Sustainable Agriculture with Organic Fertilizer

Preface

Sustainable agriculture is recognized as a farming system producing foods and fiber materials on a sustainable basis harmonizing agricultural production with the natural environment. Recently, organic fertilizer is more apt to be a focus, as it may contribute to the reduction of the use of chemical fertilizer, which has been causing environmental problems such as eutrophication in water system or land degradation. Additionally, chemical fertilizer and chemical pesticide applied in agricultural fields affect food safety and human health.

The compost made from crop residues or the fallen leaves of trees utilizing the decomposition ability of soil microbes or animals can maintain land productivity continuously. That is the way of substance circulation through agricultural production.

However, there is a tendency for more chemical fertilizer and chemical pesticide to be applied in farmland for increasing agricultural productivity in the short run. This tendency is obvious not only in the developed countries but also in the developing countries in Southeast Asia, and has been causing serious environmental problems.

This guidebook has been prepared for the purposes of advancing compost use and decreasing the amounts of chemical fertilizer and other chemicals in farmland. We are happy if many people realize the importance of sustainable agriculture with organic fertilizer through this guidebook.

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1. Soil supporting our life

Soil looks like the weathered materials of rocks covering the earth's surface. However, focusing on the soil inside, the complicated mechanism for supporting life on earth can be understood. The soil has been supporting human and living things in several ways:

a. Soil is the habitat of humans, animals, plants and microorganisms.

b. Soil is functioning as a medium of substance circulation. When living things die, their bodies turn into soil as inorganic substances through the decomposition mechanism of soil microbes or animals. This soil function provides the essential substance circulation for food production.

c. Soil is a material for construction and pottery. Therefore, there is no life that can survive on earth without any relation to the soil. To understand the potential for feeding the world on a sustainable basis, we need to know how the soil forms, how it degrades, and what we can do to conserve and rebuild good soil for agriculture.

Agriculture also receives benefits from the soil and is performing food production in substance circulation of inorganic and organic matter. Faster even than we think, the soil is changing continuously. Big changes occur in the soil of farmland by farming systems, especially by fertilization.

2. Soil conserving environment

The soil consists of 3 phases as solid, water and air. Water and air are filling soil pore. Aggregation contributes to increase soil pores as shown in **Fig. 2-1**. The variety of soil structures affects the type and properties of the soil. Also, these factors influence its capacity for conserving environment. The function of environmental conservation is explained as shown in **Fig. 2-2**.

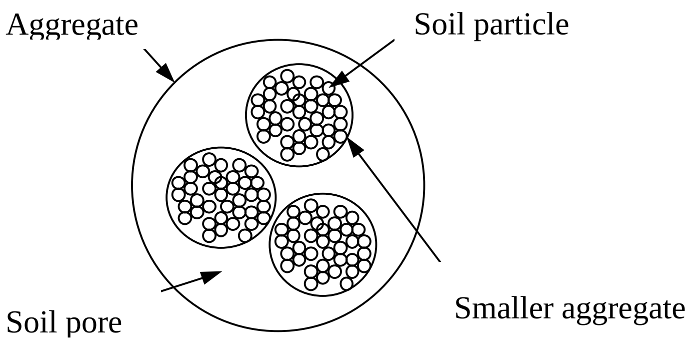


Fig. 2-1 Structure of soil

2.1 Purification functions

2.1.1 Filtration:

Soil pore structures having various shapes, large and small, are effective in filtrating suspended materials in percolating water.

2.1.2 Adsorption:

Moreover, as shown in **Fig. 2-3**, clay particles have the function of ions exchange, so the particles can adsorb and replace many kinds of ions such as nitrogen, phosphorus, potassium, calcium, magnesium, etc, which are essential and necessary nutrients for plant growth.

2.1.3 Decomposition:

Soil microbes decompose the dead bodies of living things, and form soil organic substances. Then the organic substances are converted into inorganic substances and can be absorbed by plants.

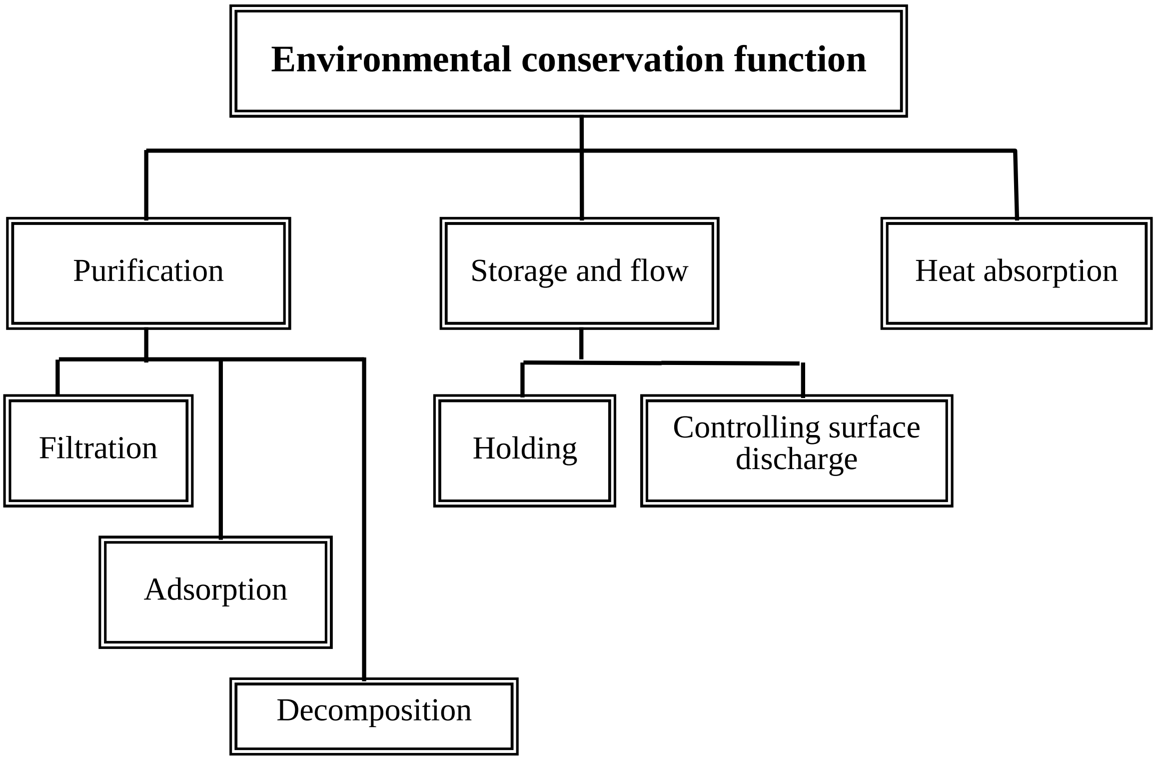


Fig. 2-2 Environmental conservation function

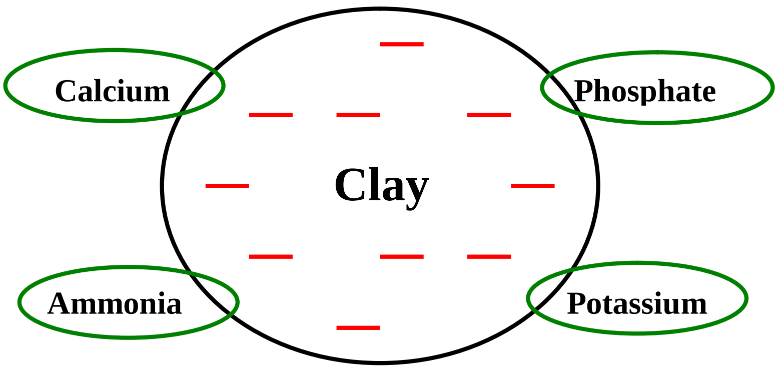


Fig. 2-3 Ion exchange function of clay particle

2.2 Water storage and percolation function

Water flows through larger pores in the soil, and the excessive soil water can be drained into groundwater. In finer soil pores, water is stored for a long time, and absorbed by plants. This water storage function of the soil has the roles of supplying water for plants and decreasing the peak discharge of flooded rivers or streams.

2.3 Heat absorption function

The soil also adjusts temperature and humidity as a storehouse of thermal energy.

3. Environment problems of soil in farmland

As the demand for food production is increasing due to the rapid growth in population in recent years, reclamation and farming activities are apt to exceed the environmental capacity. Consequently, various environment problems are occurring in the soil as shown in **Fig. 3-1**.

3.1 Drought

Drought occurs by fault pasturage or deforestation. In the drought area, the lack of irrigation water and low nutrient reduces the crop production.

3.2 Soil erosion

Soil erosion by water or wind occurs extensively in bare land. It causes not only soil and nutrient losses from farmland but also transportation and sedimentation of chemical substances further down stream. Then, the chemical substances including poisonous components cause toxic problems and water quality degradation (**Fig. 3-2**).

3.3 Salinization

High evaporation rate of soil water in drought area transports salt components from salty rock or saline groundwater to the soil surface. High salt concentration interferes with plant growth, as plants suffer water absorption deficiency.

3.4 Soil pollution

Application of high chemical concentration, such as chemical fertilizer, pesticide, herbicide and fungicide, damages the beneficial soil microbes. Then plant pathogens can spread easily. In addition, excess chemicals can be absorbed by the soil and so affect water storage capacity of the soil and obstruct root growth. Furthermore, the toxicants in the soil can be absorbed by plants and transmitted to human body through the food chain.

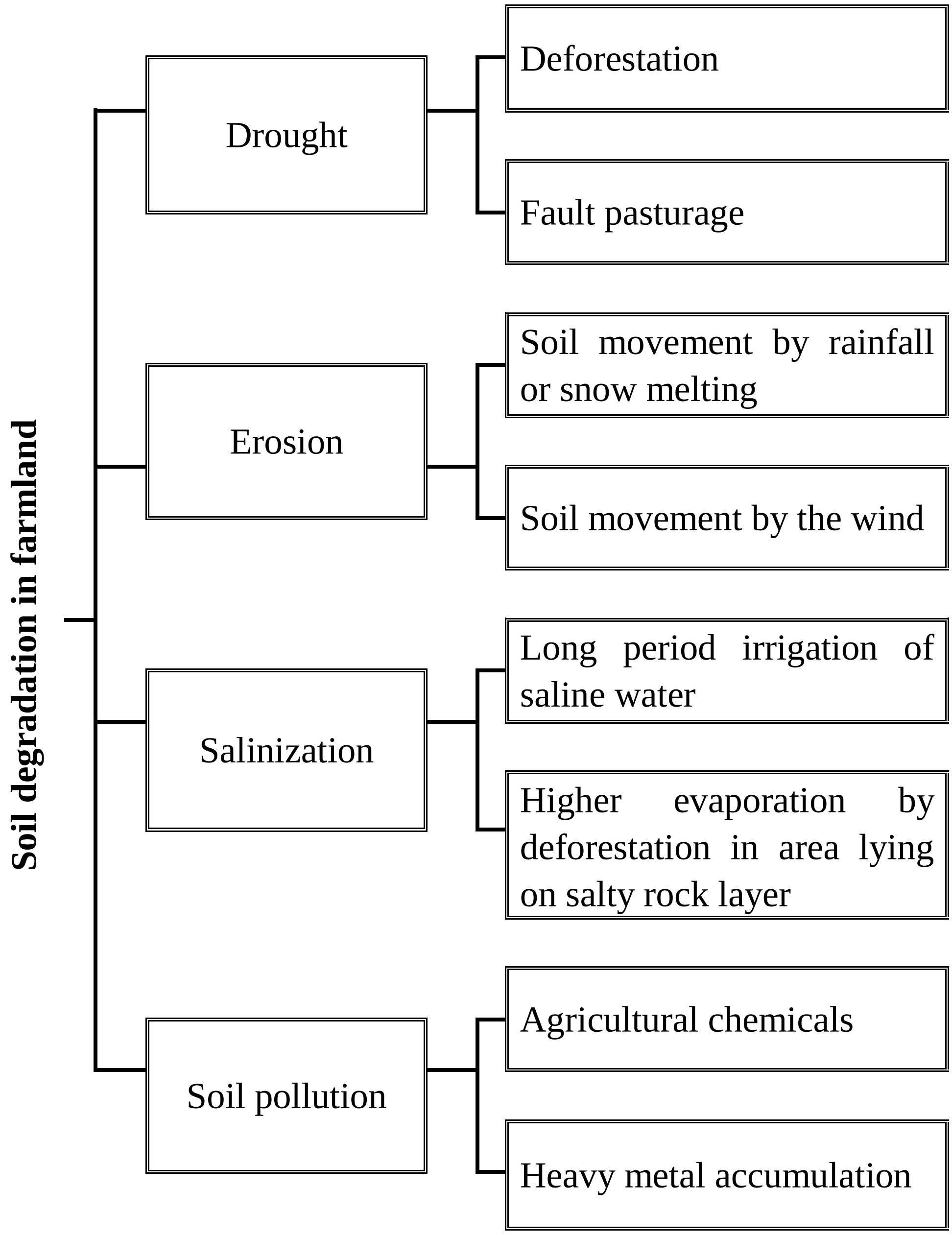


Fig. 3-1 Causes of soil degradation in farmland

Fig. 3-2 Soil erosion and water quality degradation by eutrophication

4. Importance of sustainable agriculture

It is predicted that the world population will increase up to 9.2 billion by 2050 from 6.5 billion in 2006. An important question is whether food production will meet the world population demand. For 30 years from 1960, though the population increased 1.6 times, grain production was doubled, so the supply and demand was improved. This was the result of the modernization of agricultural sector, such as large scale farming with mono-cropping, intensive chemical fertilization and modern agricultural machinery. However, soil degradation processes such as drought, soil erosion or soil pollution are spreading as a result, and land productivity is tending to decline. Therefore, attention is being focused on sustainable agriculture in order to sustain agricultural production and conserve the environment for future generations.

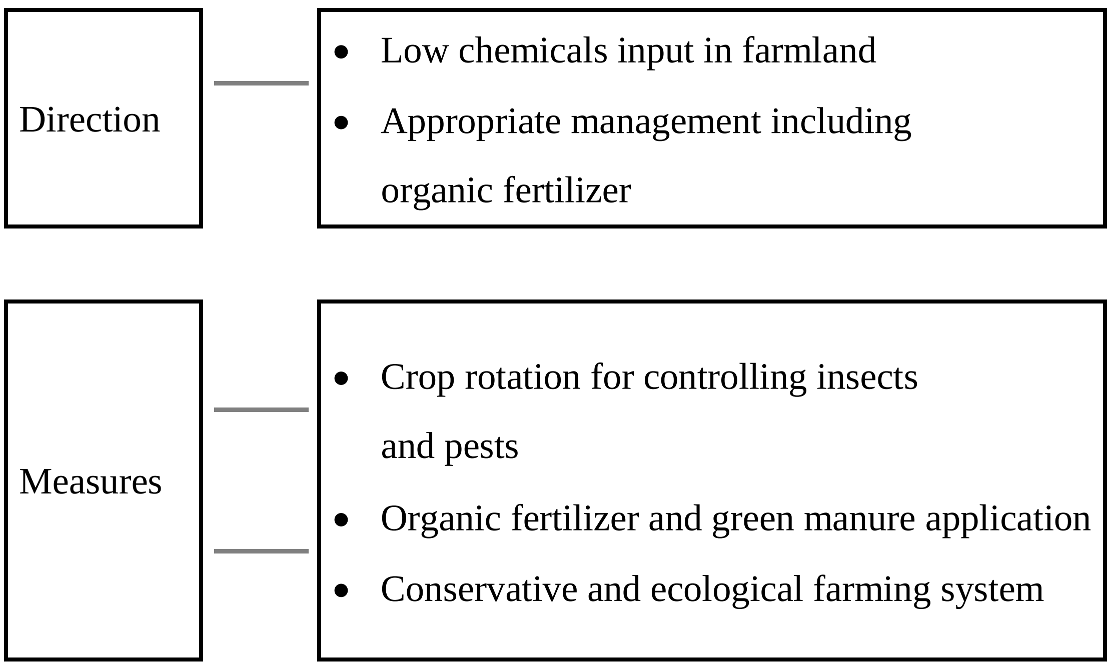


Fig. 4-1 Strategy for sustainable agriculture in the USA

4.1 Sustainable agriculture in USA

In the USA, large areas have been facing severe soil erosion and pollution due to overuse of chemical fertilizer and other agricultural chemicals. The large-scale farms enhance soil erosion, and use of chemical fertilizers leads to groundwater pollution. At present, many scientists are concentrating on the study of effective ways of sustaining agriculture.

4.2 Sustainable agriculture in Southeast Asia

Slash-and-burn farming has been based on natural substance circulation. As the speed of decomposition in the humid tropical region of Southeast Asia is high, soil degradation tends to occur easily. So at least a 25-year interval is indispensable for the slash-and-burn farming system. In order to supply enough foods for the increasing population, this interval has been shortened. Consequently, severe soil erosion is presently damaging farmland. Additionally, soil fertility is diminishing as organic components supplied to farmland are decreasing.

Recently, conservation agriculture, such as organic fertilization, agro-forestry or diversified farming, has begun to spread in Southeast Asia countries in order to sustain agricultural production of safe foods.

5. Organic fertilizer maintaining soil quality

Recently, soil degradation has become wide spread everywhere on the earth. Therefore, agriculture depending on chemical fertilizer should be improved from the viewpoint of substance circulation. Organic fertilizer is indispensable to sustainable agriculture, and it has many advantages compared to chemical fertilizer that consists of inorganic components (**Fig. 5-1**).

5.1 Diversification of soil biota

More than 10,000 kinds of soil microbes and animals are in the soil, and these microbes and animals are using organic matter as staple food. Since organic matter contains various microbes, applying organic fertilizer into farmland activates microbial growth. The improvement of the decomposing properties, the variety of soil biota and the plant disease prevention in the soil can be expected from organic fertilizer application. Soil microbes and animals mostly produce these effects, while chemical fertilizer damages the activity of beneficial soil microbes.

5.2 Improvement of soil physical properties

Soil to which organic fertilizer is applied forms aggregate structure by soil microbes and animals. A soil structure that forms such aggregates contributes to improve soil permeability and fertility in addition to water holding capacity, and this condition then support root growth in the soil.

5.3 Improvement of soil chemical properties

Soil to which organic fertilizer is applied contains many kinds of nutrients, such as nitrogen, phosphorus and potassium. The variety of chemical components, especially micronutrients produce good taste of foods comparing to vegetables or fruits grown only by chemical fertilizer.

Additionally, organic components in the soil play a buffering action and increase ion exchange capacity in the same way as clay minerals.

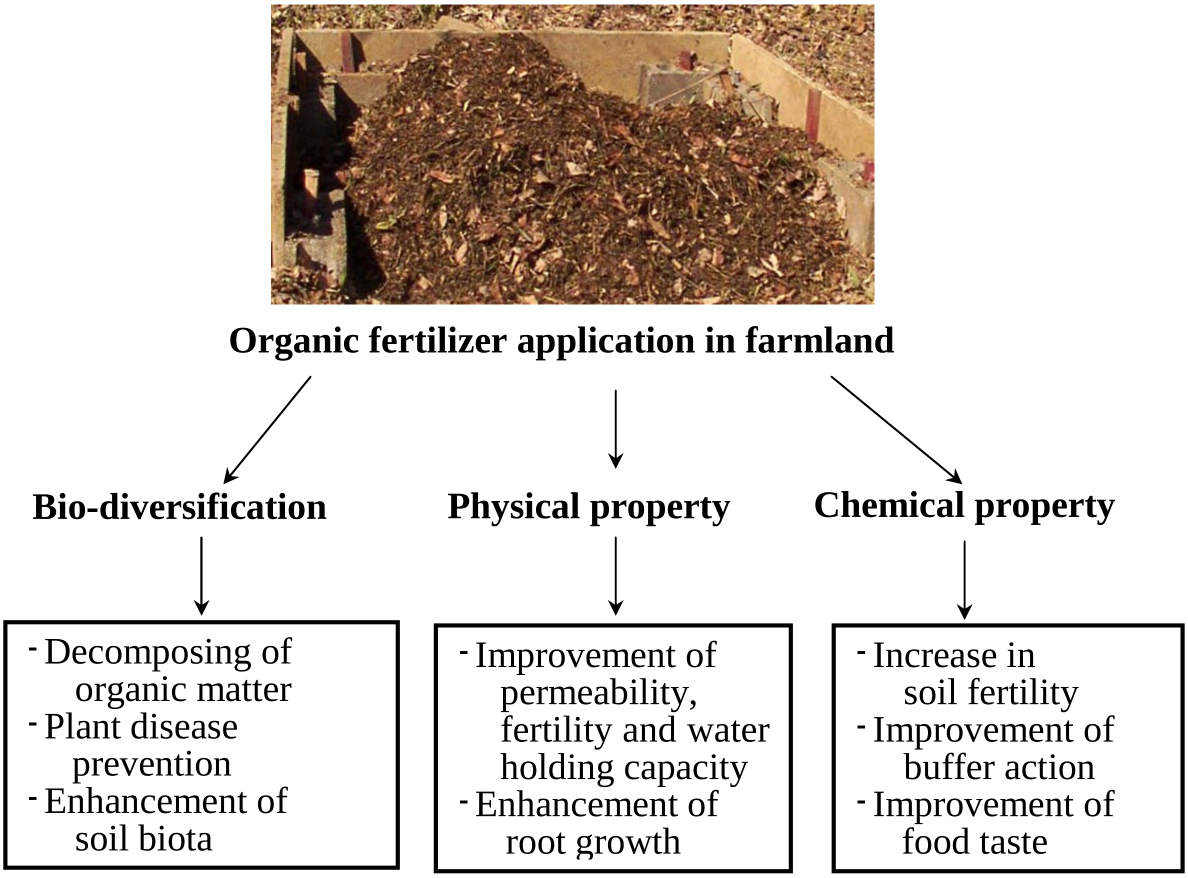


Fig. 5-1 Soil improvement by organic fertilizer

6. Application of non-composted organic fertilizer

Organic fertilizer is produced from natural organic matter such as plant or animal residues, excreta, etc. The crop productivity of chemical fertilizer seems to be higher than that of organic fertilizer in the initial stage. However, the farmers have to increase the amount of chemical use in order to sustain the productivity. But organic fertilizer increases crop yield in the long run. It can be explained that organic fertilizer slowly releases nutrients for plant growth, while nutrients in chemical fertilizer are immediately ready to be absorbed by plants. However, some of the nutrients in chemical fertilizer are not absorbed by plants; they are lost by surface runoff or percolation into groundwater. Therefore, chemical fertilizer causes more environmental problems than organic fertilizer. In addition, plants in farms applying organic fertilizer can maintain better resistance against pest and disease compared to farms applying chemical fertilizer.

The amount of organic fertilizer application should be around 10 times more than that of chemical fertilizer. Chemical fertilizer is composed of pure synthetic nutrients, for example 16-20-0 chemical fertilizer consists of 16 kg nitrogen, 20 kg phosphorus and zero potassium in 100 kg net weight. However, organic fertilizer contains not only macronutrients of nitrogen (N), phosphorus (P) and potassium (K) but also micronutrients such as Mg, Ca, Co, Si, B, Fe, Mo, Zn, Mn, S, C, H, Cl and O for plant growth including organic matter and microorganisms.

Farmers conducting organic farming face lower productivity in the first 3-5 years. However, after the soil becomes healthy, the productivity recovers and often being beyond the productivity obtained by applying only chemical fertilizer. In addition, their net incomes may be higher than those of farmers depending on only agricultural chemicals, because the running costs of organic farming are much lower than those of chemical farming.

6.1 Mulch plow

Residue of crops after harvesting is good for conserving soil moisture in the dry season, controlling weed growth in farmland and providing organic nutrients for plant growth. Burning of crop residues destroys many substances such as ground cover, soil organism, organic matter and nutrient components. Therefore, burning degrades the soil. In addition, heat resistant weeds can easily spread. For example, spreading of bashful plant (*Mimosa pigra* L.) in Northern Thailand has been found in recent years.

However, farmers in Southeast Asia still depend on burning practice. So the farmers who want to leave the residue cover on the soil in farmland can conduct the following methods for preventing wild fire, especially near road or village.

- Mulch plow after harvesting
- Mulch plow and sowing seeds of nitrogen fixation plants at a ratio of 30 kg/ha or covering the soil to make organic matters
- Making fire protection line around the field by plow or residue clearing. The width of fire protection line should be more than 2 m
- In saturated soil, farmers can construct drainage canal around the field. This drainage canal is also available for freshwater fish cultivation or aquatic vegetable cultivation
- Making a strip of edible plants or nitrogen fixation plant such as acacia (*Acacia insuavis* Lace), lemon grass (*Cymbopogon citrates*), leucaena (*Leucaena glauca*), tamarind (*Tamarindus indica* L.), fiber crops

(*Hibiscus cannabinus* L.), etc

- Construction of ridge for cultivation around the field. This ridge should be wider than 2 m. It is available for fruit tree, kitchen garden and evergreen tree.

However, the amounts of nutrients in plant residues differ according to the type of plant as shown in **Table 6-1**. Rice straw contains 5.5 Nitrogen g/kg of dry weight, 0.9 Phosphorus g/kg of dry weight, and 23.9 Potassium g/kg of dry weight. Assuming that rice crops are transplanted in 20 cm interval, there are 250,000 stalks in 1 ha. As the dry weight of each stalk is around 250 g, total weight of rice straw is 62,500 kg/ha. Therefore, residues of rice stalks in 1 ha contain 344 kg of nitrogen, 56 kg of phosphorus, and 1,494 kg of potassium.

Table 6-1 Amount of nutrients in plant residues (g/kg of dry weight)

Residue	Nitrogen	Phosphorus	Potassium
Rice straw	5.5	0.9	23.9
Sugar cane leaves	4.9	2.1	5.6
Corn trunk	5.3	1.5	22.1
Soy bean tree	35.4	10.4	35.4
Grass	4.9	5.8	7.4
Saw dust	3.0	1.2	23.3
Paddy husk	3.6	0.1	10.6
Pineapple leaves	11.2	4.8	26.4
Ash	0.6	19.5	134.8

Source: Land development department, Thailand

Furthermore, let us assume that a 50 kg pack of chemical fertilizer of 15:15:15 is 12 USD. Each pack consists of about 22.5 kg of nutrients; therefore the price of 1 kg of nutrients is 0.53 USD. So multiplying 0.53 USD/kg of nutrients by the net weight of nutrients in rice straw of 344+56+1,494 kg, the price of nutrients in rice straws per ha becomes 1,004 USD. Therefore, burning rice straw residues of 1 ha means burning 1,004 USD annually. Farmers may then realize how much nutrients they burned away from their farmland.

6.2 Cultivating nitrogen fixation plants in farmland

Nitrogen fixation plants are mostly members of leguminosae such as beans, sesbania (*Sesbania javanica* Miq.), leucaena (*Leucaena glauca*), bashful plant (*Mimosa invisa* Mart.), Indian hemp (*Crotalaria juncea*), etc. These are called “Green manure”. The ratio of seeding is recommended at 30 kg/ha. Farmers can sow in non-tilled or tilled soil. These nitrogen fixation plants may be mulch plowed after flower blooming; normally it takes 40 to 60 days after seeding.

6.3 Cultivation with no tillage or minimum tillage

No tillage or minimum tillage is named as conservation tillage as it mitigates soil and nutrient losses from farmland and saves the energy taken by tillage. It is widely accepted in the USA or other developed countries, but not fully accepted by farmers in Southeast Asia countries.

Some short-term research has found that crop yield of non-tilled area is lower than that of tilled area applying chemical fertilizer. However, farming with conservation tillage may not affect the income of farmers especially for long-term application, as farmers can reduce the cost of tillage and chemical fertilizer.

6.4 Application of farmyard manure

Farmyard manure is excreta of livestock. It contains more nutrients than plant residues (**Table 6-2**), and is easier to be decomposed. Therefore, crop yield in farms which applied farmyard manure is higher than those which applied compost made from plant residues under the same weight application. However, it is recommended that farmyard manure should be applied at 10,000 to 13,000 kg/ha.

Table 6-2 Amount of nutrients from farmyard manures

(g/kg of dry weight)

Manure	Nitrogen	Phosphorus	Potassium
Cow	19.1	5.6	14.0
Chicken	37.7	18.9	17.6
Buffalo	12.3	5.5	6.9
Duck	21.5	11.3	11.5
Pig	28.0	13.6	11.8
Bat	10.5	148.2	18.4

Source: Earth Net Foundation, Thailand

7. Application of composted organic fertilizer

If fresh or spoiled organic material such as foods, fruits or kitchen garbage is put directly into the soil, crops tend to get diseases and face root rot. In addition, mixing sludge or excreta with soil is hard and dirty work.

7.1 Composted organic fertilizer

Composting is the method used to solve these problems. Fermentation is important for composting. The temperature increases up to 60 to 70 ^{o}C during the first and second fermentation processes. Then the insects and weed seeds are killed. Grass, rice straw, rice bran, fallen leaves, vegetable waste, powdered bones, livestock excreta and food garbage are available as organic matter for composting (**Figs. 7-1, 7-2**).

The main principle of composting is fermentation. Therefore, microorganism is important for making compost. Additionally, aerobic microorganism is much preferred than anaerobic microorganism, as it produces no undesirable smell.

Fig. 7-1 Plant residues before composting

Fig. 7-2 Compost after decomposed

The second is size of composting pile, which should be large enough to keep heat inside. The third is moisture inside the composting pile, as this affect microorganism activity. The moisture inside the pile should not be too high or too low but should be kept moist.

7.2 Formula for making compost

There are several ways to make compost. The formulas can change according to the local materials and preference of farmers. Here, simple composting methods are set out.

7.2.1 Formula 1:

Materials:

Any kind of plant residue such as rice straw, sugar cane leaves, bean residues, bean trees, saw dust, corn trees, corn residues, grasses or leaves can be materials for making compost. It is better if the materials contain fresh as well as dry matter.

Procedure:

1) Dig a pit 1 to 2 m wide, 15 to 30 cm deep, and as long as preferred
2) Put the residues into the pit, then compress. The height of the pile should be 1 to 1.5 m
3) Pour water until the materials become moist
4) Cover the pile with plastic or thatch to protect from rain
5) Mix the materials in the pit every week

7.2.2 Formula 2:

Materials:

Any kind of plant residue and healthy soils being dark, fine and moist can be materials.

Composting in the pit of soil

Fig. 7-3 Procedure for making compost (Formula 1)

Procedure:

1) Arrange the residues in compost box having the dimension of less than 3 m wide, 1 m high, and long as preferred
2) Pour water until the materials become moist
3) Cover with healthy soils up to 1 to 3 cm high
4) Repeat from step 1 to 3 until the pile becomes 1 to 1.5 m high
5) Mix materials in the box every week

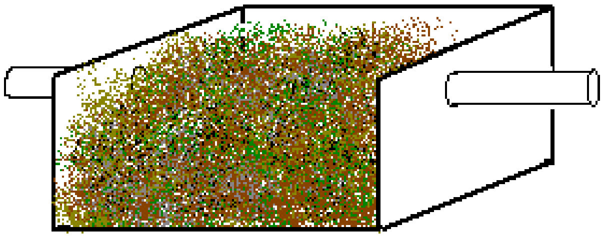
7.2.3 Formula 3:

Materials:

Around 1,000 kg of plant residues and 100 to 200 kg of farmyard manure can be materials.

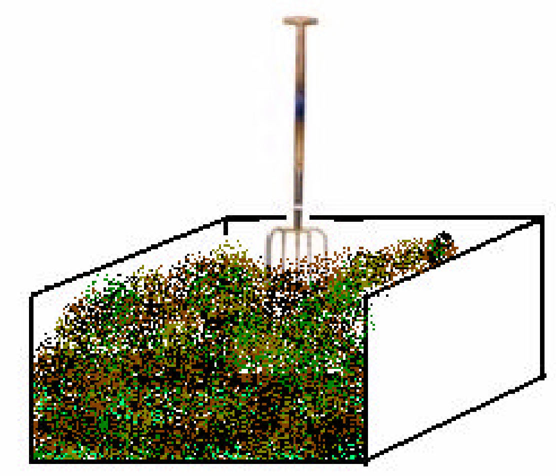
Procedure:

1) Arrange the residues in compost box having the dimension of less than 3 m wide, 1 m high, and long as preferred
2) Pour water until the materials become moist
3) Cover with farmyard manure up to 1 to 3 cm high
4) Repeat from step 1 to 3 until the pile becomes 1 to 1.5 m high
5) Mix materials in the box every week



a. Arrange plant residues, soil and/or farmyard manure into compost box

b. Supply water to the materials until moist and compact, and then cover the compost box to avoid evaporation



c. If there is no air pipe, mix materials well every week

Fig. 7-4 Procedure for making compost (Formula 2 or 3)

7.2.4 Notification:

1) Undesirable smell occurs in the composting processes, if farmers do not mix the materials in the pile. The mixing process makes materials completely fermented.
2) For better aeration, farmers may put a porous tube made from plastic or bamboo into the pile. The aeration tube should be placed in both horizontal and vertical directions.
3) The composting takes 2 to 3 months to complete fermentation. During the fermentation, the pile may be hot and 2 or 3 months later the materials become dark, cool and moist.
4) In the dry season, farmers are advised to pour some water when the pile becomes dry.
5) The pile can set up in hollow, open field or compost box depended on preference or farmers custom.
6) Nutrients in compost vary due to the kinds of materials used. The amount of farmland application is recommended at 18,000 kg/ha, because nutrient releasing rate of compost is slower than chemical fertilizer. Therefore, it can sustain soil fertility in farmland.
7) Farmers can put E.M. or another instant microorganism for enhancing fermentation or composting. The composting process with these microorganisms added may make complete fermentation faster than the basic formula.

8. Application of granular compost

It is important to make clear the purpose of applying organic fertilizer, such as for supplying nutrients, improving soil physical properties or enhancing bio-diversification. Additionally, the condition of farmland should be taken into account before selecting the compost, especially slope degree, soil properties, irrigation and drainage systems. On higher slopes, organic fertilizer applied in farmland might be washed away easily by surface runoff.

8.1 Alternative organic fertilizer: granular compost

Granular compost developed by the Institute of Environment Rehabilitation and Conservation and Tokyo University of Agriculture is an organic fertilizer having highly resistant against surface runoff. The granular compost can be made from the mixture of conventional compost, clayey soil and molasses at the ratio of 10:1:0.01. There are some ways to form granular shape from the mixture; compressing the mixture by hand after putting it into a small plastic frame or extruding the mixture using a mincing machine as shown in **Figs. 8-1, 8-2**.

As the density of conventional compost of 1.2 to 2.2 g/cm^3 is smaller than soil particles of 2.5-2.7 g/cm^3, rainfall or surface runoff may wash away compost more easily than soil particles. However, granular compost has high resistance, as molasses works as cementation in granular compost. It means that nutrient losses from farmland to which granular compost is applied can be mitigated comparing to those of conventional compost. Additionally, granular compost makes it easier for farmers to transport and broadcast fertilizer in farmland than conventional compost, as its shape is granular.

Fig. 8-1 Granular compost (17 mm in diameter and 21 mm in length) produced by hand

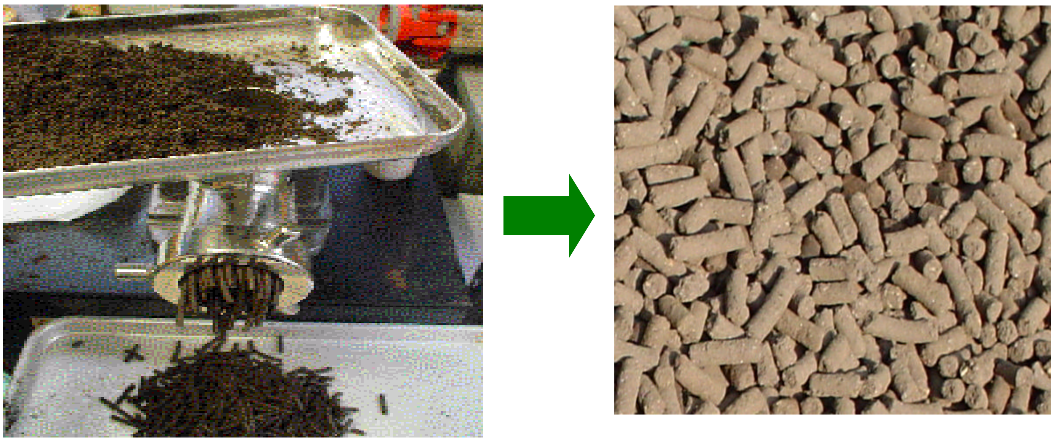


Fig. 8-2 Granular compost (5 mm in diameter and 5 to 15 mm in length) produced by mincing machine

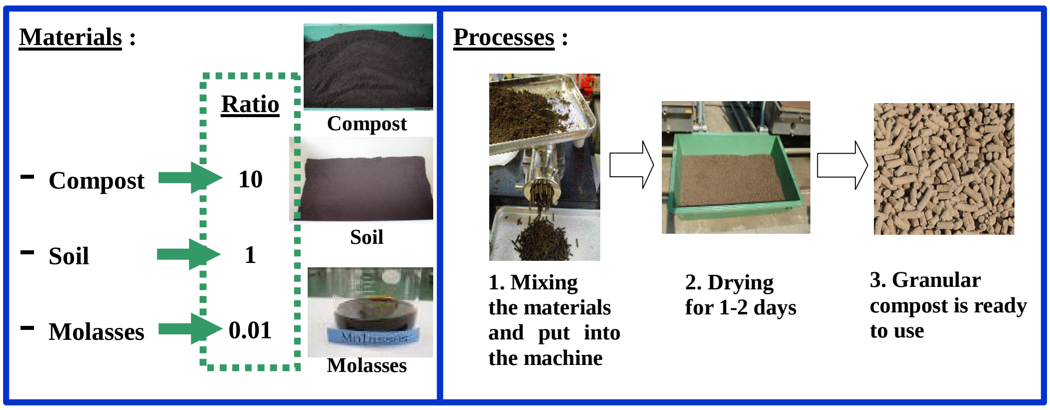


Fig. 8-3 Materials and processes of making granular compost

9. Promotion for sustainable agriculture under collaboration between NGO and university

Recently, in Thailand, Cambodia, Vietnam and other developing countries in Southeast Asia, subsistence agriculture is being converted to export-oriented mono-culture, and the amounts of agricultural chemicals applied to the farmland are increasing every year. The applied chemicals in farmland cause serious environment problems in down stream, such as eutrophication, unusual growth of aquatic plants, decrease in dissolved oxygen and accumulating bottom mud in the water resources. Also, there seem to be many cases in which people apply agricultural chemicals without understanding the impact on health and food safety.

It is necessary to promote and enhance understanding of sustainable agriculture among farmers and school children. One of the ways to support and enhance understanding of sustainable agriculture quickly, regardless of policy across a country, is facilitation by an international non-government organization. However, the knowledge or capacity of single NGO is limited. A recommended strategy for facilitating programs effectively is to collaborate between NGO and university. The knowledge and intelligence accumulated at university are expected to make the programs facilitated by NGOs more meaningful. Further cases of international cooperative programs under collaboration between NGO and university should therefore be promoted.

Conclusion

Agricultural systems are tending to change from multi-cropping systems to mono-cropping system. In Southeast Asia, many problems of health and environment occur due to various agricultural chemicals applied in farmland. Sustainable agriculture is a farming system producing foods and fiber materials based on the harmony between agricultural production and the natural environment. Recently, organic fertilizer has become the focus, as a way of contributing to reduce the expenses of chemical fertilizer.

For rural development, it is important to evaluate the environmental capacity of each area, and to limit development according to the capacity. In order to sustain agriculture, organic fertilizer is meaningful to maintain not only soil fertility but also soil physical, chemical and biological properties. It also helps to mitigate water pollution and to increase health and food safety. Granular compost developed to prevent nutrient outflow from farmland is one alternative for farmers to establish sustainable agriculture.

We hope this guidebook helps to popularize sustainable agriculture with organic fertilizer. This is one of the outcomes from the collaboration program on food, agriculture and environment education system among Tokyo University of Agriculture (Japan), Institute of Environment Rehabilitation and Conservation (Japan), Kasetsart University (Thailand), Royal University of Agriculture (Cambodia) and Asian Environmental and Rural Development (Thailand). We would like to express our special gratitude to the Ministry of Education, Culture, Sports, Science and Technology of the Japanese government for financial support to run the collaboration program and publication of this guidebook.

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