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Making and Testing an Alternative Herbicide for Smallholder Farmers

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Background

ECHO Asia Impact Center staff members first heard about alternative herbicide recipes that use fermented papaya and pineapple from a retired technical school teacher and organic farmer, Kru Pratoom. As weeding is a big part of any farmer's life, the Seed Bank staff wanted to try out a lower-risk herbicide to see if its effects on weeds would warrant its use. They also wanted to ensure that this herbicide would not pose a risk to soil pH, microbiology, structure, and plant uptake and health. This ECHO Asia Research Note describes the process used to create this herbicide, as well as a sampling technique to determine its efficacy on weeds. Look for a future note about the methodology used to help determine its effects on soil microorganisms and health.

Herbicide Use

Herbicides are one method used to control unwanted plants in crop fields, gardens, and orchards. Herbicides may be used alongside tillage, hand weeding, burning, crop rotation, and crop spacing to control weed pests. Weeds can cause agronomic and economic harm by reducing the quantity or quality of the desired crop plant by interfering at important stages in the growth and development of the crop (O'Donovan, 2009). Weeds compete with crops for space, sunlight, water, and nutrients; some species of weeds may also release toxins into surrounding soil that may damage crops (Swanton, 2009). The damage caused by weeds depends on the weed species, crop species, and stage of crop development. Weed control is most critical when crop plants are still young and are not tall enough to out-compete the weeds. A low quantity of weeds may not damage crops, and completely clearing weeds is associated with high economic and time costs for the farmer. Besides, such clearing may cause damage to the agroecosystem. Additionally, certain weeds can be used for food, medicine, and fodder, so some so-called "weeds" can be economically useful. When applied at the proper time, and in the right quantity, herbicides can be a useful tool as part of an Integrated Pest Management System to control weed species that are too numerous or that may cause undue agronomic or economic harm (FAO, 2015). In sustainable systems, herbicides are used when other control methods fail to effectively control weed pests. Unlike in conventional agriculture, they are not the primary method of controlling weeds.

Safety

The alternative herbicide recipe discussed in this ECHO Asia Note contains lye, which can be extremely caustic; this means any physical contact with the undiluted product can cause burns, and therefore

Figure 1. *Weeds present in our sample plots. (1) Imperata cylindrica, (2) Sphagneticola trilobata, (3) Mimosa pudica, (4)Convolvulus arvensis.*

Featured in this AN

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caution must be used, even around the mixed product. Always add lye or solutions containing lye to water or other liquids; never add water to concentrated lye or lye solution. Adding them in the correct order can minimize the damage caused by backsplash, because adding the lye/herbicide to water means the backsplash is more diluted. Whenever you are working with lye or the herbicide, wear rubber gloves and boots. Long pants and sleeves are recommended for both mixing and spraying. To protect your eyes, wear safety goggles or sunglasses. Perform all mixing and pouring in an open and well-ventilated area, in case the lye reaction gives off fumes. Do not mix or store in a metal container, because the lye could react with the metal.

If you do come into contact with the herbicide or with concentrated lye, immediately wash the affected area with cool water for at least fifteen minutes. Test all containers beforehand with boiling water to ensure they won't melt, because when water mixes with lye (when the herbicide is being prepared), the reaction may give off a large quantity of heat.

Recipe

This herbicide recipe was developed by Kru Pratoom, an organic farm educator in Chiang Mai, Thailand. Faced with a limited number of non-chemical herbicide choices, she made her own recipe using ingredients that were familiar to her, including pineapple, papaya, salt, and lye. Pineapple and papaya are used because they contain the enzymes bromelain and papain, respectively. Bromelain breaks down protein (Dubey et al., 2007), and papain disrupts a plant's ability to photosynthesize (Itoh et al., 2013). Salt can remove the water in the leaves by changing the ion balance outside of the cells; additionally, the leaves absorb too much of the chloride, which is present in salt, and this also damages the leaves (Romero-Aranda & Syvertsen, 1996). Lye is highly alkaline; it is used to help dissolve the salt and can cause chemical degradation of weed leaves. One concern with this alternative herbicide is its highly alkaline nature, which might negatively affect the soil biota and pH. As far as pH is concerned, we would not recommend this herbicide if your soils are highly alkaline, but it may actually be helpful for very acidic soils. The soil pH at the ECHO Asia Seed Bank is typically around 4.8-5.2, so this highly alkaline herbicide may actually help to bring our soil pH into a more neutral range.

The Basic Herbicide Recipe:

1. 20 kg very ripe pineapple or papaya (with peels, cut into 3cm X 3cm chunks)
2. 10 kg salt
3. 1 kg lye (Sodium hydroxide - NaOH)
4. 20 L water

Mixing Directions:

Add the fruit, salt, and water to a watertight plastic barrel. Slowly add the lye, carefully stirring between additions. Cover the barrel with a lid and allow the mixture to rest for 45 days (Figure 2). On day 45, strain out the pieces of fruit. The herbicide should be ready to use after straining. Keep the herbicide in the barrel until you are ready to mix it for an application. Do not add the water needed to prepare the herbicide spray if you aren't planning to use it immediately. With the lid screwed on tightly, and if kept in the shade, the herbicide can be stored approximately 6 months.

Application

1. Ideally, target weeds should be young and 8-10cm tall. If your weeds are more mature than that, cut the weeds with a weed whacker to a height of 8-10cm tall prior to spraying, to make them more susceptible to the herbicide;
2. Add 3 L of water into a backpack sprayer;
3. Stir the herbicide in the barrel with a stick for 30 seconds, and then transfer 1 L of the herbicide into the sprayer;
4. Mix the herbicide and water in the backpack sprayer; and,
5. Hold the nozzle of the sprayer approximately 30cm from the weeds. Spray the weed-infested area at a rate of 500ml/m^2. Our test plots were 2 m^2 and required about 1 minute to spray.

Table 1. *Cost of herbicide ingredients.*

Ingredient	Amount (kg)	Cost per kg (THB)	Cost per kg (USD)	Total Cost (USD)
Pineapple	20	20	0.56	11.20
Papaya	20	10	0.28	5.60
Salt	10	5	0.14	1.40
Lye	1	40	1.12	1.12

Table 2. *Total herbicide cost.*

Herbicide Type	Total Cost (USD)	Cost Per L (USD)
Pineapple	8.12	0.406
Papaya	13.72	0.686

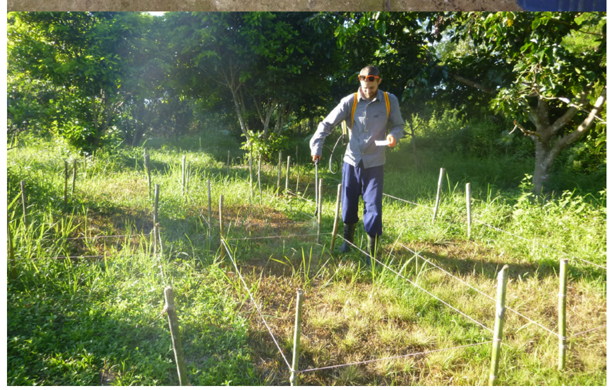

Figure 2. *(Above) Fermenting pineapple (left) and papaya (right).* ***Figure 3.*** *(Below) Spraying experimental plots with the alternative herbicide.*

Testing

1. An unused fallow plot at the ECHO Asia Seed Bank was identified as the experiment location—it contained a mix of overgrown broadleaf and grassy weed species. We used water for the control treatment. The the pineapple treatment was 1 part pineapple herbicide mixed with 3 parts water, and the papaya herbicide was 1 part papaya herbicide mixed with 3 parts water.
2. Three days before spraying, the different types of weeds were identified and the percent composition was visually estimated, with weeds categorized as broadleaf or narrow leaf weeds.

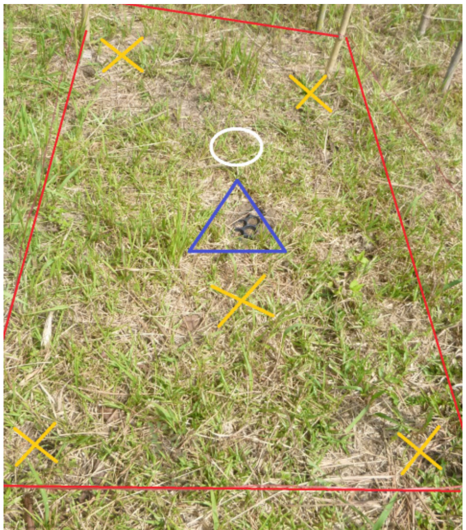

Figure 4. *(Above) Plot sampling locations and seedling flat location. Xs represent soil sample locations. Circles represent buried filter paper. Triangles represent seedling flat.* ***Figure 5.*** *(Below) Seed flats with potting soil were placed in each plot to test the effect of the herbicide on seeds.*

3. The experimental area was divided into 1m X 2m plots. Treatments (control, papaya herbicide, and pineapple herbicide) were randomized with 4 replications, for a total of 12 experimental units (3 treatments [control, papaya, or pineapple] X 4 replications).
4. Immediately before spraying, soil samples were collected (we sent them to a local university lab to test pH and microbial content).
5. Weeds were cut down to 10cm using a weed eater.
6. Filter papers were weighed, placed in mesh nylon bags, and buried to a depth of 8cm in order to observe the effects of the herbicide spray on microbial health. The filter papers would normally be decomposed by microorganisms in the soil; if the herbicide has a negative effect on the microorganisms, filter paper decay will be stopped or slowed.
7. In order to test the effect of the herbicide on seeds, seedling flats containing potting soil (but no seeds) were embedded into the middle of each 1m X 2m plot. A hole roughly the dimensions of the flat was dug to a depth of around 10cm. The flats were placed in the holes and dirt was packed around the flats so they were flush to the rest of the ground. Later, after completion of spraying, the flats were dug up and planted with seeds, to test the time to germination and the germination rate (Figure 5).
8. Each plot was sprayed with its assigned treatment—papaya herbicide, pineapple herbicide, or water. The weeds in each plot were sprayed for 1 minute at 500ml/m^2 every other day for one week.
9. The morning after a spray, treatment plots were visually rated for herbicide injury using a scale from 0-100, with a score of 0 having no injury and a score of 100 being full death. Each weed type, and species in a plot received its own damage injury score.
10. Three days after the final spray, additional soil samples were taken for soil pH and microbial testing to compare to the pre-trial samples. On this day, the germination flats were also collected and black bean seeds were planted 1 per chamber.
11. Seed germination was observed over 10 days. Mean time to 50% germination and percent germination for each treatment were used to evaluate the impacts of possible herbicide persistence in the soil on seed germination.
12. On day 10 after the final spray, the filter paper was retrieved and then weighed to find the amount of mass lost (a measurement of decay). These numbers were compared to the weight of the individual papers at the beginning of the study.

Results

We found that the herbicide treatments significantly damaged the weeds within treated plots. We observed that both the papaya and the pineapple herbicide worked better on broadleaf weeds than narrow leaf (grassy) weeds (Figures 6 & 7). We did not observe a significant difference between the damage scores of weeds treated with the pineapple herbicide and weeds treated with the papaya herbicide; they were equally effective against weeds (Figure 8). Herbicide injury increased after each treatment, and after 4 treatments, the broadleaf damage was around 90% while narrow leaf damage was around 50% for both the papaya and the pineapple herbicides.

There was no measurable difference in the soil pH before and after the spraying. The pH may have changed during the treatments but any difference in pH, if it existed, had washed out of the soil by the end of the experiment.

We had mixed results for our measures of soil microbial activity. Our filter paper decomposition test suggested that there was no difference in microorganism activity between soil treated with the herbicide and soil left untreated. In lab quantifica-

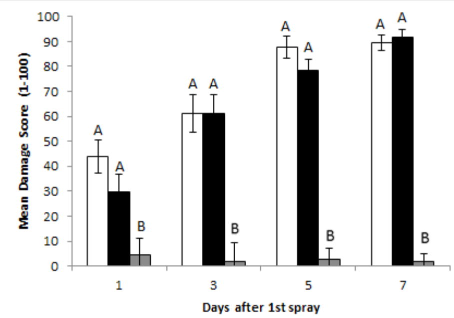

Figure 6. *Herbicide injury visual damage score for broadleaf weeds over the course of a weeklong herbicide treatment. White indicates herbicide injury score for papaya, black is the injury score for pineapple, and grey is the injury score for the control. Letters indicate no significant difference between herbicide types (A) but a significant difference in herbicide injury compared to the control (B).*

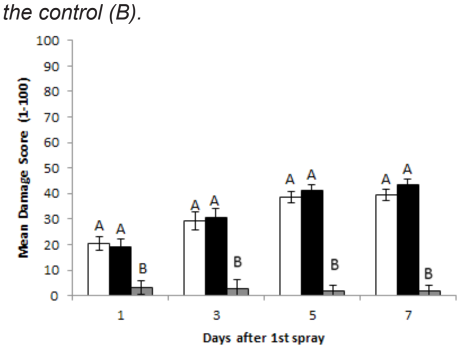

Figure 7. *Herbicide injury visual damage score for grassy weeds over the course of a weeklong herbicide treatment. White indicates herbicide injury score for papaya, black is the injury score for pineapple, and grey is the injury score for the control. Letters indicate no significant difference between herbicide types (A) but a significant difference in herbicide injury compared to the control (B).*

__Figure 8.__ Damage to the weeds after 4 applications of the alternative herbicide treatments, photo taken on July 17th, 2015. Front row, left to right: Plot treated with pineapple herbicide, water control, papaya herbicide. Middle row, left to right: Plot treated with water control, pineapple herbicide, papaya herbicide. Bottom row, left to right: Plot treated with papaya herbicide, pineapple herbicide, and water control.

tion of microbial populations, some of the treated plots experienced increased microbial populations and others experienced reduced microbial populations. The experiment was run twice but no consistent pattern was found. The decay rate of the paper suggested that treated soils were not consistently different from the control, although the papaya herbicide had the lowest decomposition rate (Figure 9). We performed a number of serial dilutions to approximate soil microbial health ourselves ([see ECHO Asia Note 15, "Soil Quality Assessment: Why and How" by Marcia Croft]) but the microbial populations varied widely between the different plots before treatment and after treatment so there wasn't a pattern in the change of soil microorganism populations. Soil samples submitted to Maejo University for microbial populations also varied widely. Differences between the initial treatment plots were so great, it was difficult to distinguish between what effects the herbicides had and what effect were from random variation in the soil. Further testing needs to be done to more accurately assess if the herbicide decreases or otherwise alters soil microbe populations, or if it has no effect.

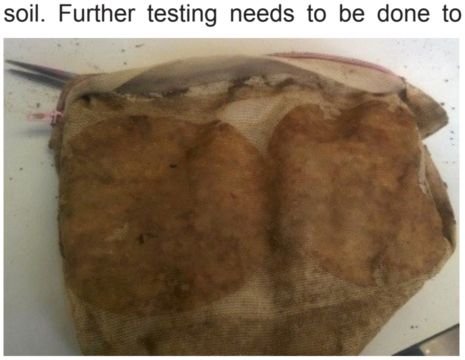

__Figure 7.__ Filter paper decomposition 10 days after the final spray.

Seedlings planted in the soil mix in the seedling flats which received the pineapple herbicide spray had the longest mean time to 50% germination, and soil treated with the papaya herbicide also took longer to reach 50% germination than the control treatment. However, the seeds in the pineapple herbicide treated soil also had the highest germination rate. The experiment was run twice; more seeds germinated in the second run when it had rained after many of the herbicide applications, suggesting that increased rainfall may wash the herbicide out of the soil more quickly and have fewer negative consequences for future crops and or soil microbial health..

Conclusion

The papaya and the pineapple herbicides both significantly damaged broadleaf and grassy weeds. We observed no obvious damage to the soil microorganisms; decomposition and colony counts were similar for plots treated with the water, pineapple herbicide, and papaya herbicide. Seeds planted in the soil of plots that had been treated with herbicide took longer to reach 50% germination, but the herbicide did not impact the overall germination rate. Rainfall may influence the persistence of the herbicide, because more seeds germinated in soil receiving the herbicide during frequent rains than in soil receiving herbicide applications during the dry season. Future studies should examine the long term impacts of this herbicide on the soil and on future crops. We would like to do further testing to ensure that the salt doesn't stay in the soil, change the soil pH with long-term use, or damage the microbial populations of the soil, but the herbicide shows promise. We would also like to conduct trials using each of the herbicidal components, to figure out the active ingredients; if the lye isn't that necessary, we would like to reduce the amount to make the herbicide safer to make and to use. We might also plant seeds and then apply the herbicide in order to examine if the herbicide could reduce weed competition without harming seedlings. Overall, it appears that this reduced-risk herbicide holds promise to help smallholder farmers to lower costs, reduce reliance on purchased inputs, and control weed pressure in their fields or gardens.

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An Introduction to the Mound, Reservoir, and Paddy Model of Water Management

Summary of an article from the Natural Farming Journal, September 2015
Written by Booonsong Thansrithong, Agriculture Program Manager,
Translated by Patrick Fitzsimons, ECHO Asia Impact Center

[Eds.' Note: This series of articles on water management has been reprinted with permission from Thailand's Natural Farming Magazine and serves as an introduction to small-scale water management. Many of the ideas offered in these articles are consistent with permaculture design principles, which promote farmer resiliency against varying weather extremes. To read more about permaculture options for smallholder farms, please see this "Permaculture in Development" article by Brad Ward in ECHO Development Note #129.]

Introduction

Farmers are people who are directly affected by drought, so it's important they have sustainable methods of obtaining water for both consumption and use. This is the reason for the "mound, reservoir, and paddy" water management project. This project is the brainchild of Ajarn Wewat Salayagamthon (Ajarn Yak), president of both the Sufficiency Economy Institute and the Agri-Nature Foundation of Thailand.

The mound, reservoir, and paddy model of water management is derived from a concept of His Majesty King Bhumibol Adulyadej—that we must manage rainfall and foster moist forests, which will both preserve water and prevent forest fires. The world is experiencing a water crisis because so little of our forests remain. Regardless, when it rains we must have places to collect the water. The mound, reservoir, and paddy model of water management promotes the following methods of water collection:

- Small reservoirs should be dug, which can act like the holes in the trays used to make coconut desserts, or "coconut dessert wells". *[Eds.' Note: "Coconut dessert wells" refers to a large dessert pan commonly used in Thailand, which is covered in small divots or retention areas, for the purpose of holding a coconut mixture. To understand this metaphor further please refer to the image at this link.]* If everyone created such holes, it would be possible to collect a significant amount of water. On flat land, on the other hand, rice paddies may be dug which will also collect water.
- We must plant trees and create forests on raised mounds. These trees will help absorb water.
- Reservoirs, canals, wells, and creeks should be dug.
- Large reservoirs should also be dug.

It is Ajarn Yak's belief that these water holes, implemented on a population-wide level, will collectively produce great benefit. The project has now been in operation for two years, and has had more than 700 participants. The project also has a "Drought Prevention Command Center," which coordinates activities, helps make plans, etc.

Water management can be undertaken in many forms. For example, in areas containing water sources, you can create terraced fields, check dams, and irrigation ditches at the end of rai and fields *[Eds.' Note: A "rai" is an upload field that often terminates downhill in a paddy field.]* In areas downstream, the same principles can be used (Figure 1). There must be places to store the water, such as in buckets, tanks, or large earthen jars. Rainwater should be collected for consumption only after the fifth rain, as by this time, the roof will be sufficiently clean. In the old days people would dig wells beside termite hills, because termites have a natural sense of where to find clean water.

Allocating and shaping mounds, reservoirs, and paddies should depend on your natural conditions: temperature, distance above sea-level, climate, clouds, and volume of rainfall. The water-storage capability of a paddy depends on the strength of its dikes. Care must also be taken to stop crabs or mice from digging holes through them.

Rain is not simply water, it also consists of a variety of minerals needed by plants. Notice, for example, that when it rains plants look increasingly lush and vibrant. If rain isn't collected, when water is later needed, an enormous financial investment will be required.

Collecting water in pools about knee-height will allow aquatic life to lay eggs and prosper, for example fish and shrimp. Farmers can then use fish droppings as a free, high-quality fertilizer for their rice fields. Moreover, fish and shrimp provide another good food source. Many kinds of fish eat shrimp, plankton, and vegetables, making it unnecessary to buy any extra fish food.

When designing and making calculations for water management on your land, there are several important factors to consider, including: wind, sunlight, rainfall, soil, and people. Management of some of these factors involves scientific understanding and calculatations. However, considerations for people with their own civilization and culture shows that management of the irrigation model must also be built upon a "social science" foundation.

Understanding Water Movement

The mound, reservoir, and paddy model of water management requires that farmers understand the movement of water on their land. In order to do so, they must know the volume of rainfall in their area, or the number of days it rains in one year. In addition, they must also know the amount of sunshine, or the number of days it doesn't rain in one year.

Furthermore, farmers must take into account the rate of evaporation and the portion and rate of water that will seep into the ground. It's important to point out that water which evaporates is still of benefit, as it creates a good relative humidity for your plants. The water which seeps into the ground likewise benefits the groundwater, or the water located even deeper down. Digging irrigation ditches, canals, reservoirs, and creeks, therefore, means collecting water that runs out from paddies and wells. If you are able to store 2,000 cubic meters of water per rai of rice paddy (or 5,000 cubic meters per acre), this may look like a lot, but after a season it will probably be dry. However, if you dig irrigation ditches, reservoirs, canals, and wells at the end of your rai and at the end of your paddies, you will likely still have water to use. More than that, these will also contain fish and other aquatic life, as well as wild vegetables that can be sources of food. These can be harvested, sold, distributed, or processed, as you wish, which in turn will lower your food expenses.

Sustainable water management means using all the water sent to us here on earth. It can be kept beneath the house, above the house, in fields, in wells, in natural bodies of water—even underground or in the air. Water management isn't simply about water, it can also provide food, such as aquatic animals and wild vegetables, and even, possibly, new friends and a little extra income.

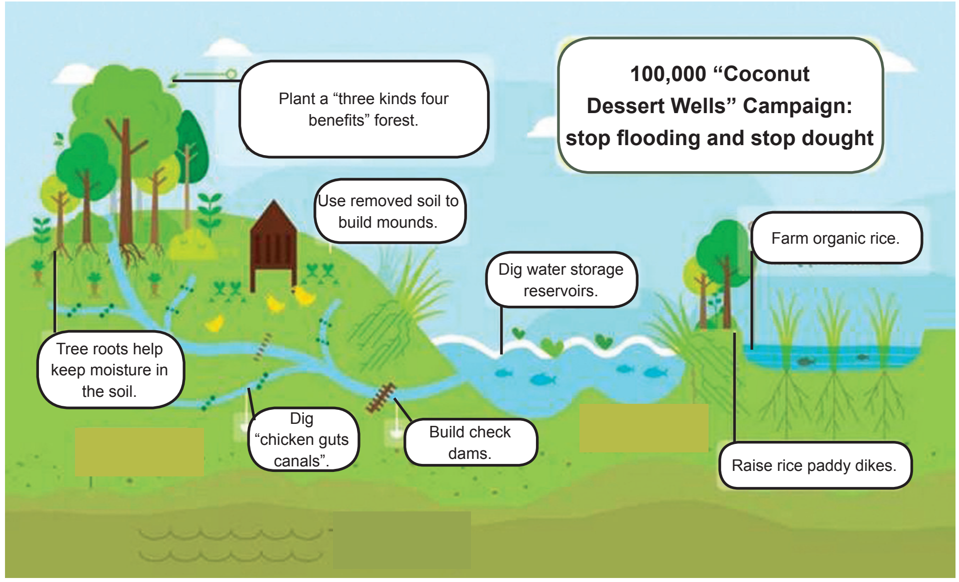


Figure 1. *.Diagram of water management.*

Options for Smallholder Farms: Water Management Design Principles

Reprinted with permission from the Natural Farming Journal, September 2015
Translated by Patrick Fitzsimons, ECHO Asia Impact Center

The Mound, Reservoir, and Paddy Model of Water Management

At the beginning of last year, Thailand experienced its most severe drought in twenty years. Only four years ago it also experienced its most severe flooding. Natural disasters are occurring with increasing frequency and severity; it is therefore vital to establish defenses against catastrophes like these. One such defence is redesigning areas based on the "mound, reservoir, and paddy" model of water management, which is one way of implementing a concept promoted by His Majesty King Bhumibol Adulyadej. This model is an efficient method of coping with water disasters, whether flooding or drought.

Five Factors to Know Before Designing Your Area

Designing a water management area well first requires gaining an understanding of the relationship between five important factors (represented here by five elements):

1. Fire (the direction of sunshine): Before designing an area, it should be surveyed to determine north, south, east, and west, as well as determining the path of the sun in each season. This will differ on exposure of the area and timing—for example, in the cold season, the nights are long and the days are short, and the sun rises in the southeast and sets in the southwest; in the hot season, the days are long and the nights are short, etc. If a survey is only made at one time, the results will be inaccurate.
2. Earth: The characteristics of the soil and its absorption capability must be understood in order to properly plan the digging of water reservoirs and making appropriate improvements. Methods must be used to rehabilitate the soil—instead of stripping the soil it should be covered with straw, leaves, or grass; it should be supplemented with both liquid and solid organic fertilizers.
3. Water: The direction of the flow of water both into and out of the area should be studied. The water reservoir should be placed in the direction of the warm wind, as this will also help make the house cooler. Reservoirs should be dug so that they wind and twist in order to increase the area that may be cultivated on their banks, as well as creating terraces within the reservoir. The first level of the reservoir should be shallow enough for the sun to reach to the bottom, to provide an ideal space for fish to lay eggs and to foster aquatic life. Aside from this, water plants should be grown to provide further space for egg-laying and habitat. A "fish sandwich" should also be created: stack grass or straw and compost in layers and place it at the water source. This will foster plankton and moina (small crustaceans), food sources for your aquatic life.
4. Air: Investigations should be made to determine which direction the hot wind, cold wind, and wind bringing rain, or monsoon wind, blows from. In general, the monsoon wind blows from the southwest, and the cold wind, or early rice wind, blows from the northeast. The house, rice-drying field, and rice-threshing field, therefore, should not be placed in the path of the cold wind. Aside from this, houses should be designed with ventilation openings in the direction of each season's wind. This will help reduce energy use in the house, as well as keeping it cool and comfortable.
5. People: This may be considered the most important factor, as the design must principally consider the needs of the people who live there, taking into consideration usefulness, their culture, and what they do for a living.

Natural Water Reservoirs

An important principal of the mound, reservoir, and paddy model of water management is collecting and containing as much rainwater as possible, and keeping it in a natural condition.

Reservoirs

A good water storage reservoir should be dug so that it twists and turns, and has varying levels of depth. This is because if you dig a square hole for a reservoir, fish have no place to lay their eggs, as they like to lay them on terraces. The depth of your reservoir should match the quantity of rainfall in your area—this information should be available through a government office website, such as that of the National Statistical Office of Thailand.

His Majesty the King Bhumibol Adulyadej has analyzed water in Thailand in great detail, and has discovered that in one year, there are about 300 days without rainfall. On days like this, when no rain falls, water will evaporate from a small reservoir at a rate of approximately one centimeter per day. In one year of 300 days without rain, therefore, three meters of water will be lost to evaporation. Small ponds or reservoirs must therefore be dug more than three meters deep, so that enough water is left over in seasons of drought or when the rain is slow to arrive. *[Eds.' Note: This is an average amount for small retention areas. Determining more precise evaporation rates of your water retention area requires further calculations. For a brief overview, see this civil engineering resource. For a more in depth understanding, please see this article at Science Direct.]*

Mounds

Take the soil that was dug out for the reservoir and use it to build mounds. On these mounds you will be able to plant a "three kinds four benefits" forest, which refers to planting edible trees, useful trees, and trees that can be used for housing materials, all of which have the additional benefit of helping to provide cool shade and maintain moisture in the area.

When planting a forest on this raised earth, trees of five heights should be planted: tall trees, medium-sized trees, short trees, shrubs, and root or tuber plants, so that their roots may weave together at many levels. The roots of plants are able to absorb rainwater beneath the soil. In addition, vetiver should be planted to help store water and prevent the soil from falling apart.

Such a mound forest, in perfect condition, will store about 50% of rainfall beneath the soil, depending on the type of soil. These mounds should be located to the west, so that they help create shade in the afternoon.

Fields

Earthen dikes surrounding fields should be raised to a height of at least one meter, so that when rain falls onto the field it is able to collect water equal to the height, multiplied by the width and the length of these dikes (height x width x length). For example, an area of one rai, or 1,600 square meters, with a dike raised to the height of one meter, will be able to collect 1,600 cubic meters of water. At least 50% of this collected water will, however, gradually be absorbed into the soil, meaning that the water remaining above the soil will be one half of the amount of rain that fell, or 800 cubic meters *[Eds.' Note: This is a gerneralization; actual amounts lost will be dependent upon many variables]*. The water beneath the soil will not disappear, however—it will help create moisture and be preserved as groundwater.

Dikes should also be built with tops that are wide and large. Not only will they perform their function of containing water within the field like a dam, but the top of this dike can also be used to plant household vegetables, or fruit trees, and other perennials.

"Chicken Guts" Canals

"Chicken guts" canals should be dug so that they twist and turn around your land, in turn feeding water to the entire property without the costly installation of pipes or sprinklers. Moreover, you can plant fruit trees and vegetables all along these canals.

Aside from this, settlement ponds should be dug at intervals along the length of these canals, also referred to as "coconut dessert wells" for water storage *[Eds.' Note: This term "coconut dessert wells is explained above in the article about Ajarn Yak, to understand this metaphor further please refer to the image at this link]*. These settlement ponds will help increase relative moisture in the vicinity, reducing the burden of constant watering.

Storing Water in Other Forms

Apart from mounds, reservoirs, paddies, and chicken guts canals, all of which are methods of storing water in a natural condition, there remain other forms of possible water storage, such as:

- Large earthen jars, or buckets are appropriate for houses with a small amount of land, where it isn't possible to dig holes, and which do not have their own rice fields. Just open their lids, place them outside beneath your roof, and connect them to your gutter so that water will run from the roof into your container. Alternatively, sheets of corrugated iron could be used for the same purpose. Or simply place buckets beneath the eaves of your

(Top to Bottom) ***Figure 1.*** *An area in the foothills: Dig "chicken guts" canals and water catchment holes to help slow the speed of the water.* ***Figure 2.*** *Reservoirs should twist and turn, and have different levels of depth so that fish can lay eggs.* ***Figure 3.*** *Soil dug up for reservoirs should be used to create mounds upon which a forest can be planted.* ***Figure 4.*** *Raise farm dikes at least a meter high, so that water can be stored within the paddy.* ***Figure 5.*** *Dig settlement ponds, spaced regularly, for water storage.*

roof, which will collect the water running off it.

- Water tanks are appropriate for storing water in areas with limited space, or in instances where water needs to be taken to a high elevation. Place the water tank at a high elevation and use a solar powered pump to bring the water up into the tank before releasing it down into the "chicken guts" canal. This will help save energy. Such a water tank can be built using local practices and materials; for example, by using woven bamboo for the structure and then plastering it, or by stacking circular concrete rings on top of each other and plastering them, etc.
- Check dams can be built in waterways or chicken guts canals, which help check the speed of the water flow and perform the function of catching sediment before it enters your reservoir. Farmers are then able to take the sediment and use it to create fertilizer.

Method of Calculating Water Quantities for an Area

What a landowner must know in order to calculate the volume of rainfall their land will receive in a given year is the size of the area and the volume of rainfall. For these calculations, an area in meters should be used, as rainfall volumes are measured by a rate of millimeters per year.

Please note the following units of measurement referred to in this article:

- 1 square wah = 4 square meters
- 400 square meters = 1 ngaan
- 4 ngaan = 1,600 square meters = 1 rai

Example rainfall calculation:

- Area: 1 rai = 1,600 square meters.
- Volume of rainfall in the area: 1,200 mm/year, or 1.2 meters/year.
- Therefore, the yearly rainfall in this area = 1,600 square meters x 1,200 millimeters = 1,920 cubic meters.

When we know the volume of rainfall, we must then calculate the area required to store it—is what we have sufficient or not?

Example water storage calculation:

- Suppose that in one year, 1,920 cubic meters of rain falls on our land.
- In one year, there may be 300 days without rainfall, and on those days the water will evaporate at a rate of at least 1 centimeter per day. At least 3 meters of the rainwater collected will therefore evaporate in a given year. A reservoir must therefore be dug deeper than 3 meters.
- Water holding capacity of a water storage reservoir = width x length x height (depth).
- If a reservoir is 20 meters wide, 10 meters long, and 6 meters deep = 20 meters x 10 meters x 6 meters = 1,200 cubic meters.
- The earth that is removed to create the reservoir should be piled up to create a raised mound 20 meters wide, 10 meters long, and 6 meters high.
- Upon this mound shall be planted a "three kinds four benefits" forest, which will help store beneath the soil surface approximately 50% of the rainwater, or approximately 600 cubic meters.

If it is necessary to increase the amount of water collected, it is possible to do so in your rice paddies and to dig additional chicken guts canals throughout your property.

Example of calculating additional collection areas:

- Create a rice paddy 1 ngaan in size (400 square meters). Raise the earthen dikes surrounding the paddy to a height of 1 meter. 400 square meters x 1 meter = 400 cubic meters.
- Dig chicken guts canals 1 meter wide x 0.8 meters deep x 30 meters wide = 24 cubic meters.
- Together, the reservoir, mounds, paddies, and chicken guts canals (respectively) are 1,200 cubic meters + 600 cubic meters + 400 cubic meters + 24 cubic meters = 2,224 cubic meters.

Therefore, if land is designed based on this example, on an area of one rai it would be possible to collect 115.83% of rainfall. This water collection process can take place even when the dam gates are closed, simply by collecting additional water whenever it rains. *[Eds.' Note: These calculations are for demonstration only. Actual water retention/evapuration measures are dependent upon many variables (soil type, gradiant level, inflow/outflow, surface area: volume ratio of reservoirs, etc.) There are many good hydogeology books available where readers can learn more].]*

Water Management for Drought and Flooding Resiliency

Designing an area so that it can collect all the rainfall it receives using this mound, reservoir, and paddy model will help provide farmers with water when the rain does not come. At times when there is flooding, these mounds, reservoirs, paddies, and chicken guts canals will act like "coconut dessert wells" and help retain the water, stopping it from overflowing into the neighboring area, and reducing the amount that will ultimately flood into other places.

If we had people take the time to make just a hundred thousand of these "coconut dessert wells", it would use less than 10% of the entire land of the Pa Sak basin. But it would mean being able to mitigate flooding, stop drought. It's an example of how we really can solve this national crisis."

Figure 6 & 7. *Large earthen jars and buckets, useful water-storage containers on small properties.* ***Figure 8.*** *Water tanks made of woven bamboo and plastered with concrete.* ***Figure 9.*** *Check dams help slow the speed of water flow, as well as storing moisture and catching sediment.*

A Small Farm Water Management Case Study: Fighting Climate Change and Promoting Self Sufficiency

Reprinted with permission from the Natural Farming Journal, September 2015
Translated by Patrick Fitzsimons, ECHO Asia Impact Center

"This year the water in the Pa Sak Jolasid Dam was so low you could see the temple ruins, trees, old buildings; all of it. It was a serious water crisis, but if it had gone another half a month without rain, the crisis would have been even worse. Because we don't have any fresh water, we can't build potable water infrastructure; we can't create drinking water. Water is essential, both for consuming and using. We campaigned for nine days about one issue: water. Some places didn't have water for showering or cooking. It was a real crisis. We went to ask for water from other people, but they didn't have any either. That's how bad the crisis was." These are the words of people from the Pa Sak water basin about the state of this year's water crisis. Nevertheless, there are ways to manage our land so that we can survive droughts like this, by means of the "mound, reservoir, and paddy model", an example of micro irrigation which has been implemented in Tambol Nong No, Amphur Muang, Saraburi Province, Central Thailand.

"For this area we've now calculated that we can collect 300% of our water. First, from rain; second, from released irrigation water; and third, water from people who haven't collected it; who don't have reservoirs. This allows us to release and distribute water to the whole of our farm," says Mr. Bunlom Taokaew.

Farming Only Rice Means Debt; Integrated Farming Means a Sustainable Livelihood

Mr. Bunlom Taokaew is the son of rice farmers. He chose a career as a businessman after he finished school. Because he didn't make enough of a living, he went into debt to the order of hundreds of thousands of baht. He borrowed money from his father, a farmer using integrated farming methods, many times to repay his debts, until finally his father told him to return to being a farmer instead. Mr. Bunlom decided to take his advice, but he didn't believe farming would help relieve him of his debts. He started by building a structure to cultivate oyster mushrooms, which didn't require a large investment, and little by little he started to produce enough to sell locally, reducing his living costs, until there was enough money left over to save, and until, finally, he was able to repay his debts. His sustainable life began more than ten years ago. It was a result of following in the footsteps of His Majesty the King, and his own father, who set an example he could follow.

Go back twenty-five years and look at this same twenty rai (3.2 ha), near one of Thailand's many "Centers for Sufficiency Economy Education". This twenty rai had only ever been used to cultivate rice with chemical fertilizers. During years that it rained and there was plenty of water, enough rice could be sold to live off and repay debts. But any year there was drought, debts would pile up. The more they farmed, the more debt they would fall into. Therefore Mr. Bunleu Taokaew, the head of the family, decided to stop renting extra fields and focus on getting the most benefit out of the twenty rai he owned. He did this by listening to talks about new agricultural theories at the Wat Mongkhol Chai Pattana temple, where His Majesty the King had also set aside land to establish an example of these principles. Every time he went to these events, he came home and adjusted his land. Especially important was creating places water could be stored for later use, helping free him from his sole reliance on irrigation, as had been the case in the past, and move him from monocropping to integrated farming.

Dig a Reservoir Both Deep and Shallow; Let it Wind Around Your Property; Your "Chicken Guts" Canals Will Feed Water Throughout the Area

As water is such an important factor in agriculture, the talks at Wat Mongkhol Chai Pattana made him decide to make his original reservoir wider, and to dig a new reservoir, so that he would only have four rai left over to farm for household consumption. However, when Mr. Bunleu dug the new reservoir for the first time, he still lacked a lot of knowledge and understanding about reservoir-digging. All he knew was to use a backhoe to dig straight down and 6-7

Figure 1. *The first reservoir dug for water storage, in a square shape.*

meters deep, in the shape of a square. It was good enough for storing water, but that was about it (Figure 1).

Later, once he went to study with Ajarn Wewat Salayagamthorn at the Agri-Nature Foundation, he came to understand that a good reservoir should share the characteristics of waterholes found in nature—having varying levels of depth, so that living things, both plants and animals, are able to develop inside, instead of being used solely to store water. When he expanded the reservoir once again, he dug it to conform to the condition of the area around it as much as possible.

"Of this twenty rai, in the past I dug out about one rai, which including the ditches around the farm, amounted to about three rai, but not dug in the same place. This year I dug more because we haven't had enough water, because this year we had the drought. Look here, the water we use for the plants and animals, for our household consumption, it was dry. It was a total crisis. The ditches on the farm were all dry, and in the big pond only about a meter left. If it had been another half a month without water, and if they hadn't released the irrigation water to help us, we'd have died. We wouldn't have had any water to use. We had the Lat Krabang's method of calculating how much water we use for consumption; how much water we use to farm rice; how much we use to raise the animals, plant the vegetables—so that one plot, say, needs a reservoir dug how deep, requires just how much water.

"This year we dug at an additional two spots, because we already saw that if there was another drought like the one this year, there wouldn't be enough water with just the big reservoir we had. So we dug more, so that we might have water we could use the whole year, including any seasons the rain doesn't come. Ajarn Yak says that out of 365 days, only 60 will rain. 300 won't. And he says that water will evaporate at a rate of 1 cm per day. So we can see that a reservoir only 3 meters deep won't be enough, because all its water will evaporate. So we added a new reservoir, so that we can match the amount we need to use on our land to our storage capacity.

"Our new reservoir isn't square, like our old one. Once I'd seen Ajarn Yak's, seen the Lat Krabang design—they didn't waste space. We dug a reservoir that took the shape of our area, twisting and turning (Figures 2-5). We planted vegetables and other edible plants all along the sides. By volume, it's as big as our big square reservoir, but we didn't have to waste any single space to dig it. Ours has tight turns, deep turns. We can see that the fish lay eggs—fish like tilapia, silver barb, they don't lay eggs in deep water. They live in shallow water, no deeper than 2 meters. They grow well, and grow fast. It's because they need to rise and breathe at this level. The water plants, meanwhile … If the water is really deep we don't get anything to eat—it's only good for storing water. But if we have a shallow level, various water plants can grow, like pandan and vegetable fern. They'll grow in depths of about a meter. This means another food-source in our reservoir. Plus they help prevent it from collapsing. If you go look at the first reservoir we dug, there are no plants growing in it at all. No morning glory. All it does is hold water. But when you come and look at shallower areas, you see food, as well as somewhere to put our water."

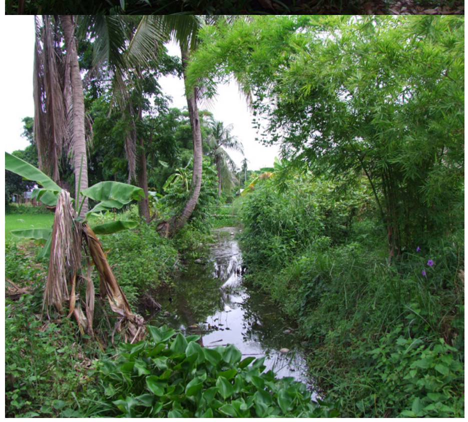
The newly expanded reservoir has three depths: a shallow level of 1-1.5 meters; a middle level of 2-3 meters; and a deep level, from 4-5 meters to 8-9 meters. This reservoir feeds the "chicken guts" canals or any smaller canals connected to it. It waters all the plants on the property—everything in the rice fields, vegetable gardens, fruit trees plots, bamboo forest—the entire year.

As well as rainwater, and water from the irrigation canals which can be released into the property, there is another source of water Bunlom can collect and use: water which hasn't been collected on surrounding properties. This is a large amount: twice as much as what he collects.

"For this area, we've now calculated that we can collect 300% of our water. First, the volume of rainfall in Saraburi amounts to 1,200 mm per year. Second, the irrigation water released amounts to the second part. And third, water from people who don't collect it. We get it from here—they don't have a reservoir, so we take all the water that comes onto our property. We've already dug canals all around the outside of our property, so we therefore have canals in all directions. However, the water must first pass through the small canal on our perimeter, and be filtered. We use the Bhumirak principle: let one evil subdue another. We use water hyacinths for filtration. And our reservoirs are earth reservoirs; we use earth as a filtration agent. We also add fermented plant juice liquid and banana-shoot microorganisms every one or two months, to adjust the water condition," says Bunlom.




(Top to bottom) ***Figure 2.*** *The additional reservoir that was dug this year. It twists and turns with the characteristics of the land, and varying levels of depth, which also imitates natural conditions.* ***Figure 3.*** *Irrigation ditches bordering the property collect water from surrounding areas, as well as helping to demarcate boundaries.* ***Figure 4.*** *Chicken guts canals or irrigation ditches help distribute water throughout the property.* ***Figure 5.*** *In irrigation ditches, frogs can be raised for consumption and sale. Plant water hyacinths to improve the water. Rice straw mushrooms can also be cultivated in the baskets.*



(Top to bottom) ***Figure 6.*** *A model of a mound planted with vegetables and perennial trees. A house can also be erected here for shelter during flooding.* ***Figure 7.*** *Raise dikes to a height of one meter. When water floods your paddies it will be collected.* ***Figures 8 & 9.*** *When there is abundant water, vegetable crops, and trees, your farm will always be lush.*

Raise Earthen Dikes; Store Water; Mold Large Dikes; Plant Edible Vegetables

As well as storing water in reservoirs, rice paddies and mounds can also be used to collect water.

"When we first implemented the new ideas, we divided our land: for digging our reservoir, for farming rice, for growing vegetables, for raising animals, and for living. At first we thought our reservoir would depend on irrigation water releases and rainfall,;that they would both keep it full. But then came the floods of 2011. It flooded, the water overflowed, and we didn't know how to solve the crisis. Now, this year, it doesn't rain, and so there's no water in the dam. Because there's no water in the dam, they can't release any water for us. So now we're facing a drought crisis. three years ago I learned about the Follow in the King's Footsteps Project, which brought up the "mound, reservoir, and paddy model" theory. I was able to go and study there, learn with Ajarn, and saw what this "mound, reservoir, and paddy model" meant.

"Digging a reservoir and making calculations based on your own area was done using the Lat Krabang principles. You could take these and calculate how much land you had, and so how deep and wide you should dig your reservoir, in order to have enough water for your particular area. In the past the top of earth dikes were small and short, and were only to secure the rice paddy. They weren't considered ways of storing water for later use, so we were always pumping water into our rice plots. But then I learned that they needed to be built bigger. They had to be raised up: about one meter wide and one meter tall. At first I wondered why they had to be so tall. But then I came to understand the principles. As well as enabling us to collect water inside our rice fields, making the top of our dikes bigger meant we could plant vegetables there, or other edible or useful plants we wanted to grow. Instead of simply being a dike that helped store water, we had this group of plants which brought a host of other benefits. So in one rice paddy, we didn't just have rice, but we had crops on the dikes (Figures 6-9). We had food, and we had income during those 4 months we spent looking after our rice. We turned these crops into income. We came to see rice as just one part of what we did; on the top of our dikes we had a lot more than rice.

"With high dikes, we had a high level of water. Weeds didn't grow in our rice paddies because they were flooded with water. So the rice sprang up, taller and taller, to catch up with the water level. It's therefore a good way to control unwanted weeds, without putting herbicides into our fields. We're farming organically!"

An Area's Design Must Consider Earth, Water, Wind, Fire, and People

For anyone who has land they want to redesign in order to more efficiently manage and control water and land use, there are some principles that must be considered.

"Important factors in assessing your area are: earth, water, wind, fire, and people. Earth: you must investigate what kind of soil you have. Water: at what points does the water flow onto your property, and from what direction. Wind: this is important for the location of your house. Wind comes from two directions: the southwest wind blows in the rain. The north wind, the cold wind, comes from the northeast. When the north wind blows, we know it's time to harvest our rice—around December, January. It will blow the rice debris into our house. We call it the early rice wind. If we plant our fields, and then build our house in this direction, we're going to be full of rice dust. Or, build our house somewhere that receives the sun on both sides—both east and west—and it'll be hot all the time.

"Fire means sunlight. To the east and the west we should plant trees, wherever they're needed—don't just let your house be hot all the time. In our rice paddies, we can also plant fruit trees on the dikes. If we plant to the east and the west, the shadows of the trees will reach over the paddy, creating shade. If we plant to the north and south, the sunlight will pass right over the dikes, and the shade won't enter the paddy. Therefore you can plant tall trees to the north and south, but to the east and west you should only plant short trees.

"The most important factor is people. The design must satisfy the people who live there. Take this theory and work out what the people want to do, and how. If we do all the thinking for them, it'll mean they won't like the area we design. So it's obvious that the human factor is the most important of them all," says Mr. Bunlom, about the principles of design.

"Every house should have a "coconut dessert well". A hundred thousand would collect as much water as a dam."

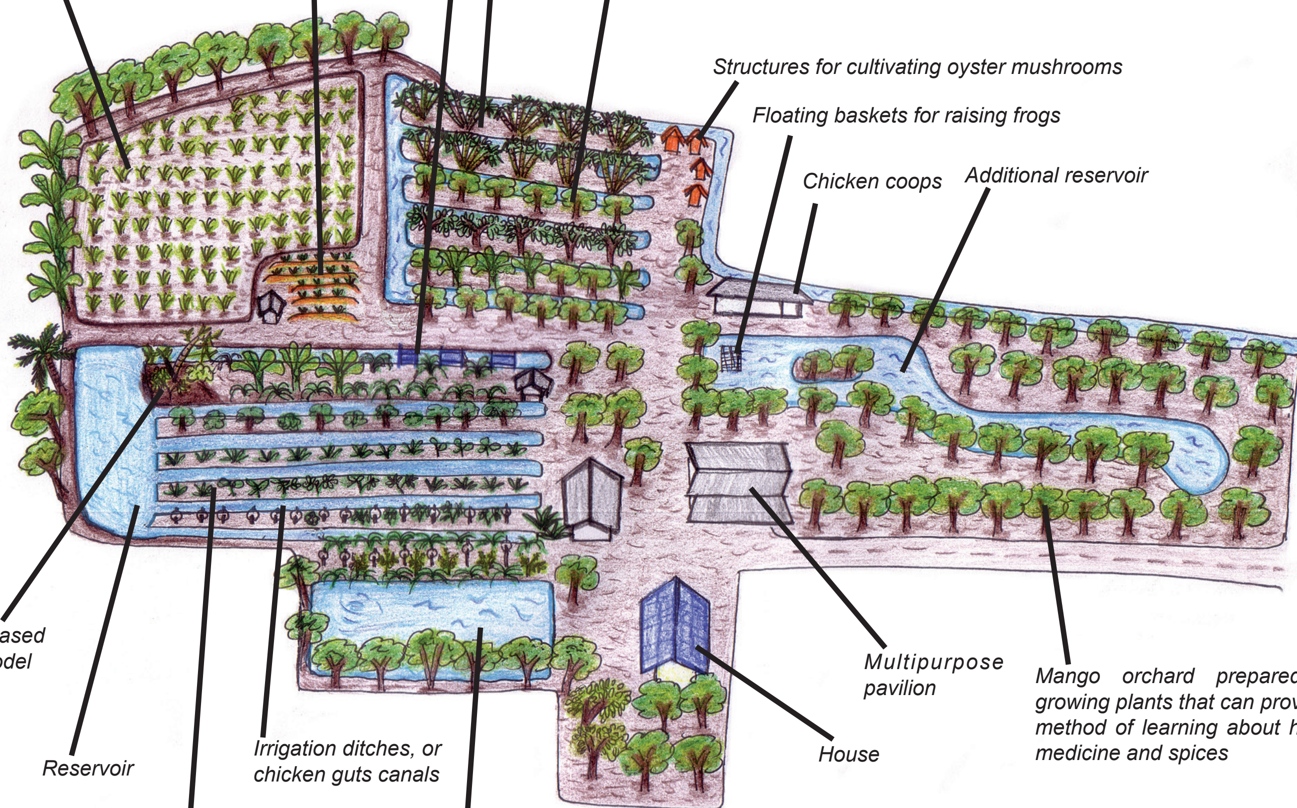


Figure 10. *An illustrated map of Mr. Bunlom's farm.*

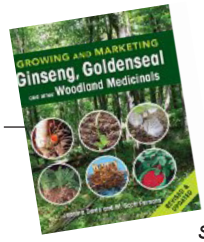
The benefits of managing water and land according to the principles of the mound, reservoir, and paddy model, aside from producing good results for the owner of the land, will also produce good results at a regional level, and a national level too.

"Creating mounds, reservoirs, and paddies are all forms of water storage. They will help both flooding and drought. If there is flooding, we can draw water in and store it on our land. We have areas to do that, and it won't flow down and find people in Bangkok. If we could collectively implement this model about a hundred thousand times in the Pa Sak water basin, it would be equal to the capacity of the Pa Sak Jolasid Dam. We'd have a dam, without ruining the forest, without appropriating land, without affecting those communities that live on that land, without all the protests—by using just the land we already have. And, what's more, the land we use for it will bring us other benefits. If we can do even more than this, we'll have the equivalent of an even bigger dam; or maybe you can only make a medium-sized reservoir—it will still keep us out of hot water. When it rains, the water can fill our reservoirs.

"Another thing: the theory of the "coconut dessert well tray". When it rains, the water will be stored in each hole, or well in the tray. This is like Ajarn Yak says: if Saraburi were a coconut dessert tray, and each and every hole collected water, some deeper and some shallower, according to each person's land, the water would no longer overflow and flood people down in Bangkok. But at the moment, we fill in all our holes to maximize our land area, so the water is flooding over a flat plain: 100 liters comes, and 100 liters passes on. But if we dug these holes, the water would flow into each hole, it would be spread out, it would be stored in the area of Saraburi. The zone beneath us wouldn't experience flooding. This is done by storing water on our own land for later use, whether that means with canals, on earthen dikes, in rice paddies. Even mounds are able to collect water, by planting various trees on them—like a mountain: when it rains, absorbs water in its soil, which later seeps down bit by bit, turning into drops, each tree releasing drops of water, bit by bit, which turn into a stream, and flow down to find the villagers."

Giving up a field or a piece of farm land for water storage in the form of a reservoir, paddy, or mound, aside from being a way to attain water self-sufficiency, is also a way to improve the efficiency of water management in the bigger picture. It's a worthy investment that farmers should all consider.

If interested, visit this area and ask for more details. Mr. Bunlom Taokaew can be contacted at 84/2 Moo 7, T. Nongno, A. Muang, Saraburi, 18000. Telephone: 08 9050 1812.



Book Review: Ginsing, Goldenseal and Other Woodland Medicinals

Review by Craig Soderberg

[Editor's Note: Reprinted with permission from Appropriate Technology and Craig Soderberg.]

Ginseng, Goldenseal and Other Woodland Medicinals, by Jeanine Davis and W. Scott Person. Published by New Society Publishers, www.newsociety.com. ISBN 978-0-86571-766-4

With 508 pages of helpful information, this book is a great resource for agricultural tips. There are 37 chapters: (1) American ginseng: Its life cycle, range, related species, and government regulations, (2) History of the ginseng trade: Ancient China to the new millennium, (3) Under artificial shade, (4) Wild-simulated planting, (5) Woods cultivation, (6) The harvest: Picking berries and stratifying seeds, digging and drying roots, (7) Business decisions and the future market outlook, (8) A grower tells his own story: Oscar Wood, (9) Ginseng resources, (10) Ginseng references, (11) Goldenseal: Its history, range, description, uses, and government regulation, (12) Goldenseal growing instructions: Methods, care, protection, harvesting, and marketing, (13) Goldenseal growers' stories, (14) Ramps: History, description, and uses, (15) Ramps growing instructions: methods, care, protection, harvesting, and marketing, (16) Ramps growers' stories, (17) Bethroot, (18) Black cohosh, (19) Bloodroot, (20) Blue cohosh, (21) False unicorn, (22) Galax, (23) Mayapple, (24) Pinkroot, (25) Spikenard, (26) Wild ginger, (27) Wild indigo, (28) Other forest botanical growers' stories, (29) Making the perfect woodland garden site, (30) Choosing the plants to grow in your garden, (31) How to grow a garden in the woods, (32) Ginseng - a horticultural challenge, (33) Making some simple products from your woodland medicinals, (34) Home gardener's stories, (35) What is wild-harvesting, (36) Why there will always be a place for wild-harvesting, (37) Rules and regulations for wild-harvesters. The supplemental information in the book includes seven helpful appendices.

This book will be of interest to many gardeners or potential gardeners because (according to one of the authors) with little capital investment, the small farmer can net a greater profit growing ginseng on a rugged, otherwise idle, woodlot than he can net raising just about any other legal crop on an equal area of cleared land.

Chapters 1 and 2 provide background information, much of it essential to the grower including plant botany, life cycle, habitat requirements, range, and related species.

Chapters 3 through 7 (in part 2) cover the three basic methods of growing ginseng (including rough production budgets for each), the harvesting and processing of seeds and roots, and the important business decisions you need to make. It also includes how to select and prepare a planting site, how to acquire planting stock, what problems we are likely to encounter, and how to prevent or deal with them. In chapter 8 there is an interview with a man who was successful growing ginseng with his own individual methods. Chapter 9 (ginseng resources) lists root buyers, sources of planting stock, consultants, ginseng related organizations. Chapter 10 (ginseng references) provides a listing of selected ginseng literature and websites.

Chapters 11 through 37 relate to other woodland medicinals. The primary one covered is goldenseal. Chapter 11 covers the history, range, description, uses and government regulation of goldenseal. Chapter 12 covers goldenseal growing instructions. Chapter 13 provides goldenseal growers' stories. Chapters 14 through 16 discuss another medicinal called ramps. Chapters 17 through 28 also have a chapter on each of the following other medicinals: Bethroot, Black cohosh, Bloodroot, Blue cohosh, False unicorn, Galax, Mayapple, Pinkroot, Spikenard, Wild ginger, and Wild indigo.

Some of the remaining chapters in the book (chapters 29-34) discuss making the perfect garden site for medicinal plants, choosing the plants to grow in your garden, how to grow a garden in the woods, ginseng - a horticultural challenge, making some simple products from your woodland medicinals and home gardener stories.

Chapters 35-37 discuss sustainable wild-harvesting including 'What is it? (chapter 35), Why there will always be a place for wild-harvesting (chapter 36), and the rules and regulations for wild-harvesters (chapter 37).

This book would be most appropriate for experienced gardeners who want to branch out into a new area (medicinals). But with the right training, it could be helpful to someone who is just getting into gardening for the first time.

Upcoming: Myanmar Agriculture & Community Development Workshop

February 2-5, 2015: Pyin Oo Lwin, Myanmar

ECHO Asia, in conjunction with the CSSDD (social development arm) of the Myanmar Baptist Convention will be conducting a Myanmar Agriculture and Community Development Workshop in Pyin Oo Lwin, outside of Mandalay, from February 2-5, 2016. Anyone working in agriculture and community development is welcome and encouraged to attend. Topics covered will be broad and applicable to communities throughout Myanmar.

For more information and to register, please see ECHOcommunity.org.