has been applied. The results of the study on the reduction of insecticide use while increasing the income significantly have been confirmed to achieve high yield and require low input; having been re-applied at many areas of rice cultivation in China to replace mono-rice cultivation (Cao & Zhang, 2016; Wu, 2015)

The conversion of mono-rice cultivation to ecological agriculture has also contributed to the increase of biodiversity in China. Up to 42 species of weeds were found when applying ecological agriculture, while there were only six species of weeds around traditional rice fields. In addition, the application of ecological farming methods improved soil fertility and quality; organic content, total nitrogen content and total potassium content increased by 69%, 75%, and 30% respectively. Heavy metals content including cadmium, arsenic and lead decreased 40.4%, 22.3%, and 36.5% respectively. The quality of rice is improved significantly, meeting the national green food standards. Compared with traditional rice production, the application of rice production according to ecological agriculture has helped farmers increase the income of 6,300. This encourages farmers to converse from their traditional rice cultivation practices into ecological agriculture (FAO, 2018b).

Philippines

In the Philippines, rice is considered as the most important food, the income of the people is largely dependent on rice production, but the only application of the traditional mono-rice cultivation in this country has not guaranteed the income for farmers and affected the environment. Therefore, there is a gradual increase in the trend of people gradually conversing from traditional farming to ecological agriculture. Farmers have deployed the model of rice – fish – duck (raising ducks and fish in the rice field). The net monthly income after the application of this model is much higher than that of rice monoculture. On the same land, people can earn more than $ 600 (higher than at least 26% compared to the old method) by applying the rice - fish-duck model (FAO, 2013).

In the process of transition from rice monoculture to ecological agriculture, one of the ways to guide farmers to apply ecological agriculture practices was to organize farmer field schools (FFS) which has been developed in the Philippines. After farmers participated in and applied what was obtained from FFS, the results showed that the average rice yield compared to the old method increased by 27.2%, the cost of production decreased by 17% (saving $ 132/ha), net income increased by $ 800 (FAO, 2015a).

Indonesia

The rice-fish model has helped to increase rice production by 10-20% (about 6.0 - 7.5 tons/ha /crop), with an additional yield of 1.2 - 1.5 tonnes/ha. Fish farming in the field has helped control pests for rice, and create less negative impacst on the environment through the use of fish feces,

reduce the use of chemicals, and contribute to food safety. The cost of rice and rice production has decreased. Income and net income have risen by more than $ 4,000 to nearly $ 8,000/ha, confirming the benefits of eco-farming in this country (Soetrino, 2015 cited by FAO, 2016).

Cambodia

To produce rice in the direction of eco-agriculture, Cambodia has applied SRI since year of 2000. Until 2007, more than 80,000 farmers participated in SRI and harvested 47,000 ha of rice (Im Sothea, 2008). Evaluation results of the SRI application from 2004 to 2011 showed a 40-60% increase in paddy yield, a reduction in production costs, a 50% reduction in seed use, and a 50-70% reduction in the amount of chemical fertilizer use. The net income and income of farmers are higher than the old farming method (Castella and Kibler, 2015).

Laos

With the support of Oxfam, Australia and the Lao National Center for Agricultural Research, SRI has been developed to replace old rice cultivation, based on 2006 trials that demonstrated the viability of SRI on some pilot models. Until 2010, total SRI rice area is 3,625 ha with more than 10,000 households participating (Castella and Kibler, 2015).

Myanmar

The SRI in Myanmar was first introduced in the IPM-FFS training courses in 2000. The results from the application of SRI showed that rice yield increased 2 times in one year. This success has attracted many farmers' responses in this country. Until 2008, there were an estimated 50,000 farmers in the Kachin and Shan states using the SRI method, with an average yield of 5.5 tons / ha, which was higher than the traditional method with only 2.5 ton/ ha (Castella and Kibler, 2015).

Thailand

Regional centers, local agricultural cooperatives, and agriculture extension agencies, projects in Thailand have begun to integrate agricultural and aquaculture systems. These units provided and distributed breeds or livestock breeds to develop appropriate VAC models for each area. In applying the VAC model, 30% of the land will be used for rice fields, 30% for fruit and vegetables, 30% for fishponds, and 10% for farming (Castella and Kibler, 2015).

Vietnam

Vietnam is known as the world's leading rice exporter. Rice is considered the main agricultural crop, accounting for more than 90% of total cereal production. It is also the main source of food for more than 95% of the population, and an important source of income for more than 60 million people whose main job is to farm and live in rural areas (Le Trong Hai, 2012; Cosslett and Cosslett, 2014). Therefore, it can be seen that rice plays a very important role in ensuring national food security as well as social security in Vietnam.

The agricultural production in Vietnam has produced greenhouse gases such as CO_2, CH_4, N_2O. The total greenhouse gas emissions in 2010 were 88.4 million tons, of which rice cultivation accounted for 50.5%, using fertilizers was 9.79%, burning agricultural by-products was 2.1% (Ministry of Natural Resources and Environment, 2015). Moreover, activities in agricultural production also cause negative impacts on the environment, with traditional farming practices such as slash-and-burn agriculture; applying irrigation, fertilizers, and pesticides unreasonably and burning straw causing erosion, soil degradation, pollution of water, air and soil; wasting of organic fertilizer and greenhouse gas emissions. The total amount of chemical fertilizers used in agriculture is about 10.2 million tons, while people are wasting a large amount of farming waste and agricultural by-products that can be used as organic fertilizer. Therefore, to save money on production and at the same time to protect the environment, the conversion of agriculture into ecological agriculture in Vietnam is very necessary.

At present in Vietnam, there are many methods of production in the direction of ecological agriculture applied as rotational, intercropping, and some different models. Some specific examples and results of agricultural production practices in the direction of ecological agriculture:

The combined rice - fish model increased the average income by 211% (Quang Binh) and 551% (Bac Giang) as compared to rice monoculture, thanks to the combination of rice and fish, thus avoiding pests for the stem and root of rice (by fish) (FAO, 2015b).

Rotations of rice - corn; rice-melon were applied in Binh Dinh, Quang Ngai with an economic efficiency that increased of 30-50% (Phạm Thị Sến et al., 2017).

Intercropping, this form of production is applied in Son La with models of upland rice, vegetable or corn intercropped with tea, longan, mango (Phạm Thị Sến et al., 2017).

Combined models such as:

Intercropped duck raising in paddy fields (duck - rice), for example, in Nam Son Commune, Tan Lac District, Hoa Binh Province, showed a 10 - 15% increase in paddy yields, a double imcrease in income and net profit per unit (Phạm Thị Sến et al., 2017).

The production of ecological rice model of "*ruộng lúa bờ hoa"* in Phuoc Long district and Vinh Loi district, rice fields applying this model save cost of pesticides from 2- 3 times, saving 15 kg of rice seed per hectare, yield was higher than that of control field of 0.2 ton/hectare, the production cost was lower than that of control field of 500 VND/kg, the profit is higher than the control of 3 million VND/ha (Minh Đạt, 2015).

Typical Garden – Fish pond – Animal cage (VAC) applied in the households in Tien Thanh commune, Dong Xoai town, Binh Phuoc province including rice, longan, pomelo, fish and pigs with a profit of 450 million VND/ha (Phạm Thị Sến et al., 2017).

The Garden – Fish pond – Animal cage - Forest (VACR), as in Quan Khe, Ha Hoa district, Phu Tho province, the farmer who had 27 ha (22 ha of forest, 5 ha of garden for food crops, farming

and fishponds comibined with raising chickens, ducks and geese) could earn 400 million VND/ha annually, not including woods. This system is scattered in midland and mountainous provinces in the North, Central, and Central highlands (Phạm Thị Sến et al., 2017).

Paddy field – Fish pond – Garden – Upland field - Forest (RAVNR) in Tam Bong village, Tam Quang commune, Tuong Duong district, Nghe An province consists of 5 hectares of forest of different species intercropped with short duration trees, combined with raising chicken, fish ponds, rice fields for 2 crops. Nghe An province has a policy of supporting the development of similar households in many districts (Phạm Thị Sến et al., 2017).

Particularly for rice production, some methods have been applied, to promote the ecological agriculture, such as:

- *Integrated Pest Management (IPM)* has been popularized in most localities throughout the country. In Vietnam, more than 1 million farmers from 22 provinces have been trained in rice IPM (Castella and Kibler, 2015). Applying the full IPM process will reduce the use of plant protection chemicals, increase the economic efficiency from 1.5 to 3.0 millions VND/ha/crop (Phạm Thị Sến et al., 2017).
- *Integrated Crop Management (ICM)* has been popularized in most of the provinces growing mainly rice and maize. The full application of ICM process will help reduce 15 - 46% of nitrogenous fertilizers, 50% of plant protection chemicals, 2-3 times amount of seeds; increase income from 1.5 to 3.0 millions VND/crop/ha. Some pilot models in the Central and Northern regions reduced 46% of nitrogenous fertilizers, 50% of plant protection chemicals, 50% of paddy seeds; increase yield and economic efficiency by 10 to 15% (Phạm Thị Sến et al., 2017).
- *Rice cultivation technique known as "3 decrease 3 increase" (3G3T*), it means reducing the use of seeds, chemical fertilizers, and pesticides while increasing productivity, product quality, and economic efficiency (Castella and Kibler, 2015). Typical application of some models in Can Tho reduced 100 kg/ha/crop seeds, 30-50 kg/ha/crop of nitrogenous fertilizer, 2 times spraying pesticides; increase profit and income of about 3 millions to more than 5 millions VND/ha/crop. 3G3T is widely used in the Mekong Delta, some provinces in the Red River Delta, and the Central Coast (Phạm Thị Sến et al., 2017).
- *Rice cultivation known as "1 must 5 reductions" (1P5G)*, "1 must" means using certified seed; meanwhile "5 reductions" means reducing the number of seeds, nitrogenous fertilizer, use of pesticides, water and post-harvest losses (Castella and Kibler, 2015). For example, the model in An Giang showed a reduction of 60-80 kg/ha of paddy seeds, a decrease of 40-46 kg/ha of urea, a decrease of 2 - 2.4 times of pesticide spraying per crop. 1P5G is widely used in the Mekong Delta and South Central Coast (Phạm Thị Sến et al., 2017).
- *Saving irrigation techniques known as "nong – lo – phoi" or "wet – dry –wet"".* Typical examples in Bac Lieu in 700 ha, reduced 30% of irrigation water, reduced by 3.3 tons CO_2/ha/crop, increased rice productivity by 0.3 - 0.5 tons/ha (Phạm Thị Sến et al., 2017).
- *Rice transplant in wide rows and narrow rows,* pilot models in Nam Dinh, Thai Binh showed a reduction of 20-40% of plant protection chemical, reduced density of weeds and pests, an increase of 10-15% in economic efficiency (Phạm Thị Sến et al., 2017).

2.3 System of Rice Intensification (SRI)

System of rice intensification (SRI) was introduced by Henri de Laulanié SJ in the early 1980s, then he introduced SRI method to Madagascar farmers to improve agricultural systems, and especially in their rice production. Up until 1990, along with several Malagasy colleagues, Laulanié formed a non-governmental organization (NGO) called the Tefy Saina Association, working with farmers and agricultural specialists to improve rice yield and livelihoods of farmers in Madagascar.

SRI was later popularized and developed by Norman Uphoff in Ranomafana National Park to replace the custom of slash and burn of the farmer. After SRI was disseminated and trained for the people, the situation of slash and burn for production was controlled, and SRI has helped to increase the yield of rice. SRI has the advantages of reducing the irrigation regime for rice, reducing the amount of seed, minimizing the impact of agrochemicals on the environment as people reduce the use of chemical fertilizers, pesticides, plant protection drugs, reduce labor, increase yield of rice (50 - 100%); creating positive effect on soil and nutrients in soil (Uphoff et al., 2009).

To ensure that the rice has optimum conditions for development, maximal branching, high growth rate, when applying SRI, it is neccessary to follow the five principles (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016), include:

1) Transplanting single young and healthy seedlings (2 - 2.5 leaves);
2) Low density of transplanting;
3) Suitable water management to ensure farmland dry - wet alternating
4) Instead of use herbicides, using handing tool to control weeds and reduce pesticide; and
5) Encourage increasing applying organic fertilizers and compost fertilizers to improve soil fertility

Because SRI satisfies both objectives of achieving economic efficiency and developing sustainable ecological agriculture, it has been assessed as a prospective intensive cultivation technique. So far, SRI has rapidly spread to rice-growing countries with around 52 countries in the world, including Vietnam (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016).

SRI has been tested and applied in Vietnam since 2003. This method is recognized by the Ministry of Agriculture and Rural Development as advanced rice cultivation technique (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016). Results in SRI trials on the farmer field shows that rice yield increased from 13 - 29%, 90% of seeds was saved, saved 50% of transplant labor and 40% of water, production efficiency increased by 32 - 35%, no herbicide sprayed or reduced spraying of pesticides from 3 to 5 times (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016).

The application of SRI is further expanded with the support of the OXFAM organization, thanks to the implementation of SRI models in 13 provinces including Hanoi, Hoa Binh, Nam Dinh, Ninh Binh, Thai Binh, Hai Duong, Hung Yen, Ha Nam, Ha Tay, Nghe An, Quang Binh, Quang Nam, Thai Nguyen so it has changed the farming practices of farmers from overusing agricultural chemicals towards sustainable cooperation and responding to climate change.

After those great successes, in 2011 Vietnam had 1 million farmers applying SRI, SRI won the first "Vietnamese Golden Rice Parnile Award" in 2012. In 2015, the SRI Vietnam network was established, thus providing opportunities for sharing information and cooperation on SRI development in Vietnam and SRI global. In the same year, 35 provinces in the country have applied

SRI, with a total area of 436,377ha, number of farmers applying SRI increased up to nearly 2 million farm households (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016).

Typical applications in some districts of Tra Vinh province such as Cau Ngang, Cau Ke, Tieu Cau show that the cost of rice production under the SRI is lower than 4 millions VND/ha compared with traditional cultivation, the yield of rice reached 7.35 tons/ha (Đặng Văn Bường, 2013).

2.4 Growing winter potato by minimum tillage method (GPM)

Growing winter potato by minimum tillage method is a method of utilizing the by-products such as rice straws as cover material (mulch) to replenish large amounts of organic matter for the soil, reducing environmental pollution, labor, production costs; increasing productivity and economic efficiency.

In 2008, being supported by Food and Agriculture Organization of the United Nations (FAO) and Oxfam, the National IPM Program and the Plant Protection Department (PPDs) has cooperated with some Plant Protection Branches and farmers to conduct a research on GPM. The results showed that irrigation water decreased by 25-67%, plant protection chemicals decreased by 75%, labor decreased 28 - 47%, productivity increased by 8-25%, economic efficiency increased by 19-37% (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016). Thanks to this success, GPM has been trusted, rapidly spread to many Northern provinces in 2012, the area of application of this technique is nearly 430ha (Kim Uyên, 2013).

In 2013, the Ministry of Agriculture and Rural Development has approved GPM as Advanced Technique in growing winter potato. There are 22 provinces with about 4,500 farmers applying this method in 2014 (Ngô Tiến Dũng and Hoàng Văn Phụ, 2016).

Actual results of the application of GPM in Thai Thuy, Thai Binh province showed that average yield is 20 - 23 tons/ha, profit is 3 - 3.5 millions VND/sao, average profit is 100 - 150 millions VND/ha (Nguyễn Hình, 2012).

In Tan Duong commune, Dinh Hoa district, Thai Nguyen province, this method has helped the farmers to obtain a potato yield of 650 kg/sao, earning profit of 4.6 millions VND/sao. Some other places such as Hong Tien Commune, Pho Yen District and Dong Dat Commune, Phu Luong District showed that this method not only helps reduce input costs for materials, fertilizers, labor, but also helps increase potato yield, quality of potato is considered good, the income is higher than the conventional method (Dương Trung Kiên, 2012).

2.5 Research gaps

With the biggest goal of encouraging people to cultivate towards ensuring the safety of the environment through reducing the use of agricultural chemicals, organic enhancement; improving soil nutrition, also still ensuring high productivity and economic efficiency, SRI and GPM are very useful methods.

However, there is no combination of two methods in an area unit to have scientific and practical basis to prove the benefits of the SRI-GPM model compared with conventional rice and potato cultivation.

3. Study approaches and methods

3.1 Study approach

Building SRI-GPM rotational cultivation model performed by farmers according to the Farmer's Field Research Approach with the principles of Field Farmer School (FFS) and the involvement of other stakeholders.

On this basis, a comprehensive study and holistic analysis of the model was undertaken by multiple stakeholders to make conclusions about the applicable feasibility, development and dissemination of models, and as a basis for promoting the conversion of rice and potato farming practices towards sustainable ecological agriculture.

3.2 Study methods

The SRI-GPM model is the rotation system with 3 crops per year on rice paddy land, including: Summer rice (from July to October) - Winter potatoes (November to January) - Spring rice (February to June).

The model was built on an area of 3.2 hectares with the participation of a group of 62 rice farmers in Vien Hamlet, Tan Duc Commune, Phu Binh District, Thai Nguyen Province from June 2017 to June 2018.

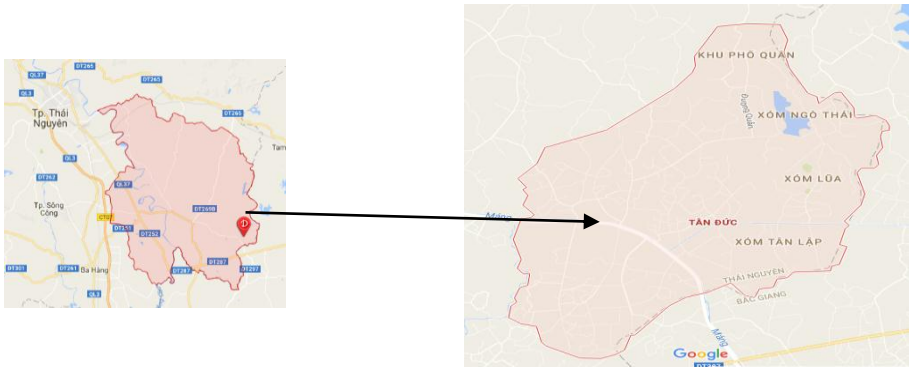

Figure 1: Maps of Tan Duc commune, Phu Binh district, Thai Nguyen province (study area)

The research was set up and compared to the following practices: Conventional rice farming (rice monoculture does not apply SRI – control); monoculture of rice with SRI application; and SRI-GPM practice.

The SRI-GPM model is conducted on the principle of Field Farmer School (FFS) and was run by the farmer group. A "bottom-up" approach has been used, based on the actual conditions of the farmers and with the support of scientists/experts. The model has been designed, implemented, recorded and evaluated by the farmer group with a basic composition of women.

Farmer's field research methodology with the participation of farmers, applied with the participation of the parties include: farmers/farmer group; technical/scientific staffs (agricultural extension staffs of commune, district, scientists/experts); agricultural business sector; social organizations and local authorities of communes, districts, and provinces).

Methodology of agricultural system research with the use of methods and PRA tools such as observation, farmer interview, group discussion, problem tree, priority ranking; methods of ecological research were also used to collect data and analysis of indicators on overall aspects of productivity and economic efficiency; straw management, biodiversity, environmental protection and adaptation to climate change; social capital; roles and linkages of stakeholders in the implementation and dissemination of the model.

The model has also emphasized strengthening cooperation and linking stakeholders including farmers, scientists/technicians, enterprises and local authorities to create value-added for the products of the model, to provide a practical basis for expansion and conversion towards sustainable agricultural ecology in rice land.

The study has also tested an approach "Public - Private Partnerships" or "Linkage of 4 partners: Farmers - Technicians/Scientists – Private sector – Local authorities" in technology transfer, agricultural transformation as well as sustainable rural development in the context of social change and climate change in Vietnam.

The open public dialogue (field workshops and project summaries) between the parties concerned (farmer groups, members of Women, Farmer's association, agricultural business enterprises, agriculture extension station, plant protection station, scientists of the International Cooperation Center, and local governments) have been made to enhance their participation in the deployment of the model in the coming years. The experience and lessons of the model were also documented by experts and key farmers.

4. Research results/Findings

4.1 Characteristics of the SRI - GPM model and condition of application

In Vietnam, rice monoculture has been existed for a long time. Rice is mostly planted in two major crops which are Spring crop and Summer crop. The characteristic of monoculture is growing only one crop on the farm land and take advantage of the period has warm temperature (<20 ^{o}C) in one year (February - November) to produce rice. The main advantages of this practice are recognized as it has been applied since ancient time therefore farmers have accumulated experience. However, this practice is mainly based on concept of the "using higher inputs to get higher outputs" that led to the overuse of chemical inputs in order to increase rice productivity then address these issues: food security, soil exploitation and the loss of biodiversity.

Meanwhile, the paddy soil is almost sandy and fertile. Furthermore, rice is harvested after November, which is proper for growing potatoes from November to February of the next year. Planting potatoes in the winter crop will enhance the efficiency of land use and step by step shift to polyculture. On the other hand, using the straws from the previous crop to grow the potatoes will not only provide soil fertile and nutrient but also help to minimise pests and diseases from the previous crop.

Characteristics of the SRI - GPM model

SRI - GPM model is a rotational pattern on paddy fields between aquatic plants (rice) and terrestrial plants (potatoes). These are two major crops that provide food and income for farmers.

In addition, they need different requirements for different conditions of the environment so rotational pattern has more advantages compared to monoculture farming.

The model still has two rice crops but the winter crops are added as presented below:

Summer: rice crop (June-October) - Winter: potato crop (November - January) - Spring: rice crop (February - June)

The addition of potato crop (Poaceae) in cropping structure on paddy land does not create competition. Furthermore, SRI-GPM will take advantage of break time between two rice crops, then take advantages of sunlight shedding on an unit of land in the short period of the year. The photosynthesis of chlorophyll in the stems, leaves of rice and potatoes look like a solar panels of carbon for the whole year, it requires low cost, low level of labor that farmers can also be able to do it. SRI-GPM utilizes the advantages that pre-crop provided good condition for the following crop (such as utilizing rice straw for potato cultivation) that improve economic efficiency of land area without damaging soil nutrients, minimizing the negative impact of monoculture on environment, and reducing the effects of climate change.

4.2 Analysis of SRI - GPM model

4.2.1 Productivity and economic efficiency

- **Productivity**

By adding one more potato crop together with the application of SRI and GPM, the advantages of the model have been demonstrated the economic productivity which is shown in Table 4.1. In the same area of land in a year, when applying SRI, the productivity has increased 7% compared to non-SRI practice. At the same time, if GPM was applied, 18.5 tons of potatoes could be harvested.

Table 4.1: Comparison of the productivity of different farming methods

Mode of cultivation	Rice Yield (kg/ha)				Potato (tubers) (kg/ha)
	Summer rice crop (2017)	Spring rice crop (2018)	Whole year	%	Winter crop
Conventional (Monoculture Summer rice; non-SRI)	5,041	5,394	10,436	100.0	
SRI (Monoculture Summer rice with SRI application)	5,394	5,772	11,166	107.0	
SRI-GPM (SRI summer rice - Winter potatoes - SRI spring rice)	5,394	5,826	11,220	107.5	18,504

- **Economic efficiency**

The analysis of economic efficiency shows that by applying SRI farmers could save around 5% of production costs (mainly saving seed, insecticides, and spraying labour), the increase of 7% rice yield of over has also increased the farmer's income by 269%, and if GPM is applied, economic efficiency has increased by 1,463% over conventional cultivation (Table 4.2).

Table 4.2: Analysis of the economic efficiency of the different farming methods

Unit: thousand VND

Items	Traditional	SRI	SRI-GPM
Revenue	73,235	78,361	199,013
- Paddy	73,235	78,361	78,739
- potato			120,273
%	100%	107%	272%
Expenditure	68,331	65,190	127,260
- Facilities	52,779	49,639	80,607
- Labor	15,551	15,551	46,654
%	100%	95%	186%
Revenue - Expenditure	4,904	13,171	71,753
%	100%	269%	1463%
Efficiency of labor investment (thousand VND/ labor)	210.5	295.5	406.1
Efficiency of investment capital (VND/VND)	1.09	1.27	1.89

Income: If only applying SRI, rice yield increases by 7% and income increases by 269% compared to conventional rice cultivation; if both SRI and GPM were used, the income would increase up to 1,463%.

Labour: Analysing the efficiency of labor investment showed that while the labor rent is 160,000 VND/man-day, if investment of labor in connventional rice cultivation reaches 201,000 VND/man-day, while using SRI the value of a man-day increases to 295,000 VND. If the SRI-GPM model is applied that will increase to 406,000 VND/man-day.

Effectiveness of capital investment: In conventional rice cultivation, 1 VND investment after one year only return 1.09 VND. If SRI is used, the investment value of 1 VND will return 1.27 VND and if applying the SRI-GPM model the profits will reach 1.89 VND.

Thus SRI-GPM contributes to the increase of income, labor productivity and capital investment efficiency.

4.2.2 Environmental protection and response to climate change

- **Straw management**

In the SRI - GPM model, by adding a potato crop, it increases the photosynthetic time of the crops per unit area generated more than 40% of biomass compared to conventional cultivation. In addition, there is not only higher yield of rice paddy and potatoes but also more organic matters includes approximately 10 tons of straws and 7 tons of potato stems and leaves (more than the traditional 35%). With conventional cultivation, the amount of rice straws (36 tons/ ha/year) farmer usually burn in the field so the amount of straws (organic matter) has lost about 18 tons/ha/year equivalent to 22 kg of protein. If this model is used, the number of organic nutrients can be retained for the next crop, contributing to soil improvement, reducing input costs in potato cultivation and spring crop next year.

Table 4.3: Estimated dry weight of the different farming methods

(kg/ha)

Items	Traditional	SRI	SRI-GPM
Total biomass (dry) (kg / ha)	35,629	36,111	49,932
%	100	101	140
Inside: - Economic products (dry) (paddy + potatoes)	10,462 (paddy)	11,194 (paddy)	11,249 (paddy) và 4,626 (potatoes)
• Organic by-products (dry) (kg/ha)	25,167 (straw)	24,917 (straw)	34,058 (straw) and 6,939 (potato stems and leaves)
% by-products	100	99	135
Protein in by-products (kg/ha)	45.3	44.8	83.5

- **Weeds and pests**

According to the farmers' assessment of the development of weeds and rice pests has been changed remarkable in the different types of cultivation.

Weeds:

Conventional farming uses herbicide, therefore, the quantity of weeds were lessen both in density and species, especially the 2 cotyledons grass are killed by herbicides. However with Echinochloa crus-galli L., the most dangerous grasses affecting the yield of rice, there is no obvious difference.

Meanwhile the species and quantity of weeds at the branching stage of SRI cultivation is higher than that of conventional cultivation, but the level of weeds is below the level of harm. By the changes in weeding practices such as weeding by hand tools at early 10 days after transplanting, weeds have been killed since germination, at the same time weeding and stir the mud has created good and rich O_2 conditions for rice then grow stronger and be able to compete for nutrition and light with weeds.

The superiority of the SRI-GPM model is shown clearly in weed control method. By alternating between the aquatic crops (rice crops) and terrestrial crop (potato crop), thus destroying the weed seeds of the species such as *Echinochloa crus-galli L., Leptochloa chinensis L., Fimbristyis miliacea L., Enydra fluctuans lour L., Eclita alba L.. Grass species 2 cotyledons such as Sphaeranthus africanus L., Spilanthes paniculata wall L., Monochoria vaginnalis burm.F.…* are also significantly reduced. Farmers were concerned mostly about weeds, but this worry could be resolved if more potato crops are planted.

Golden snail:

This pest is a very harmful species that people are concerned about. There were significant differences in the number of golden snails among different farming methods. The advantage of minimising golden snail belongs to the SRI-GPM model. Farmers were almost no longer concerned about this pest in the Spring rice crop after planting potatoes. The cause of this difference is due to soil preparation and taking care of potatoes, golden snails from the summer rice crop have been almost killed.

Insects:

Among the insect species that harms rice in the Spring crop, *Nilaparvata lugens stal L*. is the agent that need to be concerned about. There are obvious differences of harmful insect among various practices of rice cultivation. Farming under SRI and especially SRI-GPM, the harmful effect of *Nilaparvata lugens stal L.* has remarkably decreased. By not using herbicides and reducing periodic spraying of pesticides have increased natural enemies (spiders, bees) then helped to kill the egg and the worms of *Nilaparvata lugens stal L.*, and reduce the *Nilaparvata lugens stal L.* density throughout the rice crop, it does not cause epidemics.

For other insect pests such as *Stenchaetothrips biformis bagnall L., Scirpophaga incertulas walker L., Medinalis guenee L*. there is no difference between the different ways of farming.

Diseases:

Yellow roots in Spring rice crop were not observed in the SRI-GPM model. Meanwhile, it is the main disease on some low-lying traditional fields. That was the result of early weeding and stirring the mud and the soil the structure changed as the soil more spongy, creating conditions for toxic gas to escape, less damage to the root system by adding one more potato crop plus.

Diseases such as *Rhizoctonia solani kuhn L.*. *Pirycularia oryzae cav L*. are also reduced significantly in the SRI-GPM model because rice fields are controlled ventilation and not abused in the use of inorganic fertilizers, especially nitrogen fertilizer.

In summary: SRI-GPM model with cultivation methods such as healthy transplanting, transplanting sparsely, weeding and stirring the mud rice growing strongly, has better competitiveness with weeds; suitable water management and the rotational pattern on paddy fields between aquatic plants (rice) and terrestrial plants (potatoes). Therefore, the rice has higher resistance and less pestilent including the frequency and extent of the impact.

Table 4.4: Situation of weeds and pests in Spring rice crop of 2018

(Farmers rated on a 1-5 score, the higher the score, the greater the impact)

Weeds, pests, insects and deaseses	**Traditional**	**SRI**	**SRI-GPM**
Weeds			
Echinochloa crus-galli L.	3.5	2.5	2.2
Fimbristyis miliacea L.	1.7	1.2	1.0
Enydra fluctuans lour L.	1.5	1.2	1.0
Eclita alba L.	1.4	1.1	1.1
Sphaeranthus africanus L.	1.4	1.3	1.3
Spilanthes paniculata wall L.	1.2	1.2	1.2
Commelina diffusa burm F.	1.2	1.2	1.1
Monochoria vaginnalis burm.F.	1.0	1.0	1.0
Pests			
Golden snail	2.5	1.5	1.4
Insects			
Stenchaetothrips biformis bagnall L.	1.5	1.0	1.0
Medinalis guenee L.	2.6	2.2	2.0
Scirpophaga incertulas walker L.	1.5	1.2	1.0
Nilaparvata lugens stal L.	3.1	1.9	1.7
Deaseses			
Yellow roots	1.8	1.3	1.0
Pirycularia oryzae cav L.	1.8	1.3	1.2
Rhizoctonia solani kuhn L.	3.8	1.6	1.3
Xanthomonas oryzae L.	1.6	1.1	1.1

- **Ecological changes in various rice practices**

The rotational pattern on paddy fields between aquatic plants (rice) and terrestrial plants (potatoes) has benefit to kill common weed seeds that reduce their impact on the spring season. Moreover, the SRI-GPM model plays an important role in contributing to the biodiversity, and higher efficiency compare to the traditional farming method

As the result of the project. the SRI-GPM model has increased the land use coefficient from 2 seasons to 3 seasons per year and increase the number of crops that do not belong to poaceae family (alternating a dry crop - potato). Additionally, the application of SRI-GPM no herbicides applied, thus enhancing the diversity of different grass species. The nutritional and light competition of weeds for rice has decreased because it has limited the dominance of some major weeds competing with rice such as *Echinochloa crus-galli L.. Leptochloa chinensis L.. Monochoria vaginnalis burm.F.*, etc.

On the other hand, the use of weeding and stirring the mud method instead of spraying herbicide will not affect the diversity of rice population. Besides, application of SRI-GPM, which combines potato crops, has increased the insect diversity, facilitated many natural enemies (such as bees, spiders…), and beneficial microorganisms for growing rice.

Table 4.5: Ecological changes in various rice practices

	Traditional	**SRI**	**SRI-GPM**
Land use coefficient	2 crops / year	2 crops / year	3 crops / year
Type of plant	1 type (rice – rice)	1 type (rice – rice)	2 type (rice - potatoes)
Weeding	The use of herbicides reduce most of grass species	Yes. without negative effect to rice causing weeded twice in the first 20 days and no herbicide applied	Reduce various of weeds (Echinochloa crus-galli L...) by growing potatoes. Do not use herbicides and weeding in an early stage to limiting the effect on rice
Pest	Susceptible to pests and diseases due to water retention and thicken planting	Reduce the number of pesticides spraying. pest and disease severity as a result of transplanting sparsely, keep the water interspersed. balanced fertilizer	Low pests and disease severity caused by transplanting sparsely, keep the water interspersed. balanced fertilizer… and there is a dry crop interspersed
Natural enemies	Reduce the natural enemies in the soil because of water retention and overuse of pesticides	Increase the number of natural enemies of rice pests	Increasing both species and number of natural enemies of rice and potato

4.2.3 Changing people's awareness on environmental protection and climate change

- **Change in farmers' use of straws**

Straws have proven its potential in various forms such as for sale, organic fertilizer, fungus cultivation, foods for cattle, etc. However, there were a number of people who are wasting this valuable material resource.

According to Table 4.6. before the implementation of the project, farmers were tend to abandon straw at the field (20.7%), or drying to make food for cattle (22.2%), instead of collecting to take advantage of straw 57.1% of people choose to burn it. However, after the project applied, they have changed their mind to utilize straw rather than wasting it. The most visible change is that 77.8% of households choose collecting straw to incubate for potatoes, not throwing away straw at the field or burning.

The change in awareness of farmer on using straw has not only economically significant more than that it plays important implications for environmental protection and contributes to limiting climate change.

Table 4.6: The use of rice straw in the season 2017 of farmers before and after the project

% households

Method	Before the project	After the project	(+/-)
Leave at the field	20.7	0.0	-20.7
Burning	57.1	0.0	-57.1
Drying to make food for buffaloes and cows and lining cattle cage	22.2	22.2	0.0
Gathering to incubate for potatoes	0.0	77.8	+ 77.8

- **Changes in the use of manure**

At the project applied area, people have three ways to use manure including making biogas, apply as fresh fertilizer to rice and incubation then use as fertilizer for the rice. At the end of the project, only the manure used as biogas was unchanged, with the percentage of households before and after the project accounting for 7.7%.

The implementation of the project has had an impact on people's awareness in changing manure use in the other two ways, it can be seen that most people tend to incubation then use as fertilizer for the rice instead of using fresh manure fertilizer for rice. The result has described in Table 4.7. The manure incubation and then use as fertilizer for the rice increased 17.1% (before the project this number was only about 51.3%, but after the project, it increased to 68.4%). That trend led to a shift in the use of fresh manure directly to paddy field because after the project the number of people using this method has dropped by 23.5% (according to our research, people have chosen to use fresh manure for rice 41% before and at the end of the project the property of farmer using

this method was reduce dramatically to 17.5%). The fresh manure directly use as fertilizer contained various microorganisms that could pollute the environment and directly affect human health.

The application of the project has a positive change and necessary impact on raising people's awareness of the use of manure. contributing to protecting the environment and human health.

Table 4.7: Changes in manure use before and after the project

% households

Method	Before the project	After the project	(+/-)
Making bioga	7.7	7.7	0.0
Use as fresh fertilizer for rice	41.0	17.5	-23.5
Use as compost fertilizer for rice	51.3	68.4	+17.1

- **Changes in the use of pesticides and fertilizers**

The application of SRI-GPM model has reduced the use of pesticides in paddy field, before the project, people were overuse of pesticides, with 44% spraying 3 times and 37.7% more than three times. The advantage of this project is that after the project, the pesticide use was significantly decreased, most of the people only spray pesticide twice (up to 55%), especially, no household sprayed pesticide three times or even spray more than 3 times.

Table 4.8: Number of pesticides sprayed by farmers in spring crop in 2018

% households

Times of spraying	0	1 time	2 times	3 times	> 3 times
Before the project	0.0	0.0	5.4	44.0	37.7
After the project	7.6	37.4	55.0	0.0	0.0
(+/-)	+ 7.6	+ 37.4	49.6	- 44.0	- 37.7

In parallel with the spraying of pesticides, the pesticide packaging treatment problem also take concern by scientists and local authorities because the farmer does not have the habit of handling pesticide packaging. Moreover, a number of people due to lack of environmental knowledge they through pesticides packaging directly into the environment. However, a positive change was shown after the implementation of the project. The percentage of farmer throwing pesticide packaging in the trash bins was increased 62.3% (previously only 22.3% of households threw the packaging of pesticide in the trash bins, but after the project has 80.3% of households change that.

Table 4.9: Pesticide packaging treatment

% households

	Put in the trash bin
Before the project	22.3
After the project	80.3
(+/-)	+ 62.3

One of the other aspects of rice cultivation that affect the environment is the use of fertilizers including manure and chemical fertilizers. Although for agricultural production in general and rice cultivation in particular, fertilizer is essential and important as it significantly contributes to increased productivity and quality. However, the excessive use of these fertilizers will cause excess fertilization, and the nutrients will soak up to the soil and the aquifers.

Table 4.10: The use of fertilizer in spring rice crop in 2018

	Manure (tons/ha)	**Chemical fertilizer (kg/ha)**		
		Nitrogen	**Phosphate**	**Kali**
Traditional	7.7	147.3	339.2	111.2
SRI-GPM	4.2	55.6	211.3	83.4
(+/-)	-3.5	-92.3	-127.9	-27.8

Once again, the application of the SRI-GPM model has minimized the impact on the environment by changing the fertilizer using method. The results of Table 4.10 show that the amount of manure and chemical fertilizer used in applying the SRI-GPM model is significantly lower than traditional rice cultivation method, it reduces 3.5 tons/ha manure, and chemical fertilizers including nitrogenous fertilizer, phosphate fertilizer, potassium fertilizer decreased 92.3 kg/ha, 127.9 kg/ha, 27.8kg/ha, respectively.

Based on the results after the project completion, most of the farmer has enhanced awareness and change their actions in the use of manure, pesticides, handle pesticide packaging, and use fertilizer towards ensuring stable rice yields and minimize the harmful effects of traditional rice cultivation on the environment. This has a great contribution on building an ecological agriculture, protect environment and human health.

Causes of environmental pollution

Environmental problems caused by waste have existed not only in large cities but also in rural areas. household waste is mainly classified as organic and inorganic waste. At the areas where the SRI-GPM model is applied, organic waste treatment includes food for cattle, throwing out the garden or mixing with inorganic waste brought to the public garbage pit, and use as composting materials. For inorganic waste treatment the residents tend to burn, collecting for sale, throwing in public trash or even directly to the environment.

After the SRI-GPM model applied. people have changed their waste treatment method, they use organic waste as composting materials (21.5%) higher compared to traditional, they have never interested in utilizing it. However, most people still use organic waste for cattle feed (83%), and the

best sign is that only a small amount of the people threw out the garden or mixed with inorganic waste then brought to the public garbage pit (6.5%).

Similarly to organic waste. SRI-GPM model had a positive effect on farmers' waste treatment methods. Specifically, there were no household throw away organic waste or burn it, 52.5% of households dispose of waste into the public trash and 47.5% of households collected for sale, which was risen up by 30% compared to traditional method.

Table 4.11: Farmer's practice in waste treatment

% households

Organic waste	Traditional	SRI-GPM	(+/-)
- Making food for cattle	83.0	83.0	0.0
- Throwing out the garden or mixing with inorganic waste brought to the public garbage	27.0	6.5	-21.5
- Use as composting materials	0.0	21.5	+21.5
Inorganic waste			
- Throwing away or burn	69.6	0.0	-69.6
- Throwing in public trash	14.6	52.5	+37.9
- Collecting for sale	15.8	47.5	+31.7

The application of the SRI-GPM model, people have gained a better understanding of waste treatment. For example, instead of throwing or burning straw, they have used straw (organic waste) as a raw material for agricultural production. This was a proof that they have recognized the importance of waste treatment, thus contributing to environmental protection and mitigating environmental pollutants factor.

- **Changes in farmers' awareness on the environment and climate change**

Currently, environmental pollution, greenhouse gas emissions such as CH_4, CO_2, N_2O and climate change are priority issues in the world. With a desire to minimizing the impact of environmental pollution and limiting greenhouse gas emissions, it is important to change farmers' awareness on the environment and climate change.

After the SRI-GPM model applied, people were more concern about climate change, it has increased 54.4% compared to the previous and the attention of farmer to the environmental pollution also has a positive change, it increased by 48.2% compared to traditional. It is notable that in the absence of the SRI-GPM model, no farmer has knowledge on greenhouse gas emissions. However, after the model applied, 16.2% of people have an understanding of greenhouse gas emissions.

It can be argued that the application of the SRI-GPM model has not only changed the rice farming method but also changes the farmer awareness of the environment and climate change. This

could be an important momentum for the development of a larger-scale SRI-GPM model in the future.

Table 4.12: Changes in farmers' awareness on the environment and climate change

% households

Farmers' concerns	Traditional	SRI-GPM	(+/-)
- Paying attention to environmental pollution	32.2	80.4	+48.2
- Concerned about climate change	7.1	61.6	+54.5
-Understanding of greenhouse gas emissions	0.0	16.2	+16.2

4.3 Social impact

- **Establish and motivate farmers to work in groups and establish cooperatives**

Applying the SRI-GPM model has encouraged farmer participation in group activities through FFS classes. As a result, the activities of the farmer groups have been intensified, such as group-based seedling activity has saved the seed and contribute to better quality seedlings; mutual support in timely transplantation; sharing experiences. This brings in more income and new products in the winter crop (from potato crop), enhancing the farmers to change the perception from individual farming to group work. Working together in three crop times helps them to understand each other better in co-production and has confidence in the building of effective agricultural cooperatives in the future. Specifically, a cooperative agricultural service was established (Agricultural Cooperative No.1).

- **Social capital**

In the context of a shift from agriculture to industry, there has been a great shift in labor from rural to urban areas, labor from agriculture to industry, leading to a shortage of labor in agriculture, mostly elderly workers. Therefore, many families cannot not plant, transplant in time. However, with participation in the farmer model. better support for families with shortage of labor.

Production of self-sufficient rice monoculture to commodity production has created demand for connections between farmers together from the service to sell the output and cooperation with businesses, thereby increasing social capital, strong community structure.

4.4 Linkages and policies

The SRI-GPM model has provided opportunities for the development of linkages and partnerships between the four sides: Farmers – Private sector - Scientists - Government.

Table 4.13: Changes of cooperation through 3 crops of model implementation

In the rice crop of 2017	In the Potatoe crop (Winter crop. 2017-2018)	In the rice crop (Spring. 2018)
Participating agents: - Farmers - Scientist - Governing bodies	Participating agents: - Farmers - Governing bodies - Scientist - Professionals	Participating agents: - Farmers - Governing bodies - Scientist - Professionals - Enterprises
Intervention: - SRI training - Guiding the establishment of farmer group - FFS class - Field seminars	Intervention: - Training to plant potatoes - Guidelines for building a group of potato producers - Inviting businesses to discuss production cooperation (Tan Nong Company) - Field seminars - Involve professional agencies to join (Provincial Extension Center)	Intervention: - SRI training - Aiming at business cooperation in the value chain - Encourage the application of organic fertilizer in rice production (Que Lam fertilizer Company) - Field seminars evaluation - Guide to business in groups
Results: - Awareness of rice production under SRI - Awareness of group formation to cooperate - There is no cooperative enterprise - Some households are aware of rice straw collection for potato crop - The government has participated but does not direct drastically	Results: - Growing potatoes for winter crop - Consciously use rice straw for growing potatoes (some households do not have straws) - There is no cooperation with enterprise yet - Awareness about groups is still limited (some individuals do not like to work with enterprise that affect the whole group) - Have the participation of state professional agencies (Agricultural Extension Center support for seeds. fertilizers) - There is more direct direction from the local government (Secretary of the commune attended the meeting and directed specifically) - By the spring of 2018, the majority agreed to plating in groups	Results: - Most households apply SRI - Planting in groups - Cooperative group awareness is still limited, using planting of the group for transplanting in other fields - Commune authorities supported and directed drastically - Forming consciousness to planting by the group, build planting groups for the spring of 2018. - Signed contract of the seed production with the enterprise of the Summer 2018 (Thai Nguyen Seed Center) - The provincial government supports and directing support the use of Que Lam fertilizers (Provincial Department of Agriculture and Rural Development) - Plans to cooperate with enterprise in producing potato crop in winter 2018

The conversion from rice monoculture to SRI-GPM model has created opportunities and needs for cooperation with enterprises, and implement the policy of linkage of 4 sides. With the support of scientists and follow the process of SRI rice and potatoes according to GPM improve the quantity and quality of agricultural products to meet the requirements of the product through which attracted private sector to participate in.

Table 4.14: Positive effects of change before and after implementation of the model

Changes	Before	After
Land use index	2 crops/year	3 crops/year
crops	1 crop (rice)	2 crops (rice and potatoes)
Rice cultivation techniques	Conventional/Traditional method	SRI
Potato cultivation technique	Traditional method	Intensified, GPM-based and increase usage of rice straw
Ecosystem	Rice monoculture contains risks of many pests, soil nutrient degradation	Rotation of rice – potatoes, enhancement of soil nutrients through technical measures, increase use of organic fertilizer and rice straws
Pests and diseases	Use of herbicides, golden snails, spray 3-4 times/crop and disease occurrence on a large scale	Decrease risks of pests, not use herbicides and pesticide to control golden snails, the number of spraying decreases, only once or does not spray
Productivity. economic efficiency	Low productivity, labor efficiency and investment	Increased productivity and income, labor efficiency and investment capital doubled
Organization of production	Farmer working in individual, using many seeds for seedlings, use a lot of plant protection chemicals, not timely due to lack of labor, lack of sharing and mutual support	Farmer working in group, using one seed, limiting the use of plant protection medicine, jointly providing mutual support, establishing cooperatives
Linkage with private sector	No linkages or loosen linkages	Have commitment and contract (Que Lam Company, Thai Nguyen Seed Center) Farmers participate in the production chain, the company supply seeds, fertilizeers and buying products
Government involvement	Support of the state in the form of material support baed on area of planting, low efficiency.	Support of the state has changed toward eco-agriculture-oriented, encourage the development of organic products, promote

	Government professional agencies without highclear responsibility	cooperation with businesses, encourage farmers to work in groups and cooperatives

Specifically, after deploying the SRI-GPM model, Thai Nguyen Seed Center has signed a cooperation contract with farmer's group to invest 15 ha of Bao Thai rice with SRI application in summer rice crop of 2018; Que Lam Company has invested in organic rice production with an area of 50 ha in both Spring and Summer rice crops of 2018; Thien Nong Phat Company committed to invest in producing 20 ha of winter potato in 2018 with group of farmers.

Through this, the involvement of specialized agencies such as plant protection and extension organizations are more frequent. The model also receives provincial and district support for organic production such as seed support fertilizer for area of commodity production.

4.5 Difficulties and prospectives of SRI - GPM and the conversion of rice cultivation towards ecological agriculture

4.5.1 Difficulties

- **Natural conditions and facilities**

Application of SRI-GPM requires complete irrigation system. However, in the local water drainage system is not guaranteed to affect crop and production management.

- **Labor and price of agricultural products**

The orientation of industrialization has great influence on rural labor. Most of the local farmers are middle-aged or elderly, causing labor shortages. Together with the low price of agricultural products, people who are less interested in investment and production that have influenced the results of the model

- **Farmer's thoughts and habits**

Ideology and old-fashioned farming practice is the biggest difficulty for development of the model. The farmer's habit does not follow the SRI technical process, use many seeds in the seedling process, overuse of chemical fertilizers and pesticides, individual work, do not do collective, transplanted with many seedlings/hill and water retention...

For potatoes, instead of planting two rows/beds as guided, they plant one row/bed, thus have not utilized the land area, low potato yield.

Most of the farmersare used to work individually concerned about the immediate profits, less attention to long-term benefits, not keeping commitments with business sector. These lead to no one take responsibility of seed quality, the products; therefore, has no gurananty to be sold or sold with low price, resulting in low income for farmers. This is a profound lesson that farmers have grasped in complying with the process and committed to cooperating with the enterprises.

Box 4.1: Story in Vien village. Tan Duc commune. Phu Binh. Thai Nguyen

The potato Winter crop in 2017, although the project has been linked to Tan Nong Company to cooperate with farmers to grow potatoes with the potato variety is Atlantic (white potato) for processing potato chips. The company provided staff with ICC staff to train farmers and pledged to cooperate to supply inputs (fertilizer, potato seeds) and commitment to buy products at 7,000 VND/kg. However, when the provincial extension centers have policies to support a portion of potato seeds (yellow potato), farmers were cared of the benefit of this support, they refused to cooperate with the company to receive suppoort of the seeds from the Agricultural Extension Center.

Although the local leaders. technical staff of ICC, staff of Tan Nong company thoroughly explain the benefits, risks, but just because mercantile have little seed support, plus with the sales habits in the local market of yellow potato are easier to sell, farmers breaking the contract with the company, causing the company to miss the plan and to withdraw from the locality.

And the result is poor quality potato (infected with virus) no one is responsible. Lack of supervision of process implementation, low productivity (only over 600 kg/sao compared to the average yield of winter crop is 1,000 – 1,200 kg/sao; small potato, quality is not guaranteed so it is difficult to consume and the price is much lower than the price charged to the company, the people have to go to market selling.

This is a great and deeply failed lesson. But it was this failure that made people change their minds, they are committed to working with the Seed Center to produce rice seeds for the 2018 season and cooperate with Thien Loc Company to produce 2018 winter potatoes. It can be concluded that, with farmers, less successful lessons change their perception and actions by failing.

4.5.2 Opportunities and prospects for development and model replication

Since the SRI-GPM model was implemented in the farmer's fields with the practical conditions of the farmers and was also deployed the first time, the model encountered difficulties such as: farmers' not following the potatoes and rice cultivation technique procedure, and the potatoes variety did not guarantee quality; which have led to a 7% increase in SRI yield for rice while the potato yield was only 18 tons/ha (66% of the annual average). Meanwhile, many results of research and application of SRI in Thai Nguyen and Vietnam showed that: rice yield increased from 13-29%; yield of potato was from 25 to 30 tons/ha. This has affected the value of labor and capital investment efficiency (see Table).

We did an estimatation:

- *If applying most of SRI principles and GPM techniques*

Assuming to conduct better the SRI principles, the yield of rice should only increase by 15% and the potatos variety has good quality compliance with the technical procedure, the yield of potatoes reaching 25 tons/ha would make an increase in income from 4.9 million VND/ha, 215.5

thousand VND/1 labor and 1.09 VND/1 VND for the investment capital in traditional cultivation of monoculture of rice into 128.7 million VND/ 1 ha, 340.7 thousand VND/1 labor and 2.6 VND/1 VND for the investment capital in SRI-GPM cultivation (Table 4.15).

Table 4.15: If applying most of SRI principles and GPM techniques

Unit : thousand VND

Content	Convention	SRI	SRI-GPM
Revenue	73,235	88,666	268,513
- Rice	73,235	88,666	93,513
- Potatoes			175.000
%	*100.0*	*121.1*	*366.6*
Expenditure	68,331	65,190	127,260
- Facilities	52,779	49,639	80,607
- Labor	15,551	15,551	46,654
%	*100.0*	*95.4*	*186.2*
Revenue - Expenditure	4.904	23.476	141.253
%	*100*	*479*	*2,881*
Efficiency of labor investment (thousand VND/man-day)	210.5	401.5	644.4
Efficiency capital investment (VND/VND)	1.09	1.47	2.75

- *If applying most of SRI principles and GPM techniques & making contract with enterprises*

If applying most of the SRI principles and applying correctly GPM technology and cooperating with enterprises, there will have an increase of yield of rice and potatoes, and also an increase in product prices based on contracts (enterprises pay 7,000 VND/1 kg of potatoes, compared to the average price of 6.500 VND/1 kg, the price of rice increased by 10% as agreed by the Seed Center) will increase the income to 141.2 million VND/ha, 644.2 thousand VND/1 labor and 2.75 VND/1 kg for the investment capital in cultivation in SRI-GPM (Table 4.16).

As discussed above, farmers' perceptions have changed. The lessons of failure in cooperation have made farmers firmly committed to the enterprises. Specifically, companies such as Que Lam, Thai Nguyen Seed Center and Thien Nong Phat have committed to invest and cooperate with local people in production according to the rice-potato model with more largely expanded scale.

On the other hand, the commune authorities are encouraging the conversion of production from monoculture and single cropping to the restructuring of the crop towards the production of commodities and organic products and formation of production groups and agricultural service cooperatives. As such it has established The Agricultural and Service Cooperative No.1 in Tan Duc commune.

Table 4.16: If applying most of SRI principles and GPM techniques & making contract with enterprises

Unit : thousand VND

Content	Convention	SRI	SRI-GPM
Revenue	73,235	88,666	268,513
- Rice	73,235	88,666	93,513
- Potatoes			175,000
%	*100.0*	*121.1*	*366.6*
Expenditure	68,331	65,190	127,260
- Facilities	52,779	49,639	80,607
- Labor	15,551	15,551	46,654
%	*100.0*	*95.4*	*186.2*
Revenue - Expenditure	4.904	23.476	141.253
%	*100*	*479*	*2,881*
Efficiency of labor investment (thousand VND/man-day)	210.5	401.5	644.4
Efficiency capital investment (VND/VND)	1.09	1.47	2.75

4.6 Suggestion to popularize the model and change rice cultivation towards sustainable ecological agriculture

- **The techniques to increase the added-value. ensuring the economic target and a stable. sustainable production**
  - Production planning: It is necessary to plan the production area of rice and potato rotary.
  - Develop a system of facilities especially irrigation and drainage systems, field - inland paths for goods production and mechanization.
  - Promote mechanization in production from producing to harvesting processing and preservation.
- **Organizing of production**
  - Organize production in groups with strict supervision to ensure quality applying the right process for commodities such as SRI rice and GPM potato. The use of straw in potato cultivation should be encouraged to limit the incineration of straw.
  - Enhance the cooperation with companies to have the farmers join deeply into the value chain to increase income.
- **Cooperation to promote transition of conventional agriculture towards agroecology.**
  - Build up and replicate the model with potatoes or other crops so that people can see the advantages of ecological agriculture, and therefore, change their perceptions then actions.
  - Strengthen the role of the government and adopt supporting policies such as direct and targeted support focus on changing the structure of crops towards the direction of ecological agriculture.

- Support and establish the development of production groups and cooperatives.
- Encourage companies to cooperate with local people to produce sustainable organic products to protect the environment.

5. Conclusion

With the aim of changing the farming practices on the rice paddies of Phu Binh, Thai Nguyen from monoculture of rice with traditional practices to ecological farming. The SRI-GPM with its advantages has exploited the potential advantages of the locality, a purely agricultural place that mainly produces rice. SRI-GPM has changed the farming practice of rice monoculture to rotational crops with plants in the direction of commodity production, thereby increase productivity, labor efficiency and investment capital, increasing farmers' income

Applying SRI-GPM has created an ecological balance, reducing greenhouse gas emissions, helping people raise awareness about environmental protection and responding to climate change.

SRI-GPM has been developed on the farmers' fields with the real conditions of the farmers; organized, monitored and evaluated by the farmers so that it has increased the awareness of active participation, social relationship in the rural community. SRI-GPM has created a cooperative connection between farmers, companies, scientists and government. creating opportunities for farmers to participate in the value chain to increase high added value and stable for local people.

By ensuring the three targets: Economy - Society - Environment, SRI-GPM is a practical example that forms the basis for the development of new policies that promote the conversion of rice farming towards sustainable agriculture. guaranteed the sustainable development of agriculture and rural area.

REFERENCES

In Vietnamese

Bộ nông nghiệp và phát triển nông thôn (2007). Quyết định số 3062/QĐ-BNN-KHCN về việc công nhận "Ứng dụng hệ thống thâm canh tổng hợp trong sản xuất lúa ở một số tỉnh phía Bắc" là tiến bộ kỹ thuật

Bộ nông nghiệp và phát triển nông thôn (2012). Quyết định số 2752/QĐ-BNN về việc chứng nhận sản phẩm SRI đạt giải thưởng Bông lúa vàng Việt Nam lần thứ nhất

Bộ nông nghiệp và phát triển nông thôn (2013). Quyết định số 204/QD-TT-CLT về việc công nhận "Quy trình kỹ thuật trồng khoai tây bằng phương pháp làm đất tối thiểu có phủ rơm rạ tại các tỉnh phía Bắc" là tiến bộ kỹ thuật

Bộ tài nguyên và môi trường (2015). Báo cáo kỹ thuật "Đóng góp dự kiến do quốc gia tự quyết định của Việt Nam"

Dương Trung Kiên (2012). Thái Nguyên: Hiệu quả mô hình trồng khoa tây theo phương pháp làm đất tối thiểu https://nonghoc.com/show-article/69260/thai-nguyen-hieu-qua-mo-hinh-trong-khoai-tay-theo-phuong-phap-lam-dat-toi-thieu.aspx?AspxAutoDetectCookieSupport=1(truy cập ngày 13/10/2018)

Đặng Văn Bường (2013). Kỹ thuật SRI cho thu lợi gấp đôi canh tác lúa truyền thống http://www.nhandan.com.vn/kinhte/item/20184002-.html(truy cập ngày 12/10/2018)

Hoàng Văn Phụ (2005). *Kết quả nghiên cứu kỹ thuật thâm canh lúa SRI (System of Rice Intensification) vụ xuân 2005 tại Thái Nguyên*. Tạp chí Khoa học & Công nghệ. Đại học Thái Nguyên. 15-19. Số 35. 2005.

Hoàng Văn Phụ (2010). Nghiên cứu khả năng áp dụng Hệ thống thâm canh lúa cải tiến (SRI) cho vùng đất không chủ động nước tại Thái Nguyên. Tạp chí Khoa học & Công nghệ. Đại học Thái Nguyên. 143-146. Tập 75. Số 13. 2010.

Hoàng Văn Phụ (2012). Nghiên cứu một số biện pháp kỹ thuật trong hệ thống thâm canh lúa cải tiến (SRI) trên đất không chủ động nước tại huyện Võ Nhai. Thái Nguyên". Tạp chí khoa học & kỹ thuật. Bộ NN&PTNN. 20-26. Số 10. 2012.

Hoàng Văn Phụ & Vũ Trí Đồng (2006). *Triển vọng của kỹ thuật thâm canh lúa SRI ((System of Rice Intensification) trong canh tác lúa vùng Trung du Bắc bộ*. Hội nghị khoa học công nghệ toàn quốc: Nghiên cứu KH&CGCN phục vụ phát triển nông thôn miền núi phía Bắc giai đoạn 2000-2005. 167-174. Đặc san. 2006

Hoàng Văn Phụ, Nguyễn Ngọc Quỳnh, & Nguyễn Trọng Hưng (2016). Hệ thống canh tác lúa cải tiến (SRI): cơ sở khoa học và tiếp cận nông nghiệp sinh thái http://sri.ciifad.cornell.edu/countries/vietnam/vn_HVPhu_SRI_scientific_bases_and_ecoagriculture_approach0916.pdf. (truy cập ngày 12/10/2018)

Kim Uyên (2013). 20 tỉnh đã tham gia trồng khoai tây bằng phương pháp làm đất tối thiểu. Tạp chí Dân Việt http://danviet.vn/nong-thon-moi/20-tinh-da-tham-gia-117692.html. (truy cập ngày 12/10/2018)

Lê Văn Khoa, Nguyễn Đức Lương, & Nguyễn Thế Truyền. (1999). Nông nghiệp & môi trường. Nhà xuất bản Giáo dục.

Minh Đạt (2015). Mô hình ruộng lúa – bờ hoa: nhiều lợi ích. http://www.baobaclieu.vn/nong-nghiep-nong-dan-nong-thon/mo-hinh-ruong-lua-bo-hoa-nhieu-loi-ich-32533.html.(truy cập ngày 12/10/2018)

Ngô Tiến Dũng & Hoàng Văn Phụ (2016). Hành trình 10 năm SRI tại Việt Nam. http://sri.ciifad.cornell.edu/countries/vietnam/SRI_in_Vietnam_A_decade_journey_0916.pdf. (truy cập ngày 12/10/2018).

Nguyễn Hình (2012). Hiệu quả từ mô hình trồng khoai tây bằng phương pháp làm đất tối thiểu http://baothaibinh.com.vn/tin-tuc/49/7745/hieu-qua-tu-mo-hinh-trong-khoai-tay-bang-phuong-phap-lam-dat-toi-thieu. (truy cập ngày 13/10/2018)

Nguyễn Thị Thu Hà (2013). Phát triển nông nghiệp sinh thái. hướng đi mới đối với sản xuất nông nghiệp. *Tạp chí khoa học và công nghệ*.112(12)/2: 103 – 108

Phạm Thị Sến, Đỗ Trọng Hiểu, Lưu Ngọc Quyển. Lê Việt Dũng, Nguyễn Thị Thanh Hải, Nguyễn Văn Chinh, Lê Khải Hoàn, Hà Quang Thưởng, Cao Anh Đương, Lê Thị Hoa Sen, Hồ Hữu Cường, Mai Văn Trịnh, Trần Thế Tường, Chế Thị Đa, Bùi Tân Yên, & Ngô Đức Minh (2017). CSA: Thực hành nông nghiệp thông minh với khí hậu ở Việt Nam. CGIAR research programe on climate change. Agriculture and food security (CCAFS). Wageningen. The Netherlands

Phạm Thị Thu & Hoàng Văn Phụ (2014). Kết quả nghiên cứu khả năng áp dụng hệ thống canh tác lúa cải tiến SRI (System of Rice Intensification) cho vùng đất không chủ động nước tại Bắc kạn". Đăng tại Tạp chí Khoa học & Công nghệ. Đại học Thái Nguyên. 35-40. Tập 119. Số 05. 2014

In Enlish

Cao Linkui & Zhang Hanlin (2016). Study of non-point-source pollution control in integrated rice-frog agroecosystems. In Luo Shiming. Stephen Gliessman (Eds). *Agroecology in China*. CRC Press. 139–160

Castella J.C. & Kibler J.F. (2015). Towards an agroecological transition in Southeast Asia: Cultivating diversity and developing synergies. GRET. Vientiane. Lao PDR

Cosslett T.L. & Cosslett P.D. (2014). Water Resources and Food Security in the Vietnam Mekong Delta. *Natural Resource Management and Policy*. 44

FAO (2013). Pursuing rice agroecology: The APCO model – One of 52 profiles on Agroecology: Pursuing rice agroecology. http://www.fao.org/3/a-bl920e.pdf. (truy cập ngày 20/10/2018)

FAO (2015a). Stories from the feld: Philippines. Save and Grow. Bangkok. Food and Agriculture Organization of the United Nations

FAO (2015b). Stories from the feld: Viet Nam. Save and Grow. Bangkok. Food and Agriculture Organization of the United Nations

FAO (2017). Report of the international symposium on agroecology in China. http://www.fao.org/3/a-i6884e.pdf. (truy cập ngày 20/10/2018)

FAO (2018a). Family Farming Knowledge Platform: Agroecology & Family Farming. http://www.fao.org/family-farming/themes/agroecology/en/.(truy cập ngày 24/10/2018)

FAO (2018b). Agroecological rice production in China: Restoring biological interactions. http://www.fao.org/3/ca0100en/CA0100EN.pdf. (truy cập ngày 20/10/2018)

Im S. (2008). The progress of System of Rice Intensifcation in Cambodia. Annual Conference Report 2006. DAALI and CEDAC. Phnom Penh

Le Trong Hai (2012). Support for the Association of Southeast Asian Nations Plus Three Integrated Food Security Framework (Financed by the Japan Fund for Poverty Reduction): The Rice Situation in Viet Nam. Report for The Asian Development Bank. http://www.adb.org/sites/default/files/project-document/73083/43430-012-reg-tacr-04.pdf. (truy cập ngày 18/10/2018)

Liang. K.. Zhang. J. E.. Fang. L.. Zhao. B.. Luo. M.. Parajuli. P.. & Ouyang. Y. (2013). The biological control of Pomacea canaliculata population by rice-duck mutualism in paddy fields. *Biocontrol science and technology*. 23(6). 674-690

Nong Yun & Meng Hongxiang (2010). Good experience from intercropping of lotus with rice. *Nanning Daily*. 12. 1

Ngo Tien Dung (2010). SRI Viet Nam: The updated report on the Development of System of Rice Intensification (SRI) in Vietnam to Oxfam America. 2010.

Ortiz-Canãvate. J. & Hernanz. J. L. (1999). Energy for Biological Systems. In: Osamu Kitani (ed.). CIGR Handbook of Agricultural Engineering. Volume 5 - Energy and Biomass Engineering. ASAE Publication. pp 13-23.

Phu Hoang Van, Dang Hoang Ha, Avishek Datta & Nguyen Ngoc Quynh (2015). "Performance of rice in rainfed land under the System of Rice Intensification (SRI) water management and spacing practices". proceeding of the international workshop. on livelihood development and sustainable emvironmental managementin the context of climate change (LDEM). Thainguyen 13-15.11.2015. Agriculture publishing house. Hanoi. 582-592.

Stassart P. M., Baret P., Grégoire J.-C., Hance T., Mormont M., Reheul D., Stilmant D., Vanloqueren G. and Visser M. (2012). L'agroécologie : trajectoire et potentiel pour une transition vers des systèmes alimentaires durables. In Vandam D., Streith M., Nizet J. and Stassart P.M., eds. Agroécologie, entre pratiques et sciences sociales. Educagri éditions, Dijon, 25-51. http://hdl.handle.net/2268/130063

Soetrino I.C.K. (2015). Availability and use of aquatic biodiversity in rice feld and ecosystem: Case study in West Java. Cited by FAO (2016). Agroecology for food security and nutrition: Proceeding of the international symposium on agroecology in China

Tuyet Thi Anh Truong, John Fry, Phu Hoang Van & Hoang Huy Ha (2017). *Compartive energy and economic analysis of conventional and System of ice Intensification (SRI) method of Rice Production in Thai Nguyen province. Vietnam*. Paddy and Water Environment. ISN1611-240. DOI 10.1007/s10333-017-0603-1

Uphoff. N.. Anas. I.. Rupela. O. P.. Thakur. A. K.. & Thyagarajan. T. M. (2009). Learning about positive plant-microbial interactions from the system of rice intensification (SRI). *Aspect Appl Biol*. 98. 29-54

Wang Jing & Yang Haiquan (2015). The consumers know very detail information about rice produced in rice-duck field. *Farmers' Daily*. 8

Wu Yukun (2015). Farmers in Suibin County are happy to get harvest from rice-frog system in early fall. *Hegang Daily*. 1

Yu Shengmiao (2008). The impact of duck density in rice-duck system on rice yield and economic return. *Zhejiang Agricultural Science*. 1. 68–71

Zhang. J. E.. Xu. R.. Chen. X.. & Quan. G. (2009b). Effects of duck activities on a weed community under a transplanted rice–duck farming system in southern China. *Weed biology and management*. 9(3). 250-257

Zhang. J.. Zhao. B.. Chen. X.. & Luo. S. (2009a). Insect damage reduction while maintaining rice yield in duck-rice farming compared with mono rice farming. *Journal of sustainable agriculture*. 33(8). 801-809