DEVELOPMENT OF A SUITABLE LOW WATER PLANTATION MODEL IN UBON RATCHATHANI

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A Dissertation Submitted in Partial
Fulfillment of the Requirements for the Degree of
Doctor of Philosophy (Environmental Management)
The Graduate School of Environmental Development Administration
National Institute of Development Administration
2023

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ABSTRACT

Title of Dissertation	DEVELOPMENT OF A SUITABLE LOW WATER PLANTATION MODEL IN UBON RATCHATHANI
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Degree	Doctor of Philosophy (Environmental Management)
Year	2023

The study of suitable low-water planting plots in Ubon Ratchathani Province aimed to study the prototype of water-less planting plots from garden waste using the Hügelkultur technique for dry areas in Ubon Ratchathani Province, to study the factors affecting the planting of plants in the field, to evaluate the water footprint and carbon footprint of the study plots, and to suggest the guidelines for applying the model low-water planting plots, and expanding the results to drought-prone areas in Ubon Ratchathani Province. The CRD experiment was planned for seven treatments with three replications. Moreover, compared to giving water two times/per day, morning-evening at the rate of 1 1.25 and 1.5 liters/time and giving water in the morning or evening one time per day, 3 liters/time.

All plots are prepared for kale growing by using cement - pipe 80 - cm. diameter and 50- cm. height. At the bottom of cement - pipe, there were layers of 20 - cm.logs, 5- cm. leaves mixed with coconut coir, 20-cm. of soil mixed with manure and 5-cm. rice straw. The study compared the experimental and control plots containing only soil mixed with manure.

The study found that the embankment plots had the values of the environmental factors of the plots in the range suitable for the growth of kale. Soil moisture values in the plots in the experimental set with different watering methods. There was no significant difference in the 14.48 – 16.47 soil temperature values range. There was no significant difference between the mean values of 31.50 – 33.87.

The pH value was averaged between 7.0 – 7.4, which was not significantly different at the 0.05 level. Soil moisture had a high positive correlation with soil temperature. Nevertheless, not correlated with pH, and soil temperature had a high correlation with soil pH.

Macronutrients in the soil, both total nitrogen available phosphorus, and potassium that are beneficial to plants Both before and after planting kale were very high.

The organic matter values were high before planting and decreased after planting but remained high, probably due to the decomposition of the wood, leaves, and rice straw used to prepare the plot. The hügelkultur plot (WT1, WT2, and WT3) given water two times/day (1.5 liters/time) had a water footprint of 118.92 – 224.48 cubic meters/ton. WT4 and WT5 provided one time/day (3 liters) of water. equal to 319.20 and 313.47 m3/ton TC equal to 352.59 m3/ton. Hügelkulturs has a carbon footprint between 229.88 and 319.20 kgCO2eq/kg.

The low-water planting plots gave the highest vegetable yield (WT1) at 2.44 tons/rai with appropriate moisture content between 15.33 -16.67 percent and the soil temperature between 27.00 - 34.33. degrees Celsius, pH between 6.5 -7.9, with high macronutrients and organic matter, which is the ridge plot that provides water two times/day, 1 liter each time, a total of 2 liters/day.

When the plots mentioned above were presented to organic vegetable growers in Ubon Ratchathani province, it was found that everyone was concerned about preparing materials for the plots because it took a long time to collect. Nevertheless, most farmers can get the material by cleaning the garden or pruning the bushes in their homes.

ACKNOWLEDGEMENTS

This thesis can be completed successfully. Best regards, Assis. Prof. Dr. Kalika Kanta, Prof. Dr. Chamlong Phoboon, and Prof. Dr. Wisakha Puchinda advised completing this study and suggested guidelines for checking and revising. Thank you to all the researchers.

The researcher would like to express his gratitude to Assoc. Prof. Dr. Sayam Aroonsrimorakot, Chairman of the Dissertation Examination Committee, for kindly giving advice and suggesting guidelines for the research to be complete.

I am grateful to all the sixth and seventh doctoral course students, including Dr.Suwanee Mishita, Dr. Panuwat Onset, and Dr. Sasamon Mantaray. Thanks to Ms. Benjaporn Pitpeng from the Faculty of Environmental Management for their cooperation. Lead, track, and advance your journey of exploration.

I salute my father and mother for motivating me to keep going. Thanks to my family, my wife and children have always supported me.

Special thanks to the administrators of Ubon Ratchathani Rajabhat University. The Human Resources Development Fund is supporting grants to continue this research. I want to thank the administrators of the Faculty of Science and brothers and sisters in the environmental science program. as well as the disciples who supported the success of this research.

I want to dedicate all the good deeds from this research to all its patrons, fathers, mothers, teachers, brothers and sisters, friends, students, and informants. It also includes those who provided academic knowledge to researchers. May the virtues of this time inspire all to experience only the good in eternity.

WATTANACHAI MALAI

April 2024

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CHAPTER 1

INTRODUCTION

1.1 Significance and Origin of The Problem

Ubon Ratchathani Province is Located 629 kilometers from Bangkok, with an area of approximately 15,744.9 square kilometers or 9,840,531 million rais, representing 9.5 percent of the northeastern region. It is the region's second-largest area and the country's fifth-largest province. It borders the Lao People's Democratic Republic for 428 kilometers. In 2022, the province is divided into 25 districts with 219 subdistricts and 2,704 villages. There are 239 local government organizations divided into 1 city municipality, 4 city municipalities, 54 tambon municipalities, 1 provincial administrative organization, and 179 subdistrict administrative organizations. There are 1,868,519 people in 642,015 households. (National Statical Office [NSO], 2023)

In the year 2022, Ubon Ratchathani Province has a total area of 10.07 million rai, with a total of 311,370 agricultural households, with a holding area of 9,471,483.08 rai, categorizing the land use as agricultural area in the amount of 5,894,125 rai (58.49%), divided into rice farming area 4,219,284 rai, farming area 681,250 rai, and fruit trees area 503,705. 722 rai of ornamental flowers and plants, 34,238 rai of vegetables and 454,876 rai of other agricultural areas, 605,337 rai in the irrigated agricultural area, representing 5.66 percent, and 5,288,788 rai in the non-irrigated agricultural area, representing 94.34 percent of the provincial agricultural area.(OPSMOAC, 2023) The agricultural area is comprehensive, and the population is engaged in agriculture more than other occupations. Preventing and alleviating drought problems due to lack of water for consumption by consumers and agriculture is a phenomenon that occurs in almost every area of the province. In the dry season, natural water sources will decrease and eventually dry up, causing people to suffer.

In the year 2021, in Ubon Ratchathani Province, there are 325,837 rai of drought risk areas, divided into 79,842 rai of low-risk areas, 73,270 rai of medium-risk areas, and 172,725 rai of high-risk areas. (LDD, 2021) Some areas have experienced repeated drought more than three times in the past ten years, covering the entire province and 215 sub-districts in 25 districts. (LDD, 2020)

Factors influencing drought in Ubon Ratchathani Province are global climate change, global warming, a severe global problem caused by human activities. The leading causes of global warming are Greenhouse effect emissions such as carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) into the atmosphere, trap heat from the sun, warming the world causes of global warming include burning fossil fuels such as coal, oil, and natural gas. Burning fossil fuels releases carbon dioxide, a greenhouse gas contributing to global warming. Forest absorbs carbon dioxide from the atmosphere, but deforestation releases carbon dioxide back into the atmosphere. There different sources of greenhouse gas shus as animal farm, industry, transportation, land use change. Global warming is a global problem that affects every country. Global warming will cause extreme weather changes such as heat waves, droughts, floods, and storms. Climate change will affect ecosystems, agriculture, the economy, and human health (Network, 2021).

Guidelines for reducing greenhouse gas emissions into the atmosphere include reducing forest degradation, carbon sinks, reducing carbon emissions stored underground, soil carbon sequestration, and ocean carbon sinks. Nevertheless, today people are doing the opposite, destroying even more forests. Burning carbon stored in the soil in the form of fossil fuels is a constant process. In agriculture, open-burning carbon emissions occur throughout the production process. Since the area's opening, pruning has been practiced clearing the cultivated land, especially in the countryside. Cities burn less than rural areas, but pruned gardens end up in landfills, producing more insulating methane than carbon. Managing waste from the source is one of the approaches that should be followed to solve the problem of increasing waste that leads to increasing greenhouse gases. Organic waste and twigs resulting from pruning of house trees is biodegradable waste, returning nutrients to the soil. It helps the soil become more fertile. If these organic wastes are separated from garbage and used to make planting materials or compost, the amount of waste that needs to be sent to landfills will be reduced. The number of collection trips will also be reduced, resulting in the use of fuel for transportation and reduced operating costs. This will also lead to fewer greenhouse gas emissions.

Branches and leaves can be used in several ways, such as using large branches for construction, chopping compost, and making various plant materials. Planting on mounds, or Hügelkultur, is one of the farming methods observed in nature by Sepp Holzer (Teerapan, 2012), In forests, fallen leaves piled up on fallen trees decompose and become piles of moist soil. More fertile than surrounding areas, especially during extended dry seasons. This concept has been adapted for use in the agricultural sector. It creates long-lasting planting without frequent watering and ditching like regular plantings. Permanent planting or permaculture with such features, which many call the art of creating plant beds that mimic nature, is widespread in Europe and Australia. Before being used in Thailand. However, this method is used only by the local wisdom group and has yet to be widely or generally accepted in Thailand. Further, this topic is needed in the province of Ubon Ratchathani (Teerapan, 2012).

Ubon Ratchathani has certain sections with thin soil. Some rocks cannot be grown during the dry season, due to global climate change. Ubon Ratchathani province experiences more frequent and recurrent drought areas. To prepare for drought disaster, Hügelkultur approach can be applied in Ubon Ratchathani. Every reason, clearing the land in preparation for planning is regarded as garden trash that must be disposed of for use. Hügelkultur supports also reduction of carbon emission into the environment.

Hügelkultur method is only employed in Thailand while creating permaculture for the natural farming group. Only one case was in Google Scholar, and this strategy was limited to planting plots throughout the research. It was also impossible to search the ThaiLIS database for it. As a result, the researcher has the notion to investigate the design of planting plots created once and utilized over an extended period. Compared to typical crop cultivation, use less water for cultivation. Can cut down on production-related carbon emissions. In this study, kale was utilized as a model vegetable since it is popular year-round and is frequently consumed in the study location.

1.2 Research Questions

1) What is a prototype of a plant plot that uses less water with garden waste using the hügelkultur technique, which was an element suitable for the area of Ubon Ratchathani Province?

2) What are the prototype planting plots' water footprints and carbon footprints that use less water?

3) What are the guidelines for applying prototype planting plots that use less water and expand the results to other areas?

1.3 Research Objectives

1) To study factors affecting the cultivation of plants in low-water use by Hügelkultur in Ubon Ratchathani Province.

2) To assess water footprint and carbon footprint for Hügelkultur in Ubon Ratchathani Province.

3) To propose guidelines for the Hügelkultur application in drought-prone areas in Ubon Ratchathani Province.

1.4 Scope of the Study

1.4.1 Scope of Area

This study aimed to develop a prototype of a plot for low-water consumption crops in Ubon Ratchathani Province. The planting plot was located at 19, moo. 6, That Subdistrict, Warin Cham rap District, Ubon Ratchathani Province. The study was conducted in 6 districts, consisting of Khong Chiam, Sri Mueang Mai, Kut Khao Pun, Trakan Phuet Phuet, Samrong, and Nam Yuen.

1.4.2 Scope of Time

Project implementation period 2 years from December 2018 to December Project implementation period two years, from December 2018 to December 2020

1.5 Study Process

This research consisted of three stages of study:

1) Literature review to search for and review information related to past research, including theories, knowledge, and related research.

2) Creating prototype plots to study related factors, control the rate of water use in the planting fields, find the relationship between the variables and the growth rate and yield of vegetables, and summarize plot for planting less water plants suitable for the area of Ubon Ratchathani Province.

3) Find ways to implement prototypes of planting plots that use less water through in-depth interviews.

1.6 Definitions of Terminology

Planting plots that use less water means planting plots made using the hügelkultur technique, made of high ridges, using logs, branches, leaves, compost, and material waste, including household food scraps. The material is the core and uses less water for cultivation.

The Hügelkultur technique refers to making plant plots using logs or sticks, leaves, and grass piled up as a base and forming a vegetable plot for growing vegetables or doing other benefits in organic agriculture.

Water Footprints (WF) indicate direct and indirect amounts of water consumption from production until the product reaches the consumer. This study will consider the water footprint from growing plants that use less water. It is a water-saving crop that uses less water than conventional crops.

Carbon Footprints (CF) means the scientific value that calculates the amount of greenhouse gas emissions from products or various activities into the atmosphere, calculated in the form of carbon dioxide equivalent, which measures emissions of greenhouse gases, both direct and indirect, in this study. It considers carbon emissions throughout the kale production cycle. There is compared to the carbon emissions from landscaping by incineration or landfill in municipal landfills.

Garden waste means organic waste such as dry grass, leaves, and twigs arising from area adjustment pruning, including pruning trees along the power lines and city parks that the municipality must dispose of, especially in urban areas.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the researchers conducted the study under the Theory and research related to developing suitable low-water crop plantations in the Ubon-Ratchathani province, areas with water scarcity outside the rainy season. Adopting a less-water cropping scheme focusing on self-reliance and living in a balanced ecosystem will lead to better life quality for people in areas. This will reduce encroachment on natural areas and be able to utilize existing areas effectively. The researcher studied the concept by planting plants on a mound (Hügelkultur).

2.1 Soil Resources

Soil is an object that plants use to hold roots to send the stems to grow. Soil resources are formed by the decomposition of the source material, namely rocks and various fungi mixed with various organic matter caused by the decomposition of humus.

2.1.1 Soil Composition Contains Four Main Components:

1) Inorganic 45 percent are the solids that make up the ground texture.

2) Twenty-five percent of air contains nitrogen (N_2), oxygen (O_2), and other gases plant roots and microorganisms use to breathe.

3) Twenty-five percent water, commonly referred to as soil moisture, is water in the soil texture and soil gap, which regulates the temperature of the soil and dissolves various minerals in the soil for plants to use. Which regulates the temperature of the soil and dissolves various minerals in the soil for plants to use.

4) Organic matter or humus 5 percent is the part that makes the soil fertile.

The decomposition of humus causes soil, the remains of soil microorganisms, and the release of nutrients into the soil. The soil composition in each area varies according to different physical, chemical, and biological characteristics: soil origin, structure, color, and ventilation. Evaporation of water, acidity, alkalinity, soil water content, and soil organisms. (LDD, 2022)

2.1.2 Soil Morphology

Typical soil morphisms can be described in two dimensions as follows: (LDD, 2022)

1) Layers of soil have classified two layers of soil: topsoil and lower soil. As for the soil, the lower layers. It has a lighter color due to the presence of less organic matter. The ground texture is finer. Clay granules are small.

2) The soil profile shows a vertical soil cross-section called seven soil layers with thicknesses ranging from 2-3 mm to more than 1 meter. Agronomists have determined the name of each layer of soil according to its physical characteristics, color, and structure of particles. as follows.

(1) O Horizon: It is the top layer of soil, usually dark in color, as it consists of organic matter or humus often found in forested areas.

(2) A Horizon: It is topsoil composed of mineral rocks and organic matter that is completely decomposed, leaving the soil dark in color. In agricultural areas, class A soil is plowed. Usually, the structure of the soil is nodular, but if the soil is compacted, the structure of the soil in class A is sheet-form.

(3) B Horizon: It is the subsoil layer. The ground texture and structure are polygonal or crystalline rods formed by leaching various minerals of the solutions moving through layer A down to accumulate in layer B in a humid climate zone. B is reddish-brown mainly due to the accumulation of iron oxide.

(4) C Horizon: Caused by the decay of parent rock. There is no precipitation of soil material from Leaching and no accumulation of organic matter.

(5) R Horizon: It is a layer of object of origin soil or Bedrock.

2.1.3 Physical Properties of Soils

2.1.3.1 Soil Color

Each soil area will have an unusual color depending on the soil environment. Soil formation period Soil organic matter content and metal oxides can be used to assess specific soil properties such as drainage, organic matter, and soil fertility levels. as follows. (LDD, 2022)

1) Black or deep brown soils or darker soils are mostly highly fertile due to the high organic matter content, especially the upper soils, but sometimes they are caused by soils with high manganese or from darker minerals such as volcanic rocks.

2) Yellow or red soil, the color of iron and aluminum oxides. Denote Soils that have undergone decay have long been severely decayed, resulting in iron oxide compounds coating the soil particles.

3) White or light gray soil It caused by the decomposition of faded soil origin objects such as granite or some sandstone, or it can be soil that has undergone a severe leaching process.

4) Gray or blue-gray soils have been in a waterlogged state for a long time. Poor ventilation drainage conditions produce gray or blue iron compounds, such as field soils in lowland areas or mangrove areas where seawater always floods.

2.1.3.2 Soil Texture

The soil texture is formed by incorporating particles of unusual sizes in different proportions, representing the coarseness or fineness of soil particles or clay grains. It affects the carrying capacity, airflow, and hardness or density of cohesion of different soil particles. Three groups are as follows:

1) Sand-sized particles loosely coexist and are visible as single grains, more than 85% as elements.

2) Loam group contains sand-sized particles, sludge, or powdery sand and clay. In similar proportions. It has a fine ground texture. In dry soil conditions, it coagulates and hardens modestly.

3) Clay group contains clay-sized particles, which are fine-grained soils. When wet, it is flexible and can absorb and exchange plant nutrients well.

2.1.4 Soil Structure

The adhesion of solid particles in the soil forms the structure of the soil. It formed as a lump of earth or grain of earth of unusual sizes, shapes, and durability. The structure of the soil affects the permeability of water at the surface of the soil. Water holding, drainage, and soil ventilation, as well as root spread divided into five types as follows:

1) The granular structure is shaped like a sphere. It is often found in class A soils.

2) The blocky structure is shaped like a box. Soil granules measuring 1-5 centimeters are usually found in class B soils.

3) Platy structure, lumps of the earth have a flattened shape and overlap in layers, usually found in layer A, which compressed from mechanical grinding. This type of soil structure disrupts water seepage, ventilation, and the coagulation of plant roots.

4) Prism-like structure, rod-shaped lumps of soil commonly found in the B-layer of soils, such as saline soils formed in arid zones and with sodium deposits.

5) Unstructured soils include sandy soils and fine-grained soils. Sandy grains are distributed in a single-grain manner, with little coagulation, so there is none. Good water-holding properties, but good drainage and air. Very fine-grained soils, such as freshly processed or stirred fields, or medium-grained soils. The particles of the soil attached are sluggish or lumpy.

2.2 Research Variables

This research was a prototype study of planting plots that use less water by experimenting with kale to study the effect of watering rate and watering time in cultivation throughout the production cycle on the growth and yield of kale. By controlling the composition of the planting materials in the plot, including soil, cow dung, type and quantity of wood, leaves, fertilizer, soil, and rice straw for mulching. Cultivation used kale at 21 days of the same size and recorded data on relevant physical and chemical factors such as temperature, humidity, and soil pH that change during the day and weekly cycles throughout the production cycle. In addition, the decomposition of wood in the field and nutrient changes in the planting soil that affected the growth rate and yield of vegetables were recorded. The relevant variables are shown in Figure 1.1

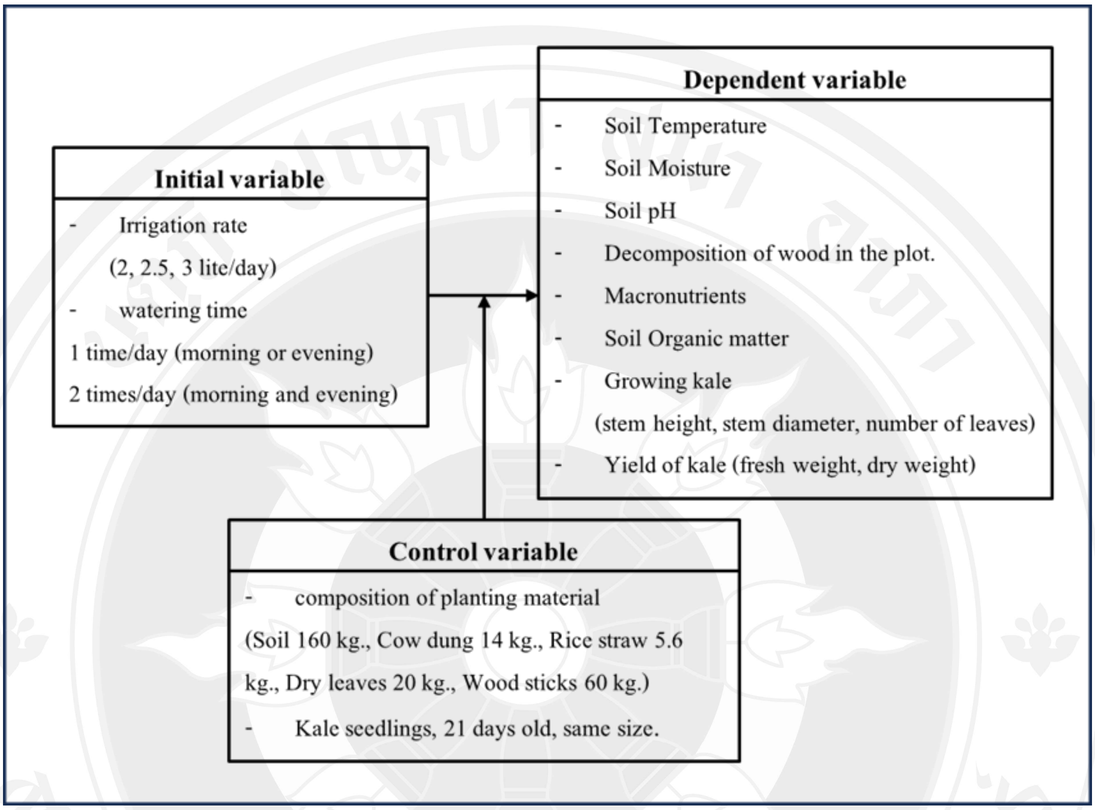


Figure 2.1 The Independent, Dependent, and Control Variables Related to the Study

2.2.1 Chemical Properties of Soils

1) pH of soil

The pH of the soil is measured by the concentration of hydrogen ions in the soil. If the soil has a pH, it is not suitable. The nutrients in the soil dissolve less and less to meet the needs of the plant, or, on the contrary, nutrients may dissolve too much to poison the roots. Soils with a pH of six.

2) The ability to suck, hold and exchange positive charges in soil (soil colloids) soil has suspended components in water and air. It takes the shape of a colloidal system, crucial to absorbing the cation exchange in the soil.

2.2.2 Biological Properties of Soils

Soil organisms can be divided into three large groups:

1) Plant or Flora: Large plants strongly influence soil and soil organisms by storing solar energy to create organic matter. When parts of a plant fall off or die, they decompose into organic matter, which becomes a source of essential plant nutrients such as nitrogen, phosphorus, and potassium.

2) Animal or fauna in the soil: The soil is home to various animals, such as ants, termites, insects, and earthworms. The role of animals in the soil is to dig for food or habitat and digest fragments of plant roots or debris, causing changes in soil properties, such as building nests or digging up ants' soil. Termites, insects, or earthworms are natural soil flipping, helping to mix organic matter in the soil or mixing the upper and lower soil. Bringing ore from underground to the surface causes gaps in the soil. As a result, the soil is airy and well-ventilated.

3) Soil microorganisms: It is a creature of small size, not visible to the naked eye. Many species, including bacteria, fungi, actinomyces, algae, viruses, and protozoa, are essential for humus formation and significantly affect soil fertility. Microorganisms are primarily responsible for decomposing organic matter to exchange inorganic substances in the soil. In addition, some species cause knots at the roots of plants and freeze nitrogen from the air.

2.2.3 Soil Fertility

Soil fertility is the soil condition used to grow a particular plant to grow and yield well. Different plants will need different soil fertility. Soil fertility is determined by its ability to release nutrients necessary for plant growth. The physical properties of the soil are suitable for plant growth, and the presence or absence of organic and inorganic compounds will be toxic to plants.

1) Macronutrient-elements Alternatively, nutrients that plants need in massive quantities. Nitrogen, phosphorus, and potassium are called primary nutrient elements because they are the nutrients that plants need most. However, they are few in the soil or are in a form that plants cannot use, making them often lack these nutrients, so farmers need to add them to the soil to meet their needs. Calcium, magnesium, and

sulfur are called secondary nutrient elements because they are nutrients that plants need in deficient quantities and are sufficiently present in the soil.

2) Plants need seven micronutrients or trace elements: iron, manganese, zinc, copper, boron, molybdenum, and chlorine. Generally, there is usually a low amount of these nutrients in the soil, but plants rarely show signs of deficiency. Except in sandy soils or soils used for cultivating crops for lengthy periods, and in some soils or conditions, these elements may be in high quantities that can be toxic to plants.

2.2.4 Soil Fertility Assessment.

Soil fertility assessment can be estimated from the amount of nutrients in the soil, both directly and indirectly. as follows.

1) Observing the characteristic symptoms that the plant manifests. This assessment method is easy to do, but it requires knowledge and expertise to distinguish the characteristics of plants that appear from the lack or over-exposure of nutrients.

2) Plant Analysis To find out what nutrients a plant contains in small quantities. The amount of nutrients in plants is closely related to the amount contained in the soil. Nutrient analysis in plants can be performed in a variety of ways, such as tissue testing, which is a simple test from only a specific part of a plant, such as juicing the juices of plant tissues with different coloring solutions and comparing them with standard colors indicating the level of nutrients.

3) Biological Test compares plant growth that receives different nutrient content in experimental plots or greenhouses.

4) Soil Analysis is taking soil samples to analyze nutrient content in the laboratory.

2.2.5 Factors Affecting Soil Fertility

1) Non – anthropogenic factor formed by objects of soil origin. Landscape conditions, ground beef Minerals that have undergone decomposition and weathering of minerals, including nutrients buffering capacity.

2) Anthropogenic factors caused by human activity affect changes in soil fertility, including forest clearing and tillage. Fertilization and use of pest suppressants.

2.2.6 Soil Problems

Soil problems in Thailand; The Department of Land Development, 2015 has used the term problem soil. Instead of all the problems of domestic soil, it means soils that are unsuitable or less suitable for agricultural cultivation, if taken for cultivation, will cause poor plant growth and low yields. Thailand's main problems include the Sour soil problem, organic soil problem, saline soil problem, sandy soil problem, shallow soil problem, Steep land problems, acid soil problems, and shale problems caused by improper land use. There are two causes of occurrence:

2.1.10.1 Formed according to the national condition, including:

1) Sour or acidic soil refers to soils containing pyrite compounds (FeS2). It is an assembly that produces vitriol.H2SO4) When undergoing the oxygen process. It covers an area of 5,565,374 rai of the entire country, found in the central region. Eastern & Southern.

2) Organic soil contains more than 20 percent of organic carbon in the soil, with organic matter deposits more than forty centimeters thick. It has an area of 344,283 rais and is found in the south and east seaside areas.

3) Saline soil refers to soils containing dissolved salts in a large amount of soil solution that affect the growth and yield of plants. It has salt deposits on the ground and has a conductivity of the solution extracted from water-saturated soils of more than 2 Deci Siemens per meter (dS m-1) at a temperature of 25 degrees Celsius, covering an area of 4,217,319 acres of the entire country. It was found in the northeast. Central Region Eastern and Southern Bhattacharya.

4) Sandy soil refers to the soil whose upper body is sandy or sandy loamy soil. It forms a layer over one hundred centimeters thick from the soil surface, including areas with a sand layer over fifty centimeters thick from the soil surface supported by a layer of shale, clay. Loamy soils or organic shales were found within one hundred centimeters. It has a total area of 11,756,733 rai.

5) Shallow soil refers to the soil in which the gravel layer was found. A layer of rubble or debris mixed in the soil equals or exceeds that. Thirty-five percent by volume, or found a marl layer, or a layer of rock shallower than 50 cm from the surface hinders the corrugation of the roots. As a result, the plant cannot grow well and has low yields. It was distributed in all sectors, totaling 34,039,375 rai.

6) Soil on steep terrain or complex slopes or mountainous areas. The soil characteristics vary according to the type of rock, both shallow and deep. Risk to Leaching and erosion. It is easy to landslides and difficult for agriculture, so it is not appropriate to use it in agriculture.

2.1.10.2 Land use problems refer to soils caused by improper human practices or land use, i.e., growing crops without soil maintenance. Growing a single plant for a long time is deforestation for agriculture. The use of agricultural chemicals until residual effects are produced in the soil. Usage of Large-scale agricultural machinery.

1) Shale Refers to a densely compacted soil layer or a layer that binds soil particles. They are tight, solid, and rigid, parallel to the benthic, where the depth varies so that it hinders the root's hook. Water seepage and air transfer affect cultivated plants' growth and yield and may arise from improper land use. Misdirection Large mechanical tillage is conducted while the soil is improperly moistened. The soil rises too much, and tillage at the same depth often lasts many years.

2) Contaminated soil means Soil pollution, soil contamination with soil pollutants exceeding the limit, causing health hazards and the growth of humans and living organisms, both plants and animals.

3) Abandoned mining soil refers to soil that occurs after completed mining. Most soil characteristics are sandy, coarse, and non-sticky. As a result, the soil is deficient in holding water and absorbing minerals, and food has already been washed away from the mining process. It has an area of about 200,000 rais, primarily found in the south.

4) Areas that have undergone shrimp farming and rapidly expanding coastal aquaculture have caused significant impacts: the degradation of natural ecosystems, including soil, water, and mangroves. Additionally, freshwater aquaculture was expanded by saltwater aquaculture. The plague will transform the land

into an abandoned shrimp field have been fed for two to three years and has encountered challenges, further depleting the resources.

The degradation of Thai soil resources is likely to be higher. (LDD, 2022) reported that there were three main reasons:

1) Changing soil properties caused by lack of soil and water conservation. Soil maintenance and improper soil management.

2) Improper land use because the population is increasing rapidly, resulting in the expansion of more agricultural land. There is deforestation to transform agricultural land. More unsuitable areas are used for agriculture, resulting in soil degradation.

3) Natural disasters, which are the result of human actions and lead to global warming. Droughts, landslides, and flash floods, all of which will lead to soil degradation.

The problem of the soil of Thailand, as shown in Figure 2.1

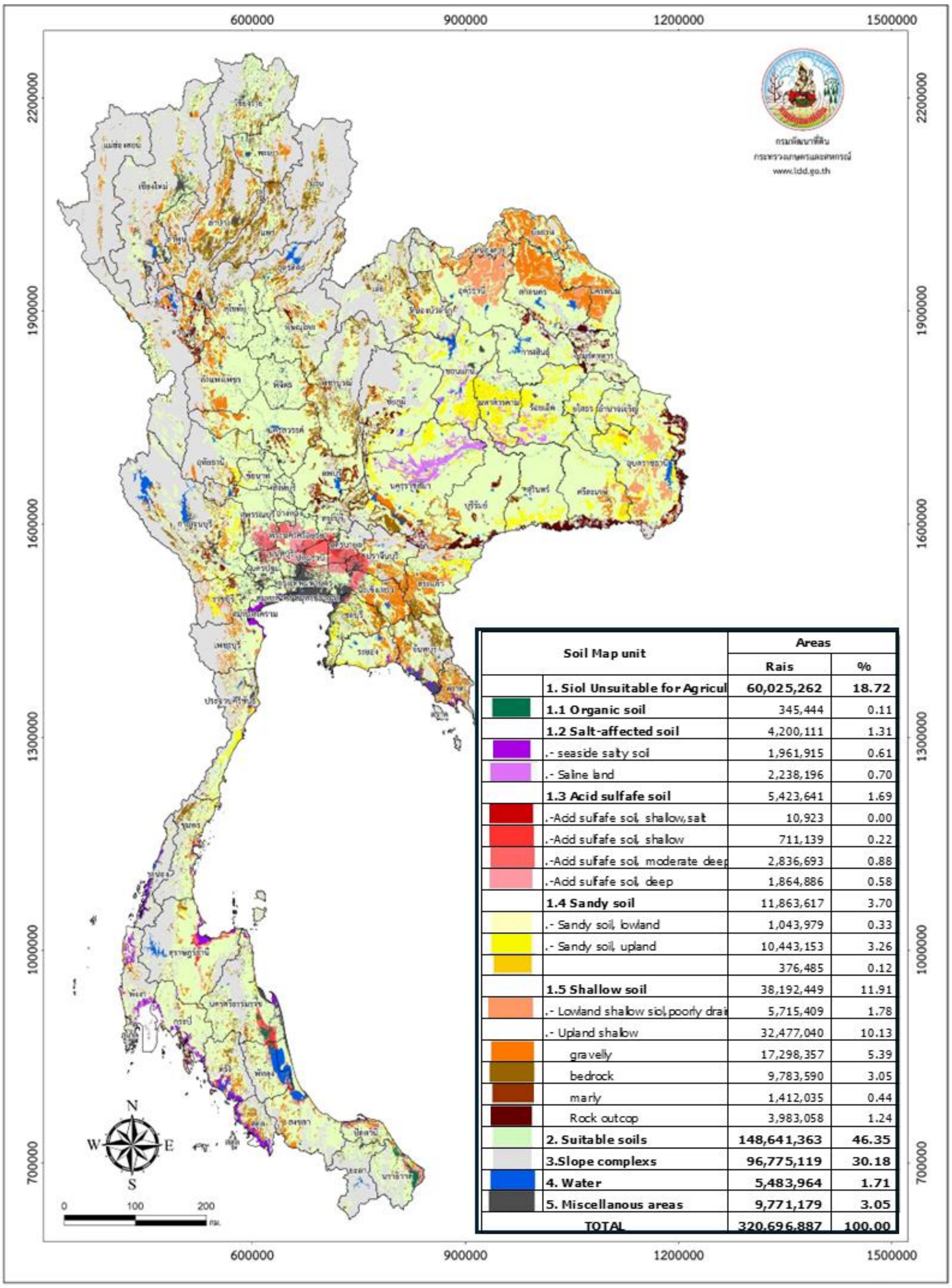


Figure 2.2 Map Showing the Problem Soil of Thailand
Source: LDD (2020).

Degraded soils are soiling whose conditions have changed from the original until various soil properties are unsuitable for plant growth, such as strong acidity, extreme saltiness, low airiness, reduced plant nutrient volume, and unbalanced conditions caused by changes in the ecological conditions of the area, from clearing and burning forests to farming, causing the soil to lack cover, reducing the accumulation of organic matter, and having a higher benthic temperature. The decomposition of various organic materials is reduced.

Soil is formed by degrading objects of soil origin, i.e., rocks and minerals mixed with organic matter. Plants use soil as a binding material. Bracing for growth by germination in the soil and various minerals in the soil as food for growth. The soil suitable for plant growth contains all the minerals necessary. Soil fertility depends on the soil's origin and soil structure. The chemical and physical properties of the soil are suitable for storing and releasing the nutrients plants need. Good soil and support for plant growth should have a critical component, namely, solid parts. Fifty percent water, 25 percent water, and air. The solid part consists of inorganic objects. nerals.45% organic matter obtained from the degradation of humus. Five percent. Organic matter is composed of living organisms. Ten percent root crops. Ten percent and 80 percent humus portion of total organic matter.

2.3 Water Resources

2.3.1 Definition of Water

Water is an essential liquid for the livelihood of all living things on earth, in many states in different areas, such as ice and snow on high peaks and poles. Rain, hail, clouds, and atmospheric steam and fluids in the sea, lakes, rivers, creeks, swamps, canals, marshes, soil, and groundwater.

2.3.2 The Importance of Water

Water is essential to life on earth because it is a solvent and carries various substances necessary for life to circulate in the body of living organisms.

2.3.2.1 Importance to Humans

Water is the most active component in the human body, accounting for two. It helps to stabilize the body temperature as a solvent in the digestive process, allowing smaller food molecules to be absorbed. It helps transport various substances in various body systems, such as food transport systems. The circulatory system excretes waste products from the body through urine or sweat, usually losing water from body activity by an average of 2.7 – 3.2 liters per day. Therefore, the body must replace it by drinking water directly or eating food that contains enough water. It is used as a raw material in the production process, as a cooling agent from various machines, and as a cleaning agent for various materials in all industries. It is used as a source of electricity from hydropower. It is used in agriculture, both cultivation and animal husbandry. Both domestic and international transportation It used as a recreational facility, a tourist attraction, and a place to play water sports. It is used for cooking, cleaning, and washing.

2.3.2.2 Importance to Plants

Water is a vital component of plants, with terrestrial plants making up 60 - 90 percent of the water. Aquatic plants contain about 95 - 99 percent water. It is an important raw material for photosynthesis, and it is a crucial factor in seed germination by helping to soften the shell of the seeds as solvents, nutrients, and various mineral salts. In the soil, the plant's roots can absorb and transport to various parts, helping to grow the plant, especially during plant growth. If dehydrated, the cells will not fully stretch, the plant will stunt, and if it lacks weight, it will wither and eventually die (NECTEC, 2022).

2.3.1 Soil Moisture

Water is a crucial component of soil suitable for plant growth, with soil water being measured as soil moisture.

2.3.1.1 Ground Water Balance

Water balance in the soil is essential for soil organisms such as plants, animals, and microorganisms, as water is important. the component in metabolic processes, such as the photosynthesis process of plants and soil microorganisms, as shown in Figure 2.3.

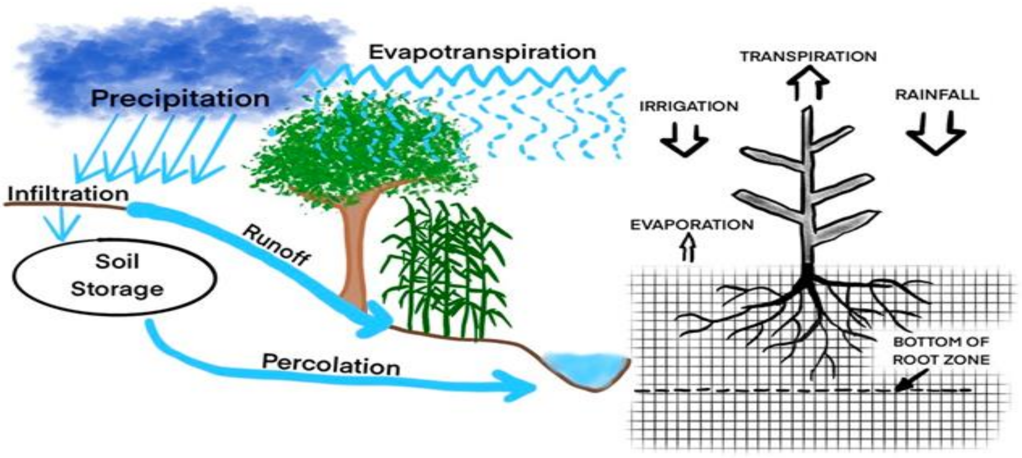


Figure 2.3 Water Balance in the Soil
Source: Anurat Saringkarnphasit (2017).

Figure 2.2 It represents the water balance in the soil, whereby the inflow is rainwater that falls, or the water obtained from irrigation. The outflow section consists of water evaporated from the soil by evapotranspiration, runoff, and seepage into the soil. The water seeps into the soil and becomes soil storage, moisture, and deep seepage.

2.3.1.2 Types of Soil Moisture

Soil moisture is divided into three types:

1) Field Capacity (FC) is when land water can be fully absorbed after the free water in the soil has been drained from a large gap, or land water can absorb quickly at a pressure level of 1/3 atmosphere (bar), making it impossible to find or calculate the exact value. Therefore, in practice, the amount of moisture in the soil that is well drained after heavy rains or stopped watering for 2-3 days is considered the irrigation moisture value, which is different in each soil. As shown in the table.2.1

Table 2.1 Irrigation Moisture Values and Moisture Values at the Permanent Withering Point of the Soil

Texture of Soil	Field Capacity, Fc) % By weight of dry soil	Permanent wilting Point, PWP) % By weight of dry soil.
Sandy soils	6 – 12	6 – 12
Sandy loamy soils	10 – 18	4 – 8
Loamy soil	18 – 26	8 – 12
Loamy, clayey soils.	23 – 31	11 – 15
Clay, Sandy sediments	27 – 35	13 – 17
Clay	31 – 39	15 – 19

Source: Royal Irrigation Department (RID, 2011).

2) Permanent wilting Point (PWP) is a point where soil moisture is left extremely low until the plant cannot be sufficiently absorbed with permanent dehydration and withering plants, or the amount of water absorbed by fifteen atmospheres of gravity (bar). Moisture values at the withering points in various ground textures as shown in the table.2.2

Table 2.2 The Ability to Retain Water that is Beneficial to Plants in the Soil

Soil Texture	Water depth range (1 mm/ 1 cm soil depth)	
	Depth Range	Average
Sandy soils	0.50 – 1.00	0.7
Sandy loamy soils	1.00 – 1.50	1.2
loamy soils	1.20 – 1.90	1.5
Loamy, clayey soils.	1.50 – 2.10	1.8
Clay	1.30 – 2.50	1.9

Source: RID (2011).

3) Available Moisture (AM) is soil moisture that plants can use to grow or Capillary Water, which is a value between Field Capacity และ Permanent Wilting Point. The difference between these two soil moisture values is what plants can use, as shown in the table.2.3

Table 2.3 The Relationship Between Various Levels of Soil Moisture and Ground Texture

Soil Texture	**Field Humidity Capacity**	**Permanent Wilting Point**	**Beneficial Water for Plants**
Coarse	5.5	2.0	3.5
Rough.	22.2	12.0	10.2
Moderate	34.6	20.3	14.3
Quite thorough.	33.8	21.3	12.5
Fine	33.5	20.2	13.3

Source: Anurat Saringkarnphasit (2017).

Soil moisture ranges from irrigation moisture to moisture at permanent wilt points. If the soil in the root zone is still moist, above the moisture level at the point of permanent withering, then most plants will still not have withering. While humidity is reduced, plants that need more water or are susceptible to dehydration will experience such symptoms. However, it will only allow the soil moisture value to drop closer to the PWP point in practice because as soil moisture decreases, plants use increased soil suction if the roots absorb less water. Therefore, the correct watering method should start when soil moisture is reduced by 20 – 25 percent of the moisture that plants can apply.

2.3.1.3 Sucking Water from the Soil in Different Layers of Plants

The suction of the entire plant root buds rises where the plant roots scattered in the soil. The roots of plants in the soil are mostly densely spread out in the root zone's upper part and at the tree's base. Therefore, the plant quickly sucks water from the soil in this layer. If the root zone depth is divided from the soil surface to the deepest point into four equal parts, the plant sucks water from the soil, about 40 percent of the plant's moisture, all of which comes from the soil in the first layer. Thirty percent in the second tier. Twenty percent in the third tier and 10 percent in the fourth tier, respectively, as shown in Figure 2.3. In addition to the moisture absorbed by the plant, the soil loses water from the soil surface by evaporating in another way.

Meanwhile, the soil moisture gradually decreases. The moisture pulls of the soil increases, and eventually the plants will not be able to suck water from the soil consistently. Plants will absorb moisture from the next layer of soil, which will be much more difficult or slower. Plants grown in soils with a uniform texture and moisture enough to meet the plant's needs throughout the depth of the root zone are characterized by similar suction of water from different soil layers.

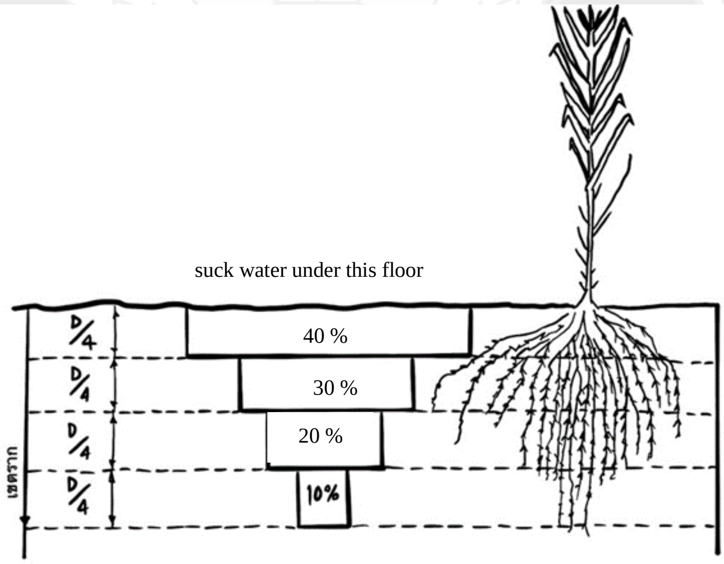


Figure 2.4 The Percentage of Moisture That Plants Can Take Advantage
Source: RID (2011).

2.3.1.4 The Rate of Water Permeability through the Soil Surface

The water permeability rate through the soil surface depends on elements such as the soil structure. Ground beef water depth on the soil surface conditions and soil moisture before watering. The value of the rate of water permeability through the soil is valuable at the beginning of watering since the surface is still dry, absorbing water quickly. However, as water continues, the soil begins to saturate with water, and this rate value gradually decreases to a certain extent. This value will be almost constant forever until watering stops. Therefore, watering plants should only water at a rate as significant as the water permeability rate through the soil surface, as this will cause water loss and soil erosion.

2.4 Crop Plot Pattern

Crop plot pattern refers to how the preparation of planting material affects the fertility of the soil or planting material. Drainage or airiness of the soil. This pattern allows the plant to grow well and produce high yields and the convenience of managing and maintaining the planting plot.

For crop plots, especially vegetable crops, the popularity in Thailand is to raise the plot grooves slightly higher to provide good drainage. Raised groove planting is a method of growing crops by digging up the soil around the agricultural plots and digging grooves into nets to raise the inner plots to a height. The trench was developed and adapted from the concept of farmers in the central lowlands, where soil was dug around agricultural plots to prevent flooding. It looks like this:

2.4.1 Raised Plots for Growing Vegetables

In the central part, which is lowland, the plot is raised to a curved bulge from the middle of the plot, sloping down to the edge of the plot to prevent water from getting trapped in the plot and leaving the edges converted into plains for passage or towing boats on both sides of the plot. The trench dug will be about 0.5-1 meters deep, 1-2 meters wide, and 3 - 06 meters wide, and pump water into the trench about 10-20 centimeters below the edge of the plot. As for raising the grooves to grow vegetables in don or flat areas is the lifting of the grooves to a height to allow the soil to be loamy and deep. Water does not waterlog. The size of the plot grooves is small and used as a walkway, which is a typical vegetable growing, as shown in the figure.2.5

Figure 2.5 Characteristics of the Most Common Vegetable Growing Plots
Source: Puechkaset (2015).

2.4.2 Raised Groove Plots for Growing Fruit Trees/Perennials

Lifting the plot grooves for planting, planting fruit trees or perennials. As for the depth, it is about 0.7 – 1 m. The width of the plot is 3-6 meters, depending on the type of wood grown.

2.4.3 KEYHOLE Plot Cropping

KEYHOLE Crop Plot combines vegetable growing and composting in the same place. Responded to the plaintiffs for arid areas, with little water, and for the best use of the area. Vegetable plots can be found. Compost ponds to dispose of fresh household waste can be considered an innovation for growing vegetables in trending households, as shown in Figure 2.5.

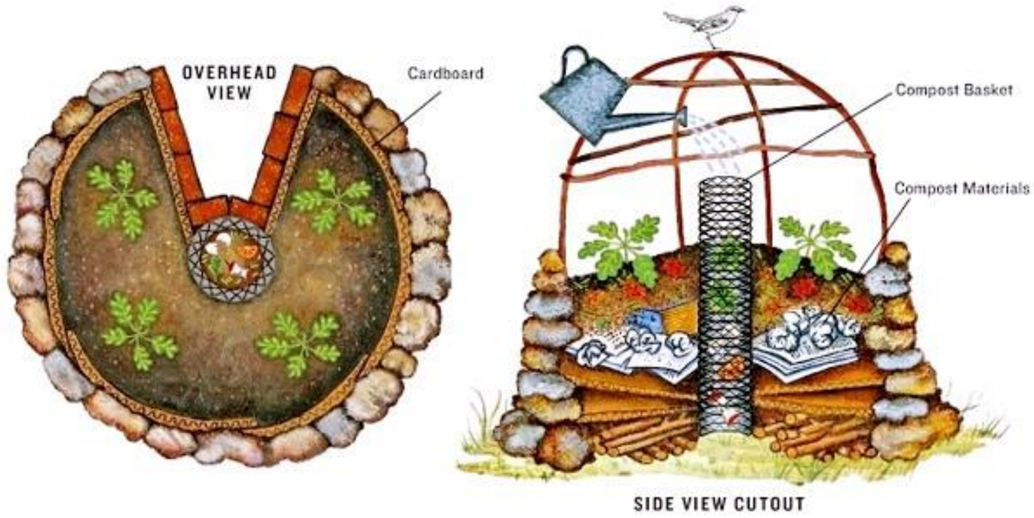


Figure 2.6 KEYHOLE Vegetable Plot
Source: Permaculturefoodforest (2016).

2.4.3.1 Advantages of KEYHOLE Vegetable Gardening

1) It takes up very little space for vegetable plots to grow for a family of 4-5 people.

2) Water saving Watering in the hole in the middle is enough to care for vegetables in the whole hole.

3) Dispose of household organic waste; various food waste, vegetables, and fruits can be disposed of. Get into the hole. The vegetables fertilize the various fermentations produced from the pits in the pit.

4) Get organic vegetables to eat. Making a keyhole vegetable plot of one hole can grow vegetables. It is eaten in the household all year round.

5) It takes less time to care.

6) It is a beautiful and perfect decoration of the garden.

7) Use locally available materials to do it. There is no need to find expensive materials that bricks, soil, or stones can use to make vegetable plots. It costs less.

9) It helps to get rid of household waste. Dispose of it in the fermentation pond, helping to save the planet.

10) It reduces the cost of buying vegetables, saving money

2.4.3.2 Principles and Methods of Making a KEYHOLE Vegetable Garden

The main principles and critical methods for creating a keyhole vegetable plot are: Find the right area for growing vegetables, get a full day of sunshine, or at least half a day.

1) Place the plot into a circular shape, about six feet in diameter, with a space in the middle, making a triangular entrance with a pointed tip to the center of the plot. The broad side of the entrance is about sixty centimeters (resembling cutting out a cake or pie).

2) Make a hole like a pipe in the middle of the plot for fertilizing; this pipe may be made of wood or a sieve, shifting to a diameter of about one foot and a height of about 3-4 feet.

3) This time, build plots around the circle using stone, use bricks. Use wood or other materials that can be obtained and created as plots.

4) Put the cooked soil on the plot at the bottom, and find branches, rubble, and rubble to put on the bottom first to help drainage.

5) Put leaf litter, grass, and food debris into the pipe in the middle of the plot.

6) Water thoroughly both in the soil area in the plot and the middle pipe, leaving for about one week.

7) Then start growing vegetables on the plot. (Home and Garden Publishing, 2019)

2.4.4 Raised Bed Cropping

Figure 2.7 Convert Raised Bed
Source: Home and Garden Publishing (2019).

Using this vegetable growing pickup allows us to look at the vegetables thoroughly because we can design the length of the vegetable plot, and the way to do it is hassle-free. Just use natural materials to create a pickup truck that is about 20-30 centimeters high. The materials used can be used for anything, such as wood, coconut cladding, and coconut balls. Bamboo Stone, brick blocks, and twigs There are so many options and ideas. However, avoid chemically contaminated materials because they contaminate the vegetables we grow with, and then filling the planting ground with this kind of pickup allows us to control the temperature of the soil. Do not worry about the effects of the temperature under the ground. In addition, it can plant as many times as possible. Because already mixing soil, mixing fertilizer. It can be planted in pickups at close range. It also solves the grass problem in vegetable plots because the vegetables will block the sun, making it impossible for the grass to grow. Watering will also be easier because the water will flow easily. Ventilated. The vegetables will also grow well (ProgressTH, 2015).

2.4.5 Planting Plants on The Ground Rod (Hügelkultur)

Cultivation of plants on the ground is a method of farming that is caused by observing nature in areas of fallen trees or branches that fall over each other in the forest; it is an area that can maintain moisture better than other surrounding areas and often has lichen, moss or mushrooms sticking to the wood, especially in dry seasons. When the wood decomposes, it makes the soil nearby. Khon Wood is more abundant than in other areas too. For ten years. After the plant residues wholly decomposed. The area then becomes a mound with abundant nutrients. The Sufficiency Garden Page, 2017, has provided water-saving data on the earthen plots. If the plot is planted on a soil rod with a height of about sixty centimeters, the plants can live for about three weeks without watering. In the second year of the plot, we will be able to grow vegetables without watering them at all during the dry season. However, they are accustomed to making vegetable plots on a low and flat top.

Growing plants on the ground rod (hügelkultur) is the cultivation of plants in the plots of earthen rods that imitate natural mounds using logs or twigs. Leaf litter, the leaves of grass, form the base and form a higher vegetable plot. As a result, the cultivated vegetable crops receive nutrients that decompose from branches, and wood chips, in slow piles. In addition, twigs. The leaves also help maintain sufficient soil moisture for plant adoption without watering or using very little water for cultivation.

2.4.5.1 Crop Plot Format

Creating a crop plot on a soil rod can be performed in various techniques, as shown in Table 2.3 and the shape of the crop on the soil rod. Anything can do depending on the characteristics of the soil. The number of logs and other materials is shown in Table 2.2.

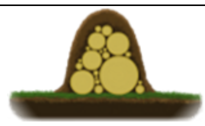
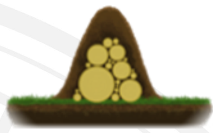
Table 2.4 Characteristics of Plant Plots on Different Types of Earthen Rods

Patterns	Area Characteristics	Method	Cross-Sectional Image
High mounds do not dig trenches.	Shallow benthic soil the soil is difficult to dig. Find soil elsewhere in the area or from outside.	Bring the logs together until they are high and sprinkle the soil you can find on top of it about 1-2 inches thick. Cover	

Patterns	Area Characteristics	Method	Cross-Sectional Image
		with mulch such as straw.	
High mounds dig trenches.	The case is not possible to find the soil from elsewhere.	Digging the soil (e.g., digging 30-60 cm deep). It is a groove, and then put the logs in the dug trench. Then sprinkle the dug soil over the pile of wood again.	
High mounds Dig grooves and have side drainage grooves.	If you cannot find the soil elsewhere and the soil is poorly drained.	It is like method two, but it digs a groove next to it to cover the soil in the groove next to it and let the water flow down this groove during the rain.	

Source: Greenfarmthai (2020).

Table 2.5 Characteristic Shape of the Plot, Balls of Plants.

The Shape of the Plot	Cross-Sectional Image
Normal shape	
Tall skinny shape	
Triangular shape	
Large stone-edged barrier	
Wooden edge barrier	

Source: Greenfarmthai (2020).

2.4.5.2 Choosing an Area to Create

When building on a flat area with no windproof line, the wind direction should primarily be considered by making mounds block the main wind path. The section is built on a sloping area. The sloping crossing was constructed with an oblique line of dirt and a sloping approach so that the earthen plot slows down the water flowing down the hill, allowing water to pass through, and the plot below receives water close to the top plot, as shown in Figure 2.6.

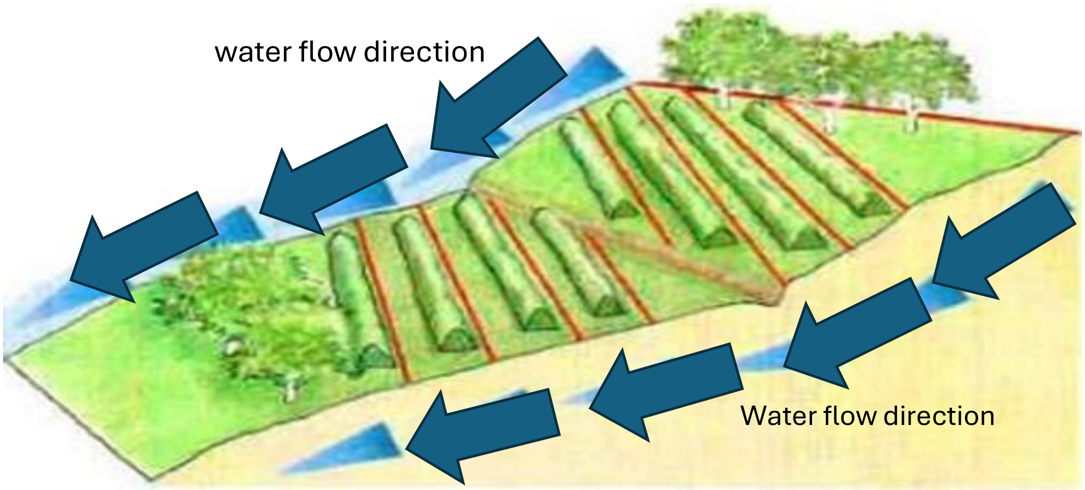


Figure 2.8 Guidelines for Creating Langkandin in Sloping Areas
Source: Teerapan (2012).

2.4.5.3 Preparation of Materials for Making Plots

The material used to make the plot consists of two parts: dry and fresh material, by collecting logs, twigs, and dried leaves. However, the ideal earthen plot should be at least 1.5 meters high so that the moisture in the plot is preserved as much as possible. Fresh leaves or fresh plants should be collected during the planting process. It calculates the proportion of dried leaves to fresh leaves. Usually, in the area, there is not enough soil for drowning above the pile of wood, but the amount of soil can increase by digging the soil into trenches about 15 - 50 cm deep, giving the width of the grooves about 1 - 2 times the height of the plot. Pile the excavated soil to the side before using it to drown the pile later. However, the dug grooves make it easy to form a pile of wood, as the wood will not spin-off to the side and help maintain moisture well.

2.4.5.4 Plot Forming

The plot should start by placing the wooden hooks along the edges of the pile and gently inserting the branches between the edges, placing the vast, slowly decomposing wooden hooks in the center of the pile and below, and placing small twigs, straw, sawdust, husks, or other small brown material on top. During the laying of each material layer, the material must tightly insert to prevent excessive collapse of the plot. Moreover, water is thoroughly used to help speed up decomposition. Nevertheless, during the degradation of brown material, a large amount of nitrogen is used, which can cause the plant to lack nitrogen. From the plot, green material must be added, which contains more nitrogen to compensate for nitrogen for the plants to be planted. Animal blood Poultry feathers, coffee powder from fresh coffee makers, nut residues from juicing, fresh plant debris, and grass scraps should not be put too thick in case of immediate planting of plants. It drowned about 5 cm thick, after which the top plot drowned with the soil dug in the first stage, 2.5 - 15 cm thick, and watered on top of the pile. The earthen plot should be at least 1.5m high to have a long service life, as large branches take a long time to decompose; if the plot is 2m high, it will last about 10 – 20 years, but anyway.

Creating plots for the pile is not exceedingly high, which the local sages, for example. Uncle Thong is perfect, unequivocal. The method of digging up the soil in the middle of the vegetable plot (digging the pig's belly) and placing the branches and fresh plants in the central groove and drowning them back with soil like Hügelkultur, but this method requires dismantling the vegetables every two -3 years, as the branches are completely decomposed.

2.4.5.5 Beginning Planting Plots

In the case of planting plots in the dry season, the plot should be left for about 2 – 3 months before planting the plant at the beginning of the rainy season. However, if it is done in the rainy season, the plant should be started at, since leaving it for a long time, weeds will come to seize the area before vegetation. Vegetables grown in the initial stages of plot formation should be acidic soil-loving vegetable crops such as tomatoes, sweet potatoes, potatoes, Parsley, peppers, beans, Broccoli, cabbage, cauliflower, onions, carrots, celery, cucumbers, Squash, Spinach, Radish, and Asparagus, among others. In the preliminary stages of use of the plot, it must help to water the vegetables appropriately, especially in the dry season. When the wood begins to decompose, it will be like a sponge, helping to absorb moisture in the plot, eliminating the need for watering as much as an ordinary vegetable plot. (Patcharaporn Uthiya, 2022).

2.4.5.6 The Problem of Making Clay Rod Plots

Nowadays, Thais are accustomed to making low vegetable plots and on top of flat vegetable plots that do not have a high pile of vegetables, so it is often too low to see the effect of this technique. If we grow vegetables without watering them throughout the dry season (after two years), we will have to make a mound of earth to a height of at least two meters. If a pile is made about sixty cm high, it can live without water for about three weeks. The moisture-absorbing properties of a sufficiently high hügelkultur are so good that people call it hügelkultur. that no irrigation raised bed gardening system (a system that raises vegetable plots that do not require watering) (Teerapan, 2012)

2.5 Factors Affecting Plant Growth

The factors that control plant growth and development can be divided into two main factors:

2.5.1 Internal Or Genetic Factors

Genes determine the growth characteristics of plants, whether they are roots, stems, branches, stalks, leaves, flowers, or fruits. How many biomasses accumulate depends on the genetics of the plant itself. Plant varieties for hydroponic cultivation, in particular, still need to be created or are very few. (Patcharaporn Uthiya, 2022)

2.5.2 External or Environmental Factors

Environmental or external factors may be divided according to the role that affects the growth and development of plants into two types:

1) Positive factors are indispensable factors, including the important environments that influence plant growth and development, including:

(1) Lighting: Plants need light to use in photosynthesis movements, creating food for use in growth and development.

(2) Anchor: The plant will grow and yield well. A strong bond is required for the stems to stay in the most optimal way, which will allow the parts to function for growth fully.

(3) Temperature: The optimum temperature will encourage the plant to grow and develop well.

(4) Air: In the growth and development of plants, they need energy derived from breathing. It must have enough air to breathe to realize fully. Plants also need carbon dioxide for photosynthesis.

(5) Water: Water is a critical component of living organisms. Water acts to help absorb nutrients, transport food (photosynthates) to various parts, and helps to reduce the temperature inside the plant. On the physical side, divide the soil water into three. Type according to the water retention capacity of the soil.

(5.1) Hygroscopic water is rigidly fixed to the surface. Plants cannot absorb this water, and it will be challenging to evaporate from the soil.

(5.2) Capillary water is water that settles on the periphery of the soil particle surface. Out of the water area, the pulp comes out. This type of water is also within the gravity distance between soil particles and water molecules, so it moves slowly, which plants can absorb and utilize, and is the plant's most important water source.

(5.3) Gravitational water is temporarily stored in the soil, perched on the periphery of the soil particles. The attraction between soil particles and water molecules cannot resist the earth's gravity. Water moves quickly through different soil layers as it moves down, accumulating in the lower soil layers and becoming groundwater.

Biologically, divide the water into three. According to the beneficial Ness of the plant, the species are: 1) Available water is the portion of water under the authority. The attraction of the soil Plants can suck out of the soil. At a rate comparable to the rate of plant water loss due to dehydration and evaporation; 2) Unavailable water is the water of the land. The greater gravity that a plant can absorb, at a rate comparable to the rate of water loss of a plant; 3) Superfluous or excessive water is excess water. The usual suction of the soil. This type of water moves beyond the area where the roots are located, influenced by the earth's gravitational forces. This type of water. If it accumulates in the area where the roots are located, the plant will create an airtight state unsuitable for plant growth. The amount of water in the soil determines the level of soil moisture, of which there are two. The level is pulp water or soil grain binding water. Water lining Seepage or residual water

(6) Permanent Wilting Point (PWP) is the amount of water in the soil, the lowest level that is insufficient or seized by soil particles with a force that is too great for the plant to absorb, causing the plant not to receive water and show signs of withering. The permanent withering point of a plant is the lower limit of the range of humidity levels that are beneficial to the plant. The humidity level below the permanent withering point will be moisture that does not benefit the plant. The relationship between the division of the type of water in the soil and the soil moisture level.

(7) Nutrients Plants need food minerals for growth and development, and they are essential components of plants and stimulate the movements necessary for living

2) Negative factors are the following:

(1) Diseases

(2) Insects' pest

(3) Weeds

(4) Toxic substances

2.6 Knowledge of Water Footprint

2.6.1 Water Footprint

Water Footprint is like the Ecological Footprint, which is an indicator of the need for space to respond. Human activity to the world the results expressed in the form of space per person. As for water footprints, the results expressed in terms of water volume or annual water volume (Hoekstra & Chapagain, 2008). A water footprint is a measure of a manufacturer's or consumer's water use. This refers to the amount of water used in the production process of goods and services, both directly or indirectly, by calculating the amount of water from the sum of all stages throughout the chain of production and services in cubic meters per year or cubic meters per person per year. Water footprint is considered a metric because, in addition to showing the amount of water used and the amount of wastewater discharged, it also shows the location and duration of water use (Chapagain, Hoekstra, Savenije, & Gautam, 2006). Water footprints can divide into three categories:

1) Green Water Footprint (WFgreen) refers to the amount of water that is in the form of soil moisture due to rainwater and use in the production of goods and services. This does not include rainwater that becomes surface water. Green water Footprint called "rainwater."

2) Blue Water Footprint (WFblue) means the amount of water from natural sources, including surface water sources such as rivers and lakes, as well as catchment basins, and groundwater sources such as groundwater used to produce goods and services to meet consumer needs. Green water Footprint called "irrigation water."

3) Grey Water Footprint (WFgray) means the amount of water used to treat wastewater generated from the production process of goods and services into bile according to the value. Leach into water bodies.

This research study Only blue water footprints assessed based on the kale tree's water demand. Greywater Footprint is not evaluation.

Currently, there is an ISO 14046 standard to assess the water footprint from the Life Cycle (LCA) of goods and the Sustainable Development Index. As a sustainability indicator, it looks at the water tension and the impact of water use with each type of water footprint valuation method. There were two methods: a top-down approach and bottom-up approach. Water footprint from import-export data, which is a quick and straightforward way to get a product, has a disadvantage: the resulting value can be highly discrepancies. The bottom-up analysis method calculated based on raw material usage data in the production process (Thamrongrat Mungcharoen, 2011). For the unit of measurement of water footprint in cubic meters per ton. The water footprint in a plant is calculated based on the amount of water used by the plant (cubic meters per rai) per the amount of the crop's yield (tons per rai). Water footprint in animals is based on the total amount of water in animal production and feeding. Drinking water of animals and water used in activities other animal husbandry, such as water used to clean aquarium stalls used for cooling, and water footprint in plant and animal products, are the sum of water footprints producing plant and animal products from Start the process until the end has come out as that product.

The water footprint of the process is an estimate of the amount of water footprint throughout the plant growth period, which obtained from the sum of Green Water footprint (WFgreen), Blue Water Footprint (WFblue), and Grey Water Footprint

(WFgrey) expressed in cubic meters per ton. Displays the calculation details as in the equation.

$$\mathbf{WF_{Total} = WFgreen + WFblue + WFgrey}$$

This is calculated from two parts as follows:

The calculation of the amount of water that the plant needs to use, which is obtained from the plant's water demand (CWU), express in cubic meters per rai. Divided by the amount of yield (Y) tons per rai, divided into

1) Green Water Footprint (WFgreen). The water footprint of crop production is calculated based on the ratio between crop water use (CWU) (cubic meters per rai) and yield per plant area (tons per acre). As the equations

$$WFgreen = \frac{CWUgreen}{Y}$$

where WF_{green} is the Green water Footprint of Crop Production (cubic meters per ton).

CWU_{green} is the amount of rain consumed by plants (cubic meters per rai).

Y is the amount of yield per acre (tons per rai).

2) Blue Water Footprint The calculation of the Blue Water Footprint of crop production calculated from the ratio between the amount of water from natural water sources, the irrigation water used to produce crops (cubic meters per acre) and the amount of yield per acre (tons per acre) as in the equation.

$$WFblue = \frac{CWUblue}{Y}$$

WF_{blue} is the bluewater footprint of crop production (cubic meters per ton).

CWU_{blue} is the amount of water used to produce crops from natural water sources, irrigation water (cubic meters per rai).

Y is the amount of yield per acre (tons per rai).

3) Grey Water Footprint calculated from the amount of water used to dilute water pollution to the effluent quality standards or concentrations found in nature as in the equation. However, this study did not evaluate Greywater Footprint.

$$WFgrey = \frac{(a \times AR) \div (Cmax - Cnat)}{y}$$

WFgrey is a grey water footprint of crop production (mm/ton).

α is leaching fraction or Leaching-Runoff fraction.

AR is the rate of chemical consumption on farmland (kilograms per acre per year).

C_{max} is the most acceptable concentration (kilograms per millimeter).

C_{nat} is the concentration of natural pollution (kg millimeters).

Y is the amount of yield per acre (tons per rai).

2.6.2 Calculation of the Amount of Water that Plants Need to Use from the Assessment

For Green and Bluewater Footprint, the calculation principle is the same. Crop Water Requirement (CWR) was analyzed from rainwater and irrigation water, which is caused by the need for water for dehydration under ideal growth conditions from the date of cultivation. Crop Evapotranspiration (ET_c) is a calculation to determine the amount of water lost from the plant area, both from surface dehydration and dehydration processes. So, to determine the total water demand of a plant (CWR) from the beginning of planting, growing until ready to harvest, it was estimated based on the total of the plant's dehydration values (ETc.) at each age until the planting anniversary. However, only in the assessment section. The demand for water to grow kale in deep peculation (DP) plots of water in the plots into the ground included in the assessment as shown in the equation.

$$ET = K_c \times XET_0$$

$$CWR = \sum ET$$

$$ETc = \sum (ET_0 + DP)$$

ET_c is the evaporation potential or water demand of a plant (mm per day).

K_c is the dimensionless coefficient of plant water consumption.

ET_0 is the dehydration value of the reference plant (mm per day).

DP is the deep percolation of water in the plot (mm per day).

CWR is the water demand value of a plant.

Crop Water Use (CWU) calculated based on the accumulation value. Plant dehydration (ET) throughout the Length of Growing Period (LGP) and determination of plant dehydration calculated based on climate data. Using CROPWAT 8.0, a tool to calculate the dehydration value of plants. The data required for calculating dehydration values include Spatial data, climate data (maximum temperature, amount of sunlight, wind speed, relative humidity, and rainfall) using average evenings over a 30-year period (1981– 2010), based on actual data from the Meteorological Department based on the study area from nearby stations or stations that represented crop inputs data (plant type, planting and harvesting date, plant growth age, plant water consumption coefficient, and root length) and soil properties data (soil set data, soil moisture, maximum surface water penetration, soil surface water penetration, etc.). Plant root depth, initial humidity, phase when water begins to fall short), according to the Department of Land Development's information system and related research.

Crop Coefficient (K_c) The coefficient of plant water consumption is one of the factors used for calculating the amount. The plant's water consumption coefficient is specific to seventeen, representing the actual humidity in the crop plot, depending on the type and age of the plant.

Crop Evapotranspiration (ET_c) Determination of the required water value for dehydration (ET_c) under ideal growth conditions from planting date to harvest day can be obtained from the equation.

$$ET_c = K_c \times ET_c$$

ET_c is the water demand value of a plant (mm per day).

K_c is the water consumption coefficient of the plant.

ET_c is the dehydration evening of the reference plant (mm per day).

2.6.3 Rainwater Consumption and Irrigation Water Requirements of Plants

Determination of the rainfall used, and the amount of irrigation water needed for planting. Plants assessed by determining the difference between the calculated plant's water demand and the effective rainfall (Pe) available on the plantation, which calculated in a variety of ways, such as the USDA method and the Irrigation Department's method. as follows.

1) Assessment of rain using USDA methods, rainfall use, or rainfall falling on farmland and Benefits to that cultivation It calculated as an equation.

$$\text{Pe, monthly, USDA} = \text{monthly} \times \frac{(125 - 0.2 \times \text{Pmomthly})}{125} \quad \text{for Pmonthly} < 250\text{mm}$$

or

$$\text{Pe, monthly, USDA} = (0.1 \times \text{Pmomthly}) + 125 \quad \text{for monthly} > 250\text{mm}$$

$P_{e,\ monthly,\ USDA}$ is the amount of precipitation calculated according to the USDA method (mm per month).

$P_{monthly}$ is the average monthly rainfall (mm per month).

2) Rain assessments are based on the Irrigation Department's method, in which the factor is set to multiply the monthly weighted rainfall (WRFL) value on a particular farmland area by the factor method as shown in Table 2.1.

In case the amount of precipitation is greater than the effective rainfall (Pe) > CWR), the rainfall used will be equal to the water demand of the plant (CWR) and the amount of irrigation water used will be zero. No more irrigation water was needed.

In the event that the amount of rainfall is less than the effective rainfall required by the plant (Pe) < CWR) the rainfall of the plants used will be equal to the amount of rainfall used and the required amount of irrigation water will be equal to the water demand of the plant minus the amount of rain used (CWR – Effective Rainfall), or in the case of knowing the actual use of irrigation water, the effective irrigation value can be used to replace the calculation of the required irrigation water.
Factor values for calculating precipitation use.

Table 2.6 The Effective Rainfall Using Factor

Weighted Rainfall (WRFL) MM	**Effective Rainfall (Peff) MM**
0 – 10	0
11 – 100	WRFL x 0.80
101 – 200	WRFL x 0.70
201 – 250	WRFL x 0.60
251 – 300	WRFL x 0.55
301 – up	WRFL x 0.50

Source: Royal Irrigation Department (2014).

3) Finding a water scarcity footprint because, according to iso 14046 (2014), water footprint defined as an indicator of water-related impacts. In this study, there is a way to assess the water footprint impact assessment in the form of the likelihood of water scarcity impacts, also known as the water scarcity footprint, which defined from the amount of irrigation water needed for cultivation of plants and the water tension index by obtaining the required amount of irrigation water. As the equations

Water scarcity footprint = irrigation water x water tension index

The Water Scarcity Footprint is cubic meters of water equivalent per ton (m^3 H_2O_{eq}/ton).

The Water Stress Index (WSI) does not have units. Qualitative and quantitative aspects of clean water that obtained from the proportion of water that used for fresh water available in the area.

For the Water Tension Index, values for twenty-five of the country's watersheds were studied to indicate the likelihood of limited water resource sequestration in each area. The Chi Chao Phraya Basin and Tha China, respectively.

2.7 Knowledge of Carbon Footprint

2.7.1 Greenhouse Gases

Greenhouse gases are gases that have the property of absorbing heat waves well, which are essential to maintain a stable temperature in the Earth's atmosphere. These gases have absorbing properties, heat waves, and classify as greenhouse gases, the main greenhouse gases being water vapor, carbon dioxide, ozone, methane, and nitrous oxide. But greenhouse gases were cheap. Regulated by the Kyoto Protocol, there are only seven types of gases generated by human activity (Anthropogenic greenhouse gas emission), namely carbon dioxide (CO_2). There is also another important greenhouse gas caused by human activity, the CFC (CFC or Chlorofluorocarbon), which used as a refrigerant and used in the production of foam but is not define in the Kyoto Protocol as a restricted substance for use in the Montreal Protocol. The increase in greenhouse gases is as a result, the atmosphere has a greater capacity to retain thermal radiation. As a result, the average temperature of the atmosphere also increases, and each greenhouse gas has the potential to cause greenhouse gases. Mirrors (Global Warming Potential (GWP) or different global warming (GWP) The IPCC (2007) has determined the global warming potential of various gases by comparing them to carbon dioxide. For a specified period, such as 20 100 500 years. The GWP of greenhouse gases typically used at a 100-year period as shown in Table 2.2.

Table 2.7 Greenhouse Gases Regulated under the Kyoto Protocol and GWP_{100}

Common Name	**Chemical Formula**	**GWP_{100}**
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous Oxide	N_2O	298
Hydrofluorocarbons	CHF_3	
HFC-23	CH_2F_2	14,800
HFC-32	CHF_2CF_3	675
HFC-125	CH_2FCF_3	3,500
HFC-134a	CH_3CF_3	1,430
HFC-143a	CH_3CHF_2	4,470
HFC-152a	CF_3CHFCF_3	124
HFC-227ea	$CF_3CH_2CF_3$	3,220
HFC-236fa	$CHF_2CH_2CF_3$	9,810
HFC-245fa	$CH_3CF_2CH_2CF_3$	1,030
HFC-365mfc	$CF_3CHFCHFCF_2CF_3$	974
HFC-43-10mee		1,640
Perfluorinated Compounds		
PFC-14		7,390
PFC-116	CF_4	12,200
PFC-218	C_2F_6	8,830
PFC-318		10,300
PFC-3-1-10		8,860
PFC-4-1-12		9,160
PFC-4-1-14		9,300
PFC-4-1-18		>7,500
Sulfur hexafluoride	SF_6	22,800
Nitrogen Trifluoride	NF_3	17,200

Source: Intergovernmental Panel on Climate Change (2008).

2.7.2 How To Assess Greenhouse Gas Emissions

Methods for assessing greenhouse gas emissions in the form of carbon dioxide (CO_2), as well as assessing greenhouse gas emissions in the form of nitrous oxide (N_2O) and methane (CH_4) estimated in the following equations: Greenhouse gas emissions from various activities (kg CO_2eq) = activity data (units) x greenhouse gas emission coefficients of each activity (kg CO_2eq/unit)

Carbon footprint refers to data that represents the amount of greenhouse gases produced throughout the life cycle assessment (LCA) from sourcing, raw materials, transportation, production, distribution. Applications measured in kilograms of carbon dioxide equivalent (kgCO_2 equivalent) per product unit. Therefore, carbon footprints was used as a measure of impact. From human activity to the system. Environment in terms of greenhouse gas content. Carbon footprint management was divided into two categories: product carbon footprint and corporate carbon footprint. (Thailand Greenhouse Gas Management Organization (Public Organization) [TGO], 2021)

1) Carbon footprint of product refers to the amount of greenhouse gases emitted from each unit of product throughout the life cycle of the product, from raw material acquisition, transportation, assembly, use and management of product carcasses after use, calculated in the form of carbon dioxide equivalent. To inform consumers that throughout the life cycle of the product, greenhouse gas emissions in the form of carbon dioxide were released. In addition, assessing the carbon footprint in a product encourages consumers to know the greenhouse gas emissions of everyday products. Consider deciding to purchase a particular product.

2) Carbon footprint for organization refers to the assessment of the number of emissions and resupply of greenhouse gases generated by an organization's operational activities (TGO, 2021). Both at the factory, industrial and national levels, it measured in the form of carbon dioxide equivalent. The carbon footprint calculated in two parts (Warisara Sangpiroj, 2010).

(1) The calculation of the primary carbon footprint is a calculation. Greenhouse gases from direct production of goods, such as the use of fuel in the production and transportation processes, both trucks, ships, and air.

(2) Secondary footprint calculation is a calculation of the amount of greenhouse gases generated from the use of goods as well as the disposal of carcasses after use.

The concept of carbon footprint Carbon footprint developed national carbon footprint assessment guidelines and standards, as well as the development of ISO 14067 to achieve international carbon footprint standards. The development of national carbon footprint assessment guidelines and standards by the UK was the first country to develop specific standards. For carbon footprint analysis called PAS 2050, the carbon footprint calculation Life cycle assessment used, a technique used to assess the potential for climate change. This is due to the release of carbon dioxide, as well as other greenhouse gases, throughout the life cycle of products and services. Quantitatively, the result is equivalent to the climate change potential of carbon dioxide in kilograms (kgCO_2 equivalent).

$$CFP = \sum A\,i \times EFi$$

CFP is the carbon footprint or carbon footprint. Equivalent per unit product (kg carbon dioxide equivalent/product unit)

Ai is the consumption of raw materials. Energy or chemicals formed in each activity (unit/unit of product)

EF_i is the emission factor coefficient in each activity i (kg carbon dioxide equivalent/unit).

2.7.3 Product Footprint Carbon Footprint Assessment Model

1) Business-to-Consumer (B2c) is an assessment of greenhouse gas emissions throughout the product cycle. Manufacturing, transportation and distribution processes, applications, B2c carbon footprint assessments scoped as shown in Figure 2.1.

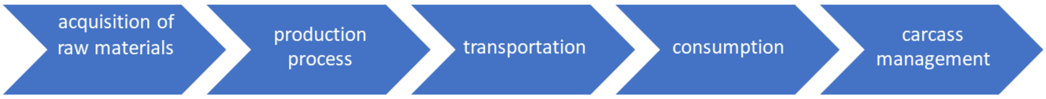


Figure 2.9 Scope of Carbon Footprint Evaluation of B2C Products

2) Business-to-Business (B2B) is an assessment of greenhouse gas emissions from the process of acquiring raw materials Production process up to the front of the factory ready for export or up to substance status. Inbound or raw materials of successive manufacturers, as defined in the specifications of each product. The B2B carbon footprint assessment has boundaries as shown in Figure 2.2.

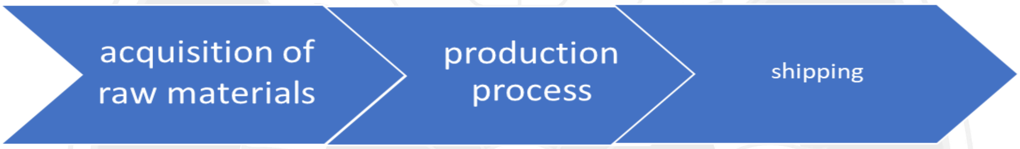


Figure 2.10 Carbon Footprint Evaluation Scope of B2B Products

3) Carbon Footprint Assessment Process The carbon footprint assessment of a product carried out according to the method of life cycle assessment of the environmental impact, also known as the Life Cycle Assessment (LCA), and the study procedure is based on the framework of the ISO 14040 series. Production Process, Transportation Product usage, reuse, and post-use product debris removal This can be said to be a consideration from birth to death (Cradle to grave) (TEI, 2004) or B2C, indicating the amount of energy and raw materials used, as well as the waste released into the to find ways to improve products with minimal environmental impact. There are four stages of evaluating the life cycle of a product: setting goals and scope of item account analysis. Impact assessment and interpretation as shown in Figure 2.3.

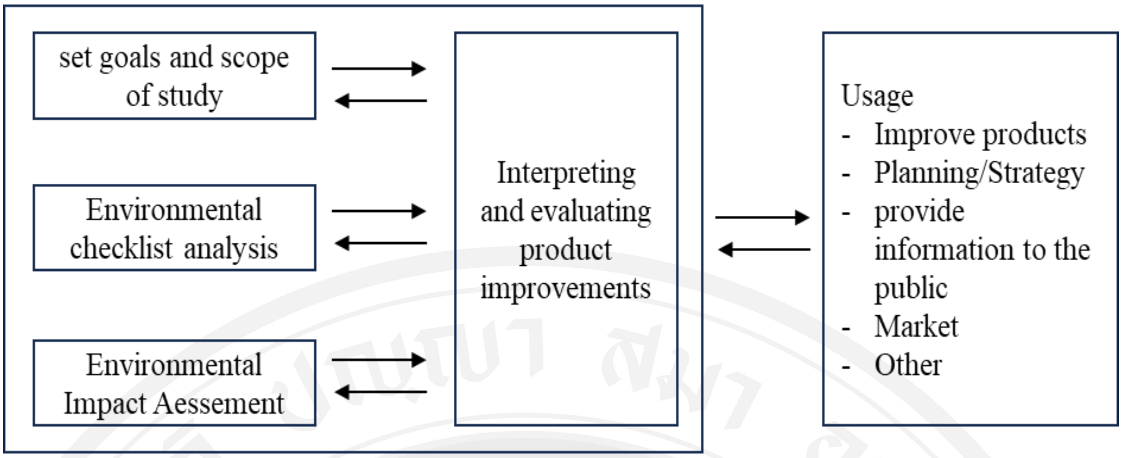


Figure 2.11 Product Life Cycle Evaluation Procedure
Source: TEI (2004).

2.7.4 Goal and Scope Definition

1) Targeting Setting goals is the first step in assessing carbon footprint. Goals must be clearly targeted, comprehensive, and purposeful. There is a reason for the study and the results of the study put to effective use. Setting goals is a key step, since if the goal lacks clarity, it can lead to confusion and can lead to miscalculations.

2) System boundary refers to the boundary between Products and environment or other product systems where the product system is the unit that collects materials and Coherent energy is a unit process that performs one or more functions, in which the phases of resources, raw materials or energy from the environment enter the system before being cheap. Scoping defines what needs to evaluate and collected that benefits the goals set. Boundaries can change when new boundaries was found to be more suitable for the study, and the scope defined to be as appropriate for use and purpose as possible. In addition, any activities do not organize into scope, namely, human energy used in activities such as grinding raw materials by hand. The customer's round trip to the retail point. Transportation by animals

3) Functional units used as the basic units for incoming and outgoing substances. This is the basis of the carbon footprint assessment because the measure of the system's performance is a comparator or measure between products.

2.7.5 Inventory Analysis

In the process of analyzing the environmental list, data collected. The source of the data is:

1) Primary information Primary data refers to data obtained from measuring production activities in a factory, organization, or data that an organization could access. Energy consumption, product volume, and distribution information include vehicle type, fuel type. Transport volume, distance transported.

2) Secondary data Secondary data refers to information obtained from sources other than primary data, which is information that a plant or organization does not have the ability to access information such as electricity generation, so it is possible to choose appropriate secondary data by sorting its reliability as follows:

(1) Thai's Basic Materials and Energy Environmental Database

(2) Data from dissertations and related research done in Thailand, which has been filtered.

(3) Generally published databases include LCA software, industry-specific databases, country-specific databases.

(4) Information published by international organizations such as the IPCC, the United Nations Collecting environmentally relevant data from processes defined in the targeting and scope procedures and calculating the inputs and outputs of the product system.

2.8 Related Research

According to the study and review of related research, Thiraphong Sawangpanyangkul (2009) stated that a similar experiment was dubbed “composting production” at Maejo University. “Do not overturn the pile” is a system that necessitates using an aeration pipe as a trendy way for making fertilizer now, but what Sep Holzer performs is not compost creation. He attempted to modify the Hügelkultur approach by stacking crops in full logs rather than little pieces of wood. He observed that by doing so, he could slow down the degrading process. which may last ten years. The plants growing on this mound receive continual nourishment for an extended period.

Similarly, Putchanat Sang-on and Roongreang Poolsiri (2010) investigated the rate of leaf decomposition in exotic forest plantations. A nylon mesh bag was used for the experiment. The humus was packed and spread on the soil surface, and nylon net bags were collected and tested monthly to assess humus weight and nutrient release over the trial period. The camphor leaves decayed the fastest, according to the results. Throughout the investigation, the decomposition constant (k) was 1.2886. Carbon concentrations fluctuated with time, while nitrogen, phosphate, and calcium initially fell and progressively climbed. The potassium concentration drops quickly and then rises.

Furthermore, magnesium levels tended to fall with longer breakdown times. Teerathat Chaisart, Rungrueang Poolsiri, Maliwan, and Haruthai Thanasan are examples. The Angkhang Royal Agricultural Station studied the degradation of plant remnants in diverse vegetable gardens. Chiang Mai Prefecture, the deterioration rate of the leaf remnants in bamboo bong yai was determined to be the greatest in the study. The average was 69.41%, with a decomposition constant (k) 1.42. The nitrogen (N) and phosphorus (P) concentrations in leaf and sheath residues were low in the early phases. Furthermore, as in the prior study, it increased with breakdown time.

Furthermore, Rujira Datesungneon (2016) investigated the effect of decomposing materials on the growth of ornamental plants in pots in the study of composting from various materials, such as fresh and dry decomposed twigs, and discovered that the pH value of the compost obtained from decomposed twigs was 6.8. -7.0. Furthermore, critical nutrients were discovered, including nitrogen (N) 1.25 - 1.59 percent, phosphorus (P) 0.59 - 0.92 percent, and potassium (K) 0.56 - 0.98 percent. There was a ten-thousand-year experiment in which compost was used to plant green trees. It was discovered that the growth was at first rather slow. Nonetheless, after two months, it was discovered that the 1000-year-old green tree was thriving and had dark green leaves. As a result, the best time to decompose waste before using them is between 60 and 90 days.

For example, research by Sudchon Woonprasert (2012) found that Kale has a high Fe requirement. Other studies on the link of nitrogen to kale growth have also been conducted. The yellowing will result from its administration in tiny doses. Young leaves that have chlorosis. The growth and production of Kale were compared to the rate of nitrogen released from organic fertilizers by (Chutimon Chuputsa, 2010). It was discovered that Kale grew and produced more while using wet organic fertilizers than when using dry organic fertilizers. Wet organic fertilizers release nutrients by fermenting in water before use, making nutrients valuable to plants. As an alternative, Wanniwsa Pattamapusit and Pornpairin Rungcharoenthong (2014) studied the effectiveness of chemical fertilizers on Kale's growth rate and yield in research literature. In treatments 2, 3, and 4 of the trial, the Bang Bua Thong 35 cultivar discovered that using chemical fertilizers with high nitrogen content resulted in 46-0-0 + 27-6-6 and 46-0-0 + 25-10. With the growth rate, the yield was higher than the low nitrogen fertilizer in Formula 5 with a value of 46-0-0 + 27-6-6. -10, 46-0-0 + 16-12-8 9 k, respectively. (Sunya Lesing & Ornprapa Anugoolpraser, 2016) examined the effects of premium organic fertilizers on the development and fruiting of Kale. Two experimental variables were identified: the Department of Land Development uses the high-quality organic fertilizer Formula 1 as an example of high-quality organic fertilizer. In addition, use high-quality organic fertilizers at three different rates of 1, 2.5, and five grams of nitrogen per five kilos of soil and high-quality fermented chicken manure. The trial findings revealed no differences in the types of high-quality organic fertilizers, fresh weight, or dried weight of Kale. This effect, in contrast, was strongly correlated with the elevated nitrogen level. It was abundantly clear from this experiment that both high-quality organic fertilizers were used at rates starting at 2.5 g. N. could replace chemical fertilizers with cow manure at 1 g. N. and studies on the effect of compost, like the study by Krongjai Somrug (2017) who examined the effect of indigo waste compost on the growth and yield of Kale. The study discovered Kale grew and produced well when planted with indigo waste compost. The Kale can grow up to 35.19 cm in height. As an alternative, (Chanjarat Veerasan, Atinuch Saejiw, & Prai Mattawarat, 2009) investigated how different organic fertilizers affected the flow of plant nutrients into the soil. To research how applying organic fertilizer affects the distribution of N, P, and K in the soil. It was discovered that adding dung increased the rate of N, P and K release.

For the study of water use of kale (Sampao Kaewsasaen, Charuek Sinthurat, & Watcharee Kongkaew, 2015). Sampao Kaewsasaen, Manthana Sujarit, Charuek Sinthurat, and Watcharee Kongkaew (2016) conducted experiments to discover the optimum proportion of water to Kale while studying the vegetable's water use. The planting experiment was carried out across two years, the first from January 12 to March 3, 2015, and the second from January 6 to February 23, 2016. It was discovered that Kale required K/p equal to 0.9 for the best water consumption in year 1. Kale produced 5.83 tons/rai while receiving 200.65 mm, or 312.06 cubic meters, of water per rai during the growing season. The K/p value for Kale was 0.9 in the second year. During the growing season, Kale received 312.06 cubic meters of water per rai or 195.04 millimeters.

Kale's environment was described by Wasan Krisadarak (2001) Chinese Kale can thrive in virtually any soil. However, Chinese Kale is climate-resistant and does best in sandy soil with good drainage, high humidity, a pH of 5.5 to 6.8, and a temperature range of 20 to 25 degrees Celsius. Good high and yield satisfactory results at temperatures higher than 25 degrees Celsius. According to a summary of the water needs of Chinese Kale by Chanai Yodpetch (1999) the soil moisture needed to be about 80% and get enough water to produce high-quality Chinese Kale. The growth of Chinese Kale will continue in the presence of water. It does not taste good and is quite high in fiber.

CHAPTER 3

RESEARCH METHODOLOGY

This research was to study and develop suitable low - water use cultivations in the Ubon Ratchathani province. The research was an experimental research methodology in which there are three stages as followings: The first stage was the preliminary study consisted of reviewing documents and creating comparative crop plots between typical plots and Hügelkulturs plots to analyze factors related to the growth of cultivated plants, bringing to The second stage was designed to grow low-water crops which was suitable for the area of Ubon Ratchathani province. Last stage was to provide guidelines for the dissemination of prototypes of crop plots for utilization that had the detail of the research methods as follows**.**

3.1 Documentary Review

Related documents and research are reviewed, including agricultural condition in study area, drought status in study area, Hugelkultur in abroad and Thailand, affected factors for Kale growing, etc. The documentary review constructed mainly this research methodology.

Review documents and related research to Review knowledge and theories related to soil resources, water resources, and soil moisture. Water needs of plants Suitable environment for growing vegetable Factors related to growth and yield of vegetables The form of planting plots currently used. Moreover, to study the findings related to this study.

3.2 Experimental plots

This study studied kale plants' growth and yield because kale is another type of vegetable popularly grown in Thailand. It is a popular vegetable and has high nutritional value, namely higher vitamin A and vitamin C than other vegetables, and 53 kilocalories of energy per kale (100 grams) (Salukukhe & Kadam, 1998). The part used for consumption is the leaves. And the stem of kale has benefits in helping to relieve the stomach. Because kale has a lot of fiber, it helps with excretion. It also has the properties of reducing cholesterol and nourishing the skin. However, nowadays

Therefore, this study selected kale to experiment with the appropriate plant plot design and water use in Ubon Ratchathani Province. The study's results will be a form of planting plots that use less water suitable for promoting and expanding the use of plant plots that use less water in drought-prone areas in various areas, including promoting the use of tree branches. Leaves or agricultural materials that must be discarded can be used again. Reducing production costs and continuing to use materials efficiently and cost-effectively.

The Hügelkultur technique requires assembling a raised bed with wood, twigs, and leaves arranged from large to small. Prepare the planting material by mixing soil with manure in a 4:1 ratio and place it in a circular cement pond. Cover the plot with rice straw and arrange it according to the experimental plan. Finally, cover the plot with a transparent plastic roof to control rainwater.

3.3 Experimental Factors

This research Considered and studied the factors related to the growth of vegetables, as shown in Figure 3.1.

1) The initial variable is studied on the effect of timely watering and unequal rates on the environment, nutrients, organic matter in the planting fields Growth, and Yield of Kale in Low – Water plots.

2) Control variables: In this study to study the factor of watering rate Therefore, different variables were controlled to be the same as follows: Prepare the planting plot with the same planting material. In Hügelkulturs plots and the control

plots, the same soil was used for Hügelkulturs plots, and the mature 21-day-old kale seedlings were selected and of the same size. Transplanted on the same day and left 14 days for kale to adopt.

3) A dependent variable refers to a variable that analyzes the impact of an initial variable, as follows: soil temperature, moisture, acidity, and wood decay and macronutrients on the growth and yield of kale in each plot.

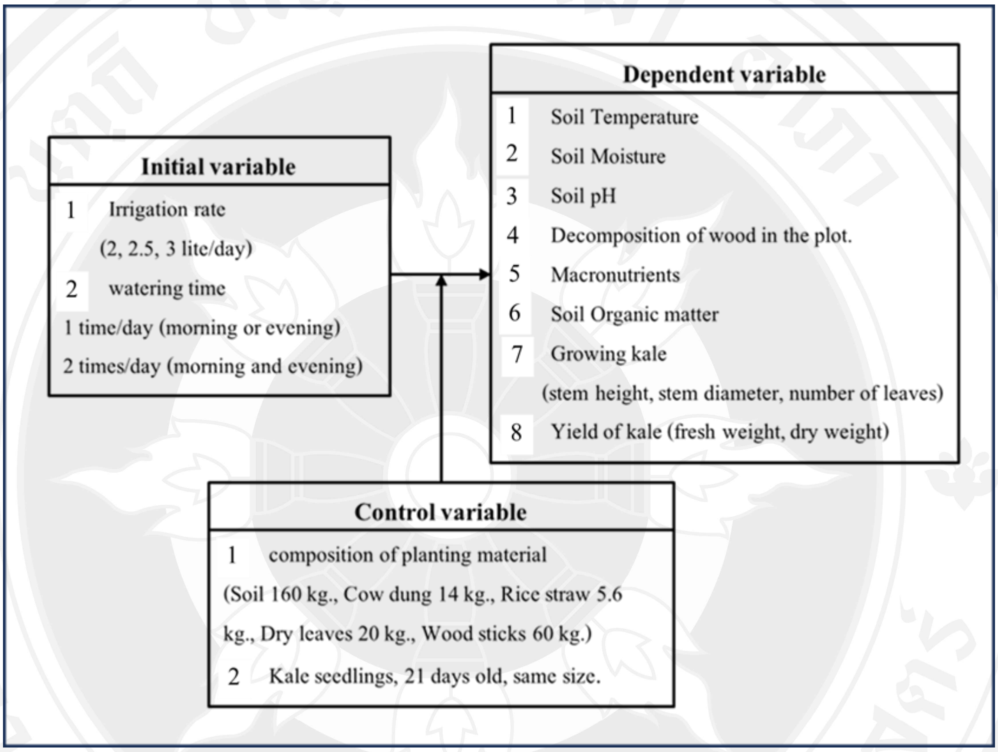


Figure 3.1 Research Framework.

3.4 Experimental Plan

The study of suitable low water consumption plots in Ubon Ratchathani Province Using a completely randomized design (CRD) experimental plan for kale, seven treatments with three replications were used to study the effect of three levels of watering which are 1 l/day, 2.5 l/day and 3 l/day.Details of each treatment are shown in Table 3.1 and Figure 3.2.

Table 3.1 Shows the Details of Each Treatment

Treatment	**Plot**	**Watering time**	**Amount of Water (liters/time)**
WT1	Hügelkultur	Morning-Evening	1.00 (2 liters/day
WT2	Hügelkultur	Morning-Evening	1.25 (2.5 liters/day)
WT3	Hügelkultur	Morning-Evening	1.50 (3 liters/day)
WT4	Hügelkultur	Morning	3.00 (3 liters/day)
WT5	Hügelkultur	Evening	3.00 (3 liters/day)
TC1	Control (typical	Morning-Evening	1.50 (3 liters/day)
TC2	Hügelkultur (no plant)	Morning-Evening	1.50 (3 liters/day)

Figure 3.2 Experimental Plot Arrangement Diagram

3.5 Stages of Research

3.5.1 Preparation of Planting Material

1) To select only the most mature plants for planting in the experimental plot, sow vegetable seeds in seed trays. Take care of the plants by giving them water two times a day, in the morning and evening, five liters each time, throughout the age of 21 days.

2) Prepare the plot for planting using the Hügelkultur technique as follows: The research applied cement pond rings for the planting plot. There are 15 plots and control plots (TC), with a diameter of 80 cm and a height of 50 cm. There are six plots in total for the control group, resulting in a total of 21 plots.

3) Prepare wood samples, divided into four sizes: (1) branches (2) small size (3) medium size (4) large size. To study wood decomposition, wood logs were placed in nylon mesh bags, as shown in Figure 3.3.

Figure 3.3 Wood Preparation for Wood Degradation Studies

4) Arrange planting material layers inside the experimental pots, as shown in Figure 3.4, as follows.

Figure 3.4 Schematic Diagram of the Placement of Materials inside the Plot

Bring the branches into the prepared cement pond. Take the leaves and cover them tightly over the branches. After that, cow manure was mixed with the soil and covered over the leaves at the last of stage to covered with straw and watered thoroughly.

5) Control Plots (TC)

There are two control plots, TC1 and TC2.

For TC1, soil and cow manure should be mixed in a ratio of 4:1, and the mixture should be placed to a depth of 40 cm. Three plots need to be created and watered twice a day (morning and evening) with a total of 3 liters of water.

For TC2, soil and cow manure should also be mixed in a ratio of 4:1, but with planting material added. Three plots must be created without any vegetables. These plots should also be watered twice daily (morning and evening) with a total of 3 liters of water.

6) Growing Kale

(1) Kale seeds should be planted so that the seedlings are around 21 days old.

(2) Kale seedlings that are similar in strength, size, and height should be selected for transplantation into a cement pond.

(3) The planting point should be determined at a distance of 20 x 20 centimeters, and eight kale plants should be used per plot.

(4) Kale buds should be planted at designated points (see Figure 3.5).

(5) Weekly growth data for kale should be recorded every Friday at 5:00 p.m. The first recording should be made when the kale is 49 days old.

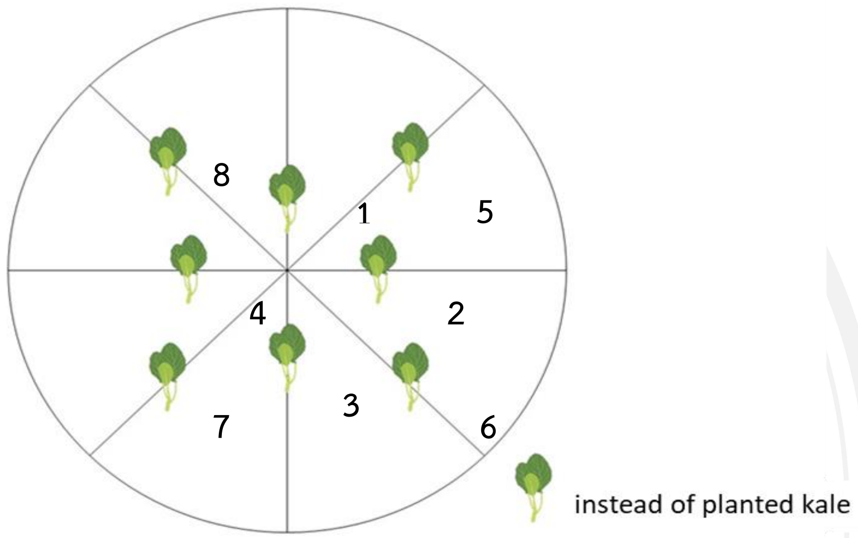


Figure 3.5 Kale Planting Plan instead of Planted Kale

3.5.2 Soil Sampling.

For soil sampling, use the composite sample method with the following steps:

1) Collect the soil using a shovel to dig the soil in a wedge about 15 centimeters deep. After that, collect the soil by using a shovel to wash the soil next to the pit (smooth side) to obtain a sheet about 2-3 centimeters thick to the bottom of the pit. The soil collected should be placed in bags or plastic buckets.

2) Mash each soil collected well and pour it over a plastic cloth. Mix again by lifting the plastic fabric corners at two angles opposite each other. Do alternate angles 3 - 4 times.

3) Collect the soil obtained from the mash for further analysis at the laboratory.

3.5.3 Data Collection

Record data of the planting fields, consisting of forth main aspects:

1) Climate:

(1) Record data every 3 hours between April 10 and April 12, 2020.

(2) Record weekly changes at 5:00 p.m. on days 14, 21, 28, 35, 42, and 49 after planting for five weeks.

(3) monitoring parameters as shown in Table 3.2

Table 3.2 Climate Parameters

Parameter	Methods
1. Temperature	Thermometer
2. Relative Humidity	Hygrometer

2) Soil:

(1) The soil environment data in the field should be recorded in the same way as the weather data.

(2) monitoring parameters of the Bureau of Land Development Science, Department of Lands (2004), as shown in Table 3.3

Table 3.3 Soil Sample Analysis

Parameter	Analysis methods
1. Temperature	Thermometer
2. Moisture	AOAC Official Method 967.03
3. Conductivity (EC)	EC meter
4. pH	pH Meter
5. Organic Matter in soil (OM)	Titration method
6. Nitrogen (N)	Five percent of the volume was calculated.
	Organic calculated objects
7. Phosphorus (P)	Bray II

Parameter	Analysis methods
8. Potassium (K)	Flame Photometer

Source: Land Development Department (LDD, 2010).

3) Plant growth.

Measure the growth of the entire plant every 1 week throughout the planting period by measuring the growth of the plant 2 weeks after planting) at 5:00 p.m. as follows:

(1) Plant height measurement method

(1.1) Use a ruler or tape to measure the area of the stem with the root part up to the apex of the kale.

(1.2) Record the height of the kale.

(2) Stem diameter measurement:

(2.1) Use a vernier caliper to measure the widest part of the stem.

(2.2) Record the diameter of the stem.

(3) Leaf count:

(3.1) Count the number of leaves for each plant.

(3.2) Record the number of leaves.

(4) Methods for measuring fresh weight and dry weight:

(4.1) Remove the entire plant and clean the soil and dirt with water.

(4.2) Weigh and record the fresh weight.

(4.3) Allow the freshly weighed kale to dry at 70 – 80 °C for 48 hours.

(4.4) Weigh and record the dry weight.

4) Degradation Rate of Studied Logs:

To determine the degradation rate of studied logs, follow the methods below:

(1) Sampling and preparation:

(1.1) Randomly sample logs in the plots and dry them at 50 – 60 °C for 24 hours.

(1.2) Pack the wood samples in nylon bags.

(1.3) Place the bags in the layer of wood in the plot and cover them with planting material.

(1.4) Plant kale.

(2) Digging and weighing:

(2.1) After planting and collecting kale, excavate the plot to retrieve the buried logs.

(2.2) Clean the soil attached to the logs completely.

(2.3) Dry the logs at 50 - 60 °C for 24 hours.

(2.4) Weigh and record the dry weight of the logs.

3.6 Water Footprint Assessment

This study calculated the water footprint of kale growing in low water-intensive plots to compare the water consumption of all plots. However, the yield obtained from each planting plot is unequal, resulting in unequal water footprint values.

In addition, excessive watering can lead to poor yields, such as bottoms. Therefore, the water footprint of the plots was calculated to find the optimal amount of water to grow the highest-yielding kale and the lowest water footprint.

In this study, the blue water footprint of agriculture was used to calculate the water footprint of crop production. Irrigation water used in crop production (cubic meter per rai) to the amount of yield per cultivated area (tons per rai) as the equation.

$$WFblue = \frac{CWU\text{blue}}{Y}$$

WFblue is the blue water footprint of crop production (cubic meters per ton).

CWUblue Is the amount of water used to produce crops from natural water sources, irrigation water (cubic meters per rai).

Y is the amount of yield per acre (tons per rai).

3.7 Carbon Footprint Assessment

This study applied carbon footprint calculation from life cycle assessment (LCA) considering materials. The process is from planting seedlings, growing kale, and harvesting. By referring to the calculation according to the guideline for assessing the carbon footprint of products by the Technical Committee on Carbon Footprint of Products (2011) as follows:

$$CFP = \sum A\,i \times EFi$$

CFP is the carbon footprint or carbon footprint. Equivalent per unit product. (Kg carbon dioxide equivalent/product unit)

Ai is the consumption of raw materials. Energy or chemicals formed in each activity. (Unit/Product Unit)

EFi is the emission factor coefficient in each activity (kg carbon dioxide equivalent/unit).

In this study, the value of the carbon footprint of the product was calculated. Therefore, studying the quantity and global warming potential of all vegetable growing materials is necessary. The result of the study will be the amount of carbon dioxide equivalent per unit of agricultural production.

3.8 Statistical Data Analysis

This study analyzed the environmental data of the experimental plots and the growth data of kale from all seven experimental sets, using descriptive statistics analysis to explain the study results, for example: average soil temperature, soil moisture, soil acidity, The number of macronutrients in the soil. In addition, the study also used inference statistics to compare the study results on the growth of kale from each experimental plot. Furthermore, the correlation of the study results from details as follows:

1) Pearson correlation coefficient to study the relationship of study results at a 95 percent confidence level by referring to the results of Hinkel et al., 1998. The correlation size could indicate the relationship level of the two variables studied, as in Table 3.4

Table 3.4 The Table Shows the Magnitude of the Correlation and the Meaning of the Correlation of the Variables

Magnitude of the Correlation Positive	**Magnitude of the Correlation Negative**	**Meaning**
+ 0.91 to + 1.00	0.00 to - 0.30	extremely high
+ 0.71 to + 0.90	-0.31 to - 0.50	high
+ 0.51 to + 0.70	-0.51 to – 0.70	moderate
+ 0.31 to + 0.50	- 0.71 to – 0.90	little
0.00 to + 0.30	- 0.91 to - 1.00	extraordinarily little

2) Compare the variance with Duncan's multiple range test (DMRT) statistics at the level of 95 percent to study the difference in water consumption rates, planting pattern, physical factor macronutrients, Kale growth, and yield.

3.9 Guidelines for Utilization and Expansion Guidelines

From the study results, researchs analysed the trend and prepared manual for less water from to propose to farmer in Ubon Ratchathani Province in the focus group, different comment, ideas and opinions are applied to improve the contents and communication of the low water farming manual.

CHAPTER 4

STUDY RESULTS

Study of macronutrients in Hügelkultur plots, CRD experiments were planned in No. 19 Moo 6, That Sub-district, Warin Cham rap District. Ubon Ratchathani Province to determine the effect of watering on kale yield in the Hügelkultur field plot comparing to vegetable yield from the control plot. The experiments were done during March – May 2020. The detail of experimental sets are shown in Table 4 – 1

Table 4.1 Shows the Details of Each Experimental Set

Experimental	**Characteristics**	**Watering Time**	**Amount of Water (liters/time)**
WT1	Hügelkultur	morning-evening	1.00 (2 liters/day)
WT2	Hügelkultur	morning-evening	1.25 (2.5 liters/day)
WT3	Hügelkultur	morning-evening	1.50 (3 liters/day)
WT4	Hügelkultur	morning	3.00 (3 liters/day)
WT5	Hügelkultur	evening	3.00 (3 liters/day)
TC1	Control	morning-evening	1.50 (3 liters/day)
TC2	Hügelkultur (Not plant)	morning-evening	1.50 (3 liters/day)

All seven experimental sets are in the same area. The control variables are the components of the planting material: the amount of wood, branches, leaves, soil, manure, the amount of soil manure, the size of the planting plot, and the order of planting material stratification, the size of the kale. A covered house was built to control the factors of rainwater. The study results were as follows:

4.1 Factors Affecting Plant Growth

4.1.1 Environment Change

4.1.1.1 Changes in the Day Cycle

(1) Temperature change

The study results of changes in temperature in the atmosphere and soil during the day. Between 10 and 12 April 2020, the temperature was measured every 3 hours in all seven experimental sets from 12:00 noon to 9:00 a.m. It was found that the 3-hour average temperature for three days was in the range of 28.01 – 32.71 °C, with the highest temperature at 3.00 p.m. before decreasing in the afternoon and steadily decreasing until the lowest at 6:00 a.m. to 9:00 a.m. and increases according to the light intensity during the day The graph showing the change in air temperature during the day is shown in Figure 4.1.

As for soil temperature, it was found that experimental set WT1 had the highest temperature of 40.60 °C from 9:00 a.m. to 12:00 noon, and the lowest temperature of experimental set TC2 was 25.27 °C from 24:00 to 3.00 a.m., as shown in Figure 4.2.

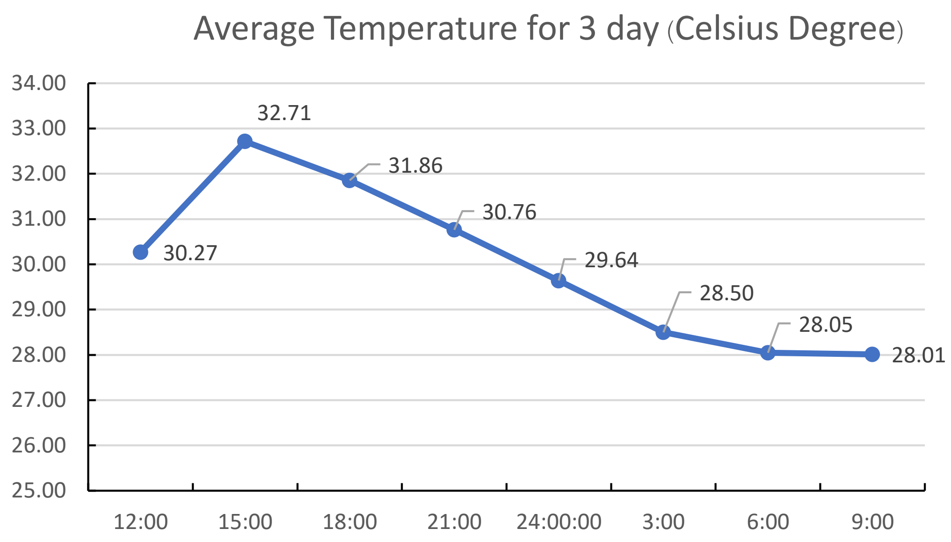


Figure 4.1 Temperature Changes in the Atmosphere During the Day

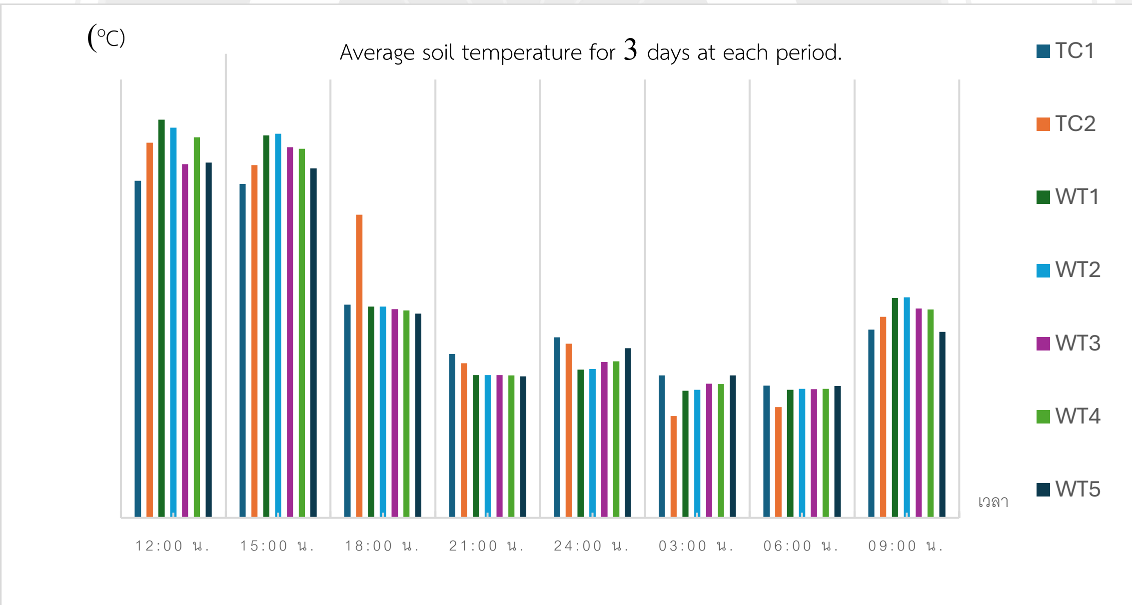


Figure 4.2 Changes in Soil Temperature During the Day

(2) Relative humidity

The results of measuring the relative humidity in the air every 3 hours during the period from 12:00 noon to 9:00 a.m. for all seven sets of experiments showed that the average relative humidity above the planted plots between 50.01 - 97.36 percent, with the lowest value at noon and increasing in the afternoon until the highest in the morning. Moreover, the temperature began to decrease when there was sunlight. Characteristics of changes in daily air relative humidity over planting plots are shown in Figure 4.3.

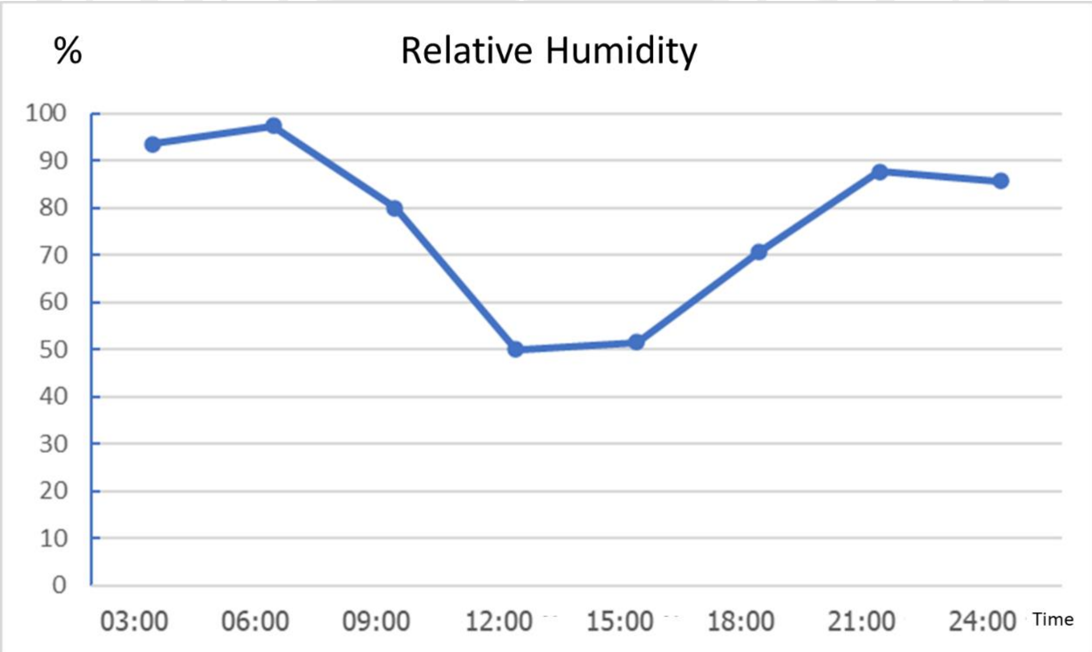


Figure 4.3 Changes in the Daily Average Relative Humidity in the Air for 3 Days (10 – 12 Mar. 2020)

(3) Changes in soil moisture

The average soil moisture content of the days of the experimental set of Hügelkultur plots in which vegetables were grown was relatively stable. The highest mean in the experimental set at TW3 was 16.99%, and the lowest in the experimental set at TW5 was 15.22%. The experimental set at TC2 without cropping had higher soil moisture values and varied in a wider range than other plots, with an average of 25 percent. The value of the experimental set WT1 was 15.33 -

16.67%. WT 2 was 15.33 - 16.67%, averaging throughout the day at 16.55%. WT3 was in the range of 15.94 - 21.71%, averaging throughout the day at 16.99%. The experimental set at WT4 was in the range of 15.16 - 16.04%, the experimental set at WT5 was in the range of 14.79 - 15.60, the experimental set at TC1, control, normal, was in the range of 15.74 - 17.61 and the experimental set at TC2, the Hügelkultur plot, was in the range of 15.88 - 30.29%, averaged throughout the day at 25.42%. Details of the day cycle change of soil moisture in the field as shown in Figure 4.4.

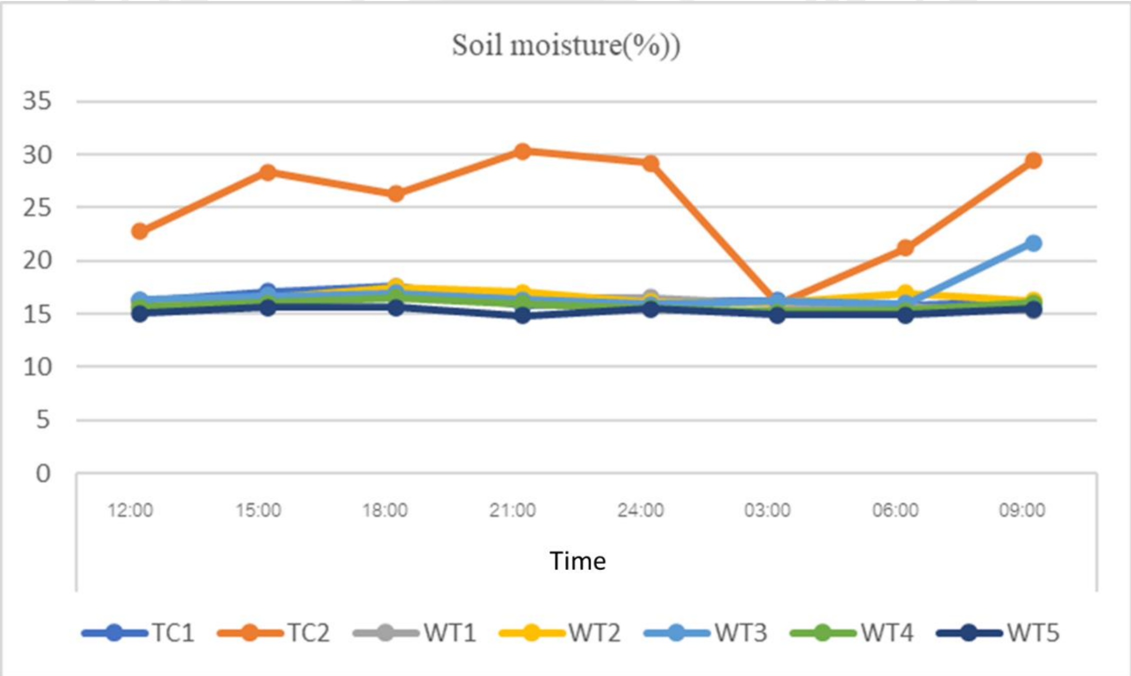


Figure 4.4 Changes in soil moisture during the day

4.1.1.2 Changes in the Week

The study results of the changes in environmental characteristics in the Hügelkultur planting plots were measured once a week at 5:00 p.m. throughout the planting period, every seven days, for five weeks between March 22 - May 6, 2020. It was found that the air temperature mean lowest was 31.86 °C in the first week, and the highest was 33.57 °C in the third week. The lowest value was 26.33 °C, and the highest was 35.00°C. The relative humidity in the first week was between 47 - 65%, the second week was 56 - 61%, and the third week was 60 - 78%. 4 was 71 - 77 percent, and week

5 was 72 - 76 percent. The WT1 experimental set had a temperature between 27.0 - 34.3 °C, an average of 32.1 °C. The WT2 experimental set, a temperature between 28.0 - 33.0 °C, an average of 31.9 °C, and the WT3 experimental set, a temperature between 28.0 - 34.0 °C, an average of 31.73 °C. The temperature of experimental set WT4 was between 27.3 - 33.8 °C, with an average temperature of 31.7 °C, and experimental set WT5, had a temperature between 26.3 - 34.0 °C, with an average temperature of 31.5 °C, and experimental set TC1, with an average temperature of 29.7 - 33.6 °C. at 31.6 °C and the experimental set TC2 had a temperature between 33.0 – 35.0 °C with an average of 33.9 °C.

The weekly soil moisture content in the Hügelkultur plots where vegetables were grown was low in the first week. Before increasing in the second week and remaining relatively stable the following week until the last week. In control plots, TC1 was highest in the first week, decreased in the following weeks, and remained relatively stable until the last week. TC2 had the highest soil moisture content. when compared to all plots The first week was 11.70 - 18.25%, the second week was 15.13 - 20.60%, the third week was 14.47 - 20.20%, the fourth week was 14.73 - 18.30% and the fifth week was 14.47 - 20.20%. 15.30 - 20.50 percent, the ambient temperature in the first week was 30 - 35 °C, the second week was 32 - 34 °C, the third week was 33 - 34 °C, the fourth week was 33 - 35 °C and Week 5 was 34 – 35 degrees Celsius. Moreover, the pH value in the first week was 6.2 - 6.6, the second week was 6.4 - 6.7, the third week was 7.2 - 7.9, the fourth week was 7.4 - 7.9, and the fifth week was 7.2 - 8.1 which throughout the experiment Relative humidity The lowest value is 47.33 percent and the highest value. Representing 77.67 percent soil moisture. The lowest value is 11.70 percent, and the highest value. Representing 20 percent. Moreover, the pH in the soil has a minimum value of 6.2 and a maximum value of 8.1. Details of the study results for each indicator are shown in Figure 4.5 - 4.9.

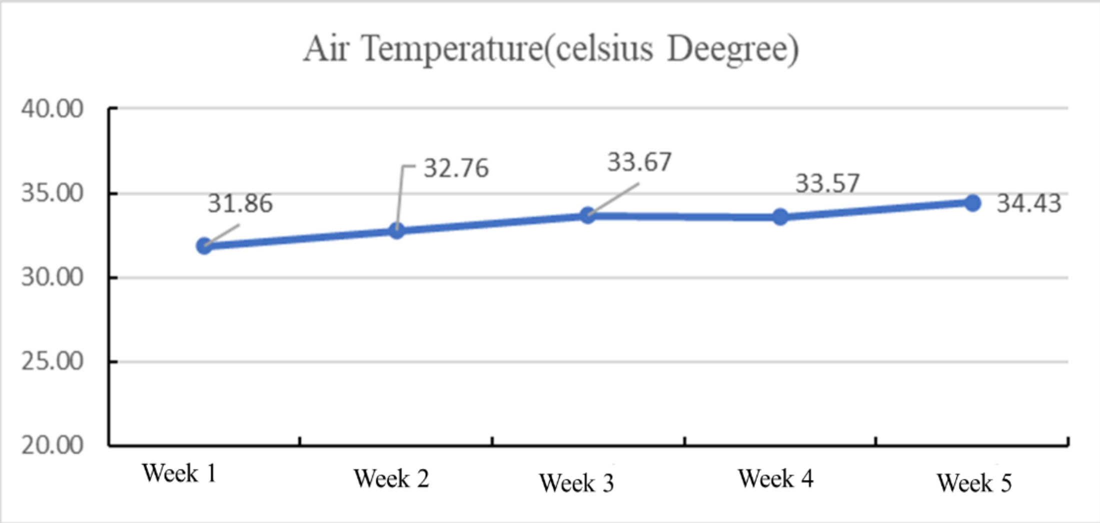


Figure 4.5 Weekly Changes in Atmospheric Temperature

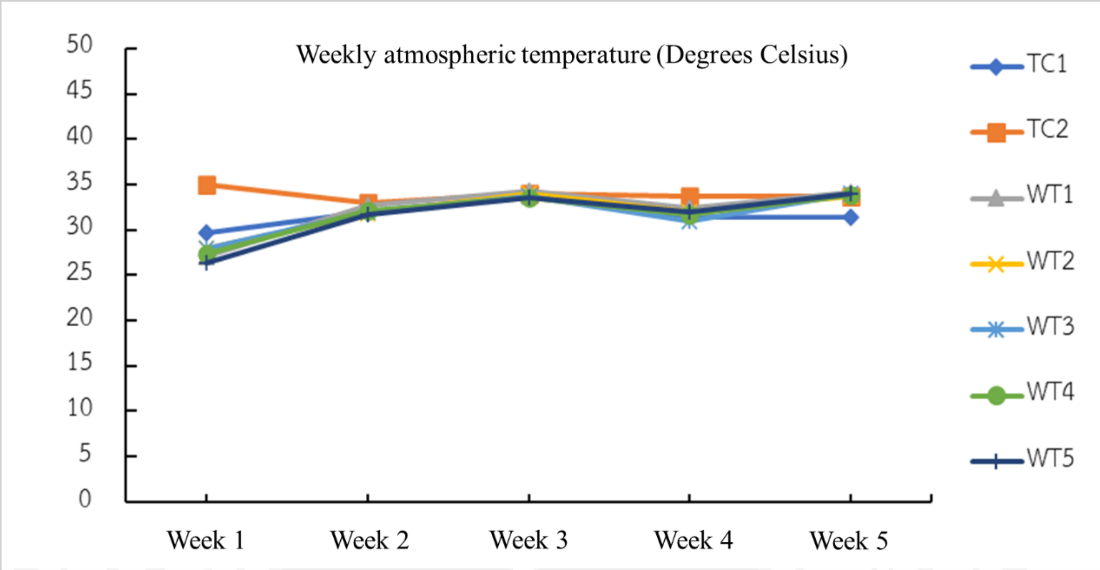


Figure 4.6 Weekly Changes in Soil Temperature

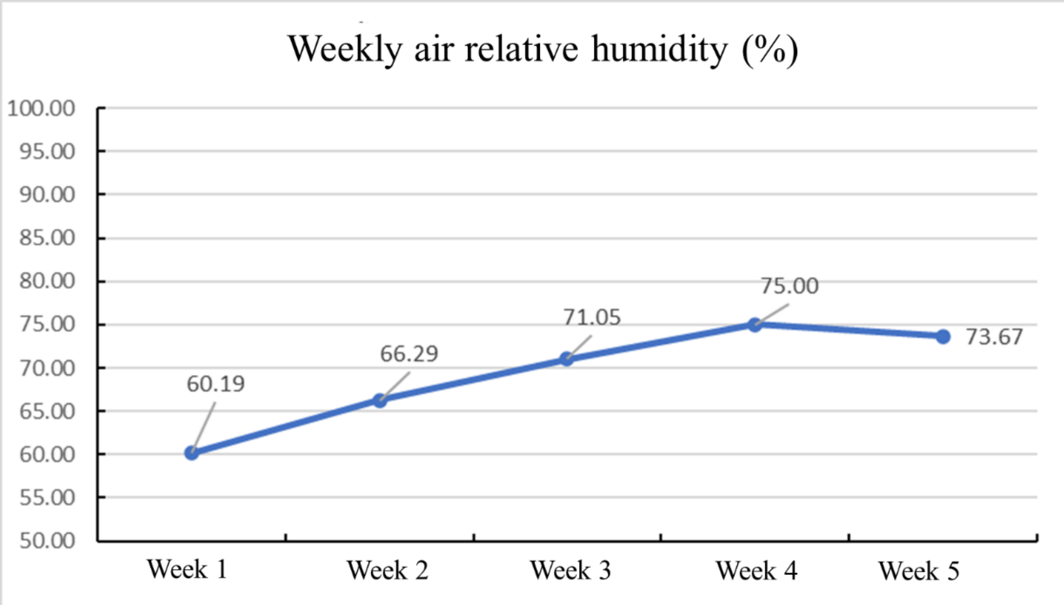


Figure 4.7 Changes in Mean Air Relative Humidity Throughout Cropping

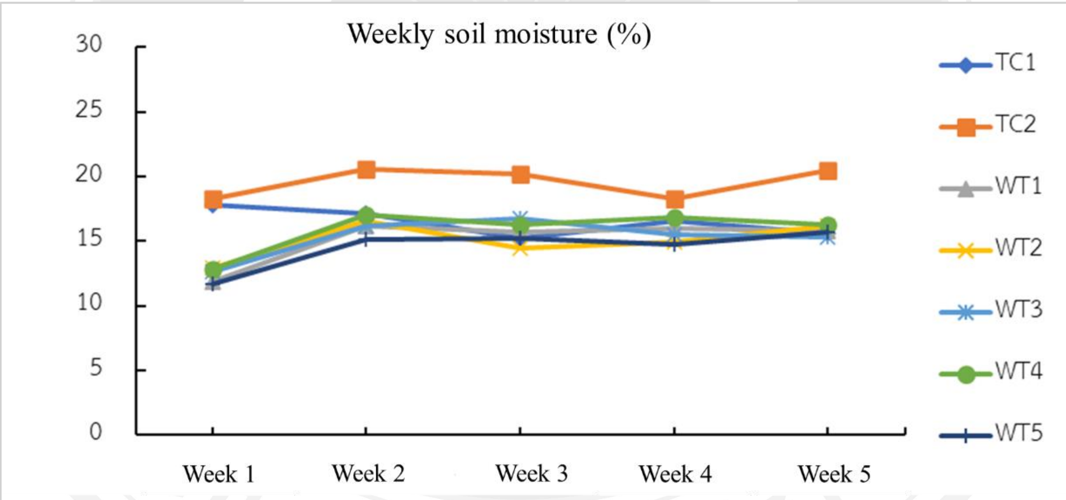


Figure 4.8 Weekly Changes in Soil Moisture

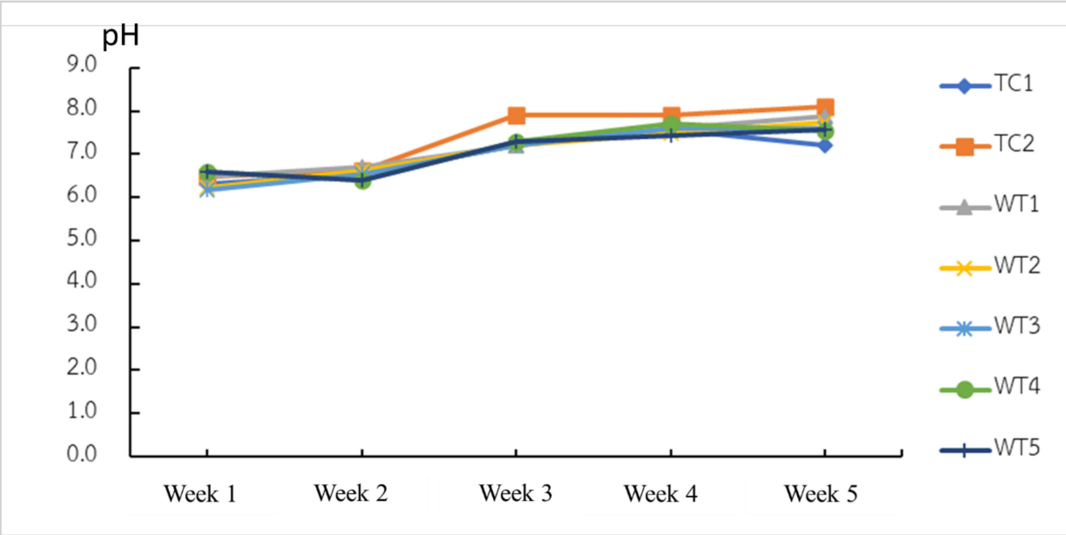


Figure 4.9 Weekly Changes in Soil pH

4.1.1.3 Comparison Results of Differences in Environmental Characteristics of Planting Plots

The field environment consisted of soil temperature, soil moisture and soil pH . The study found that the average soil moisture in the experimental set with different watering methods was in the range of 14.48 – 16.47%, which was not significantly different. Significant at the 0.05 level, except for the experimental set at TC2 in the control plot where vegetables were not grown. The mean was the highest at 19.57 and was significantly different at the level of 0.05 with other experimental sets. All experimental sets had no significant differences in soil temperature and pH. The average soil temperature was 31.10 – 32.87 degrees Celsius, and the average pH was 7.0 – 7.4, as shown in Table 4.1.

Table 4.2 Characteristics of the Physical Environment of the Planting Plots

Treatment	Watering (liters)		Soil Moisture (1) (%)		Soil Temp. (1) (°C)		pH (1)	
	Morning	Evening	Average	± S.D.	Average	± S.D.	Average	± S.D.
WT1	1.00	1.00	15.12 a	1.81	32.10 a	2.99	7.2 a	0.59
WT2	1.25	1.25	15.02 a	1.43	31.90 a	2.39	7.1 a	0.62
WT3	1.50	1.50	15.28 a	1.56	31.73 a	2.42	7.0 a	0.65
WT4	3.00	0.00	15.85 a	1.71	31.70 a	2.60	7.1 a	0.58
WT5	0.00	3.00	14.48 a	1.59	31.50 a	3.05	7.1 a	0.52
TC1	1.50	1.50	16.47 a	1.07	31.60 a	1.44	7.0 a	0.52
TC2	1.50	1.50	19.57 b	1.91	33.87 a	0.73	7.4 a	0.78
F-test (2)			*		ns		ns	
C.V. (%)			9.91		6.96		8.54	

Note: ns = not statistically different, * = statistically different at the significance level 0.05

(1)Comparison on the column side the yield of different watering kale followed by the same letter. No difference by DMRT at 95% confidence level.

4.1.1.4 Relationship between the Physical Environments

The correlation between soil moisture and soil temperature was moderately positive. Soil temperature was moderately correlated with soil pH. Environment correlation values are shown in Table 4.2.

Table 4.3 Showing the Correlation between the Environment in the Field

Correlation	R^2	P-value	Size
Soil moisture and temperature	0.675**	0.000	Moderately positive
soil moisture and l pH	0.308	0.098	less positive
Soil temperature and pH	0.632**	0.000	Moderately positive

Note: *statistically significant at the 0.05 level ** statistically significant at the 0.01 level

4.1.2 The Number of Macronutrients in The Planting Plots

Nutrients were studied before and after planting kale in the Hügelkultur plots, including total nitrogen (N), phosphorus beneficial to plants in the soil (P2O5), potassium (K2O5), organic matter. Objects (OM) and electrical conductivity (EC) found that.

The nitrogen content in the soil before planting was 756.3 – 1,463.3 mg.kg-1, and the total nitrogen content in the soil after planting was 427.7 – 1,208.7 mg.kg-1. Before planting and after planting in the Hügelkultur field of the experimental set, WT1, WT2, and WT3 had increased total nitrogen values, and the mean values were not significantly different at the significance level of 0.05 As for the experimental set, WT4, WT5, and TC1 showed a decrease in the total nitrogen value. Hügelkultur plots WT4 and WT5 showed no difference in mean nitrogen values. The evening-watered plots in the experimental set at WT5 had the lowest mean values and were significantly different from the experimental set at WT1, WT2, and WT3.

The amount of phosphorus beneficial to plants in the soil (Phosphorus: P2O5) in the soil before planting was 165 – 260.8 mg.kg-1, and the amount of phosphorus beneficial to plants in the soil (Phosphorus: P2O5) in the soil after planting was 115.1. – 293.7 mg.kg-1The pre-planting mean was not significantly different at 0.05 from the post-planting mean in all experimental Hügelkultur plots. There was a decrease in the average useful phosphorus. The mean values were not significantly different at 0.05 except in the normal plots. TC1 was increased, and the mean values were significantly different from the experimental sets WT1, WT2, and WT5 but not different. Same as the experimental set WT3 and WT4.

The potassium content (Potassium: K2O5) in the soil before planting was in the range of 239.3 – 493.9 mg.kg-1, and the content of Potassium (K2O5) in the soil after planting was in the range of 79 – 275.4 mg.kg-1. WT1, WT2, and TC1 were not significantly different in the experimental set. However, it significantly differed from the experimental set; WT3, WT4, and WT5 were lower than the first set, between 347.90 - 377.08 mg/kg. The average value of useful potassium decreased after every plot was planted. The mean values of Hügelkultur plots were not significantly different between 143.00 – 171.18 mg/kg. The values of normal plots in the TC1 experimental set decreased as well, but their average values were higher than others. There was a significant difference between the 95% confidence and the Hügelkultur plots.

The potassium content (Potassium: K2O5) in the soil before planting was in the range of 239.3 – 493.9 mg.kg-1, and the content of Potassium (K2O5) in the soil after planting was in the range of 79 – 275.4 mg.kg-1. WT1, WT2, and TC1 were not significantly different in the experimental set. However, it significantly differed from the experimental set; WT3, WT4, and WT5 were lower than the first set, between 347.90 - 377.08 mg/kg. The average value of useful potassium decreased after every plot was planted. The mean values of Hügelkultur plots were not significantly different between 143.00 – 171.18 mg/kg. The values of normal plots in the TC1 experimental set decreased as well, but their average values were higher than others. There was a significant difference between the 95% confidence and the Hügelkultur plots.

The electrical conductivity (EC) in the soil before planting was in the range of 0.06 – 0.08 dS/m, and the electrical conductivity (EC) in the soil after planting was in the range of 0.08 – 0.09 dS/m. Equals 0.08, which is less than the normal conversion value of 0.09.

Details are shown in Figures 4.10 to 4.14 and Table 4.3 -4.4.

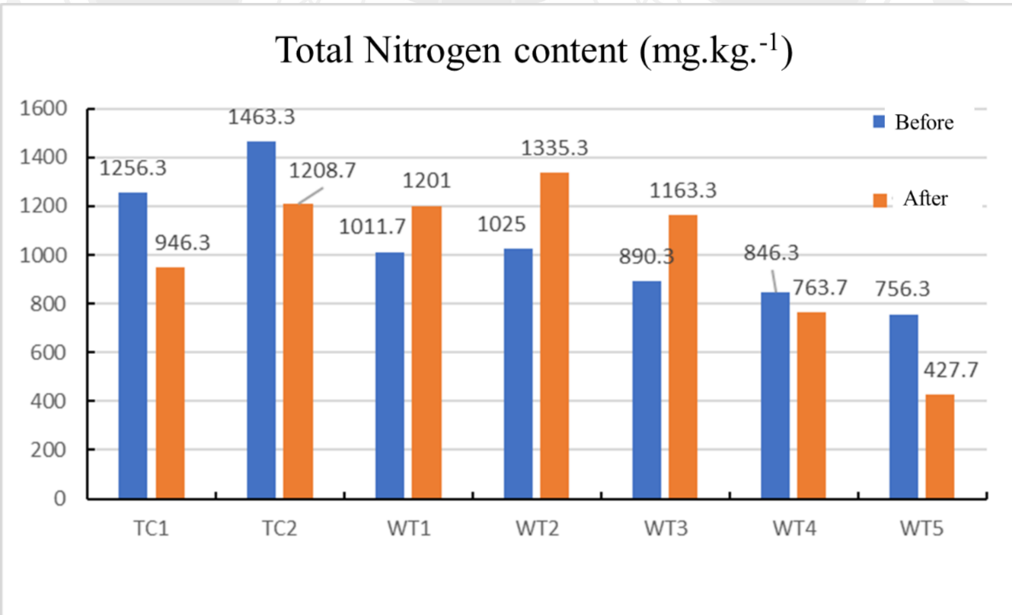


Figure 4.10 Total Nitrogen (N) Content

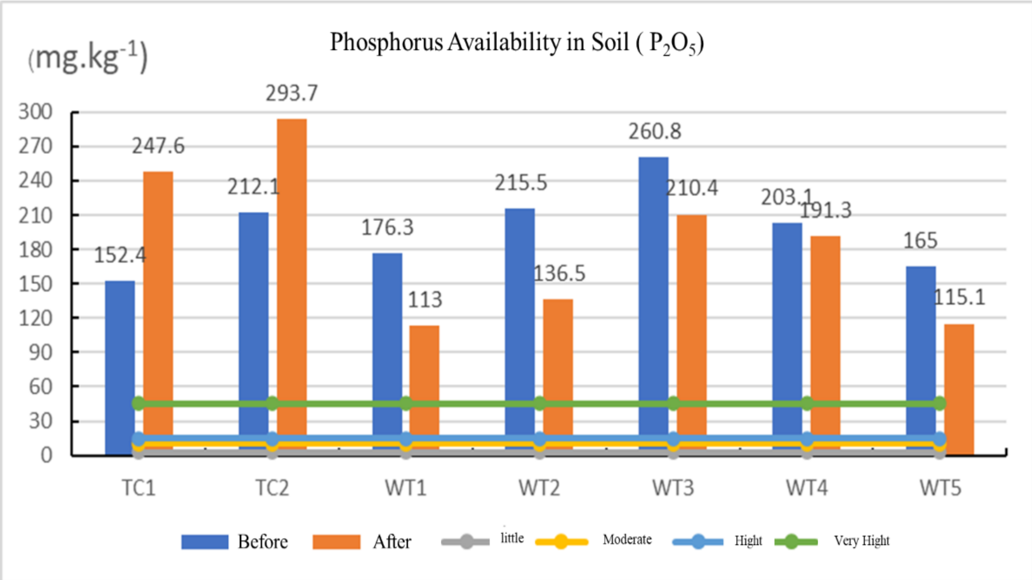


Figure 4.11 Phosphorus Availability in Soil (P_2O_5)

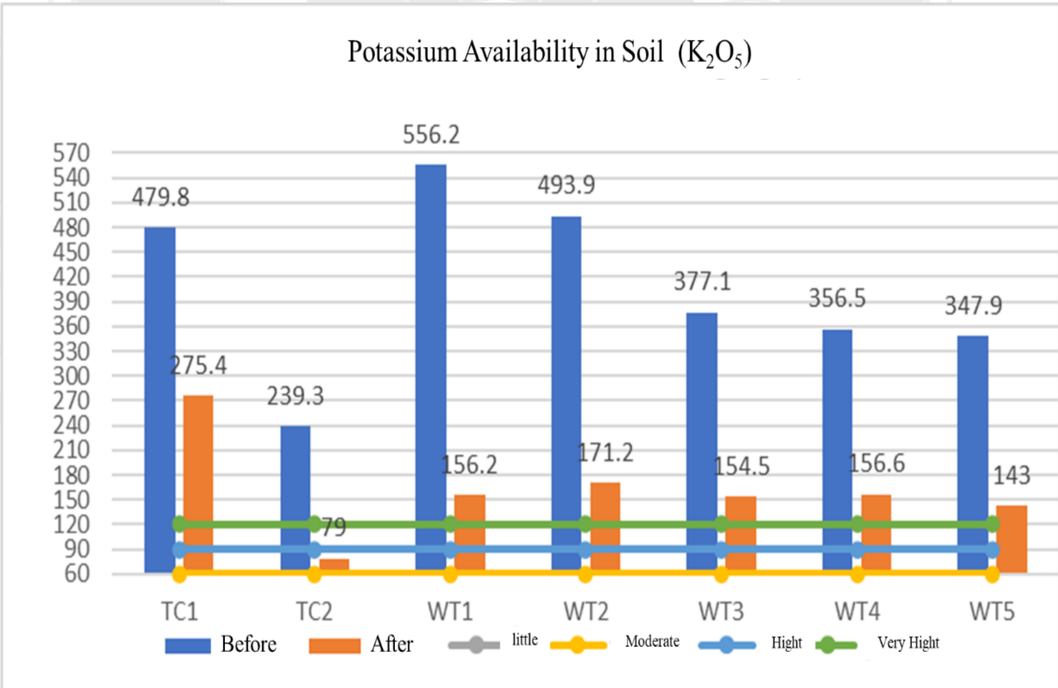


Figure 4.12 Potassium (K_2O_5)

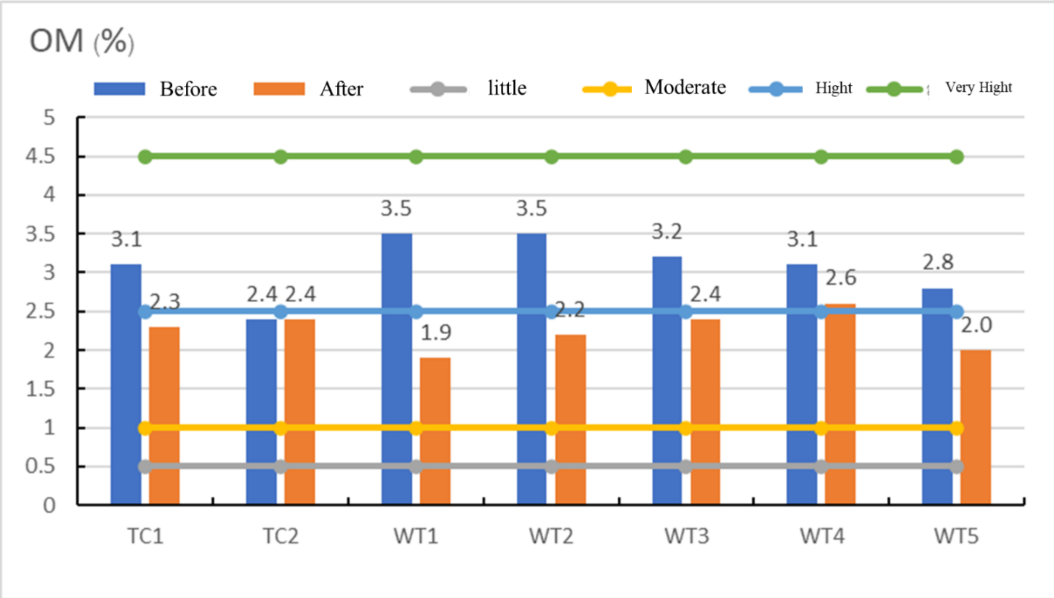


Figure 4.13 Organic Matter (OM)

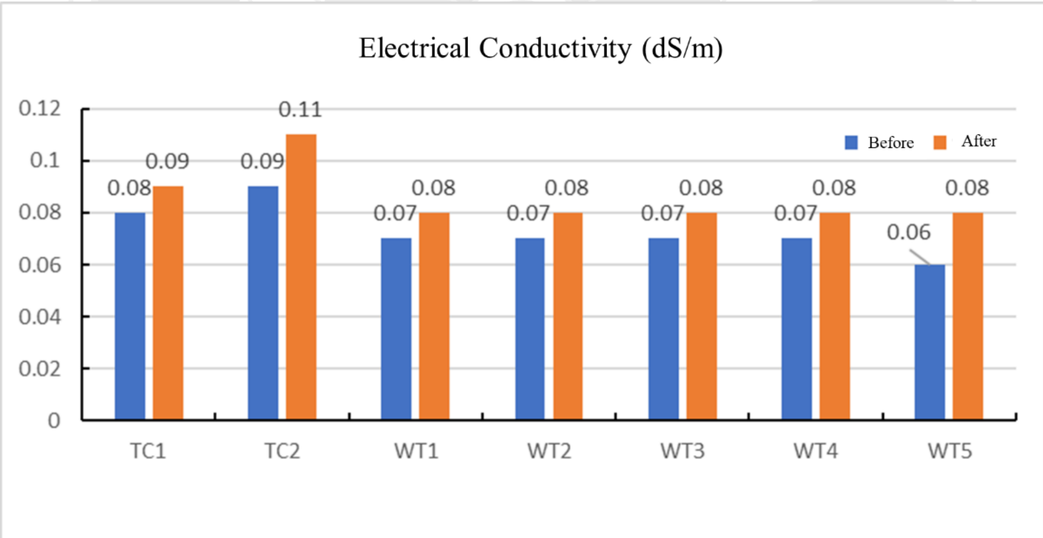


Figure 4.14 Electrical Conductivity (EC)

Table 4.4 Changes in Macronutrients in the Plot

Treatment	Watering (liters)		N(mg/Kg) (1)		P (mg/kg) (1)		K(mg/kg) (1)	
	Morning	Evening	Before	After	Before	After	Before	After
WT1	1.00	1.00	1011.67b	1201.00bc	176.25a	112.96a	556.21b	156.16a
WT2	1.25	1.25	1025.00b	1335.33c	215.49a	136.48a	493.92b	171.18a
WT3	1.50	1.50	890.33ab	1163.33bc	260.79a	210.44ab	377.08a	154.54a
WT4	3.00	0.00	846.33ab	763.67ab	203.09a	191.30ab	356.51a	156.63a
WT5	0.00	3.00	756.33a	427.67a	165.08a	115.08a	347.90a	143.00a
TC1	1.50	1.50	1256.33c	946.33bc	152.35a	247.60b	479.84b	275.39b

Note: (1) Comparison on the column side Yields of different watering kale followed by the same letter were not different by DMRT at 95% confidence level.

Table 4.5 Change of Organic Matter pH and Electrical Conductivity of All Seven Experimental Sets

Experiment	Watering(lite)		OM (%) (1)		EC (dm/m) (1)	
	Morning	Evening	Before	After	Before	After
WT1	1.00	1.00	3.40b	1.87a	0.07b	0.08a
WT2	1.25	1.25	3.53b	2.20a	0.07b	0.08a
WT3	1.50	1.50	3.20ab	2.40a	0.07b	0.08a
WT4	3.00	0.00	3.10ab	2.67a	0.07b	0.08a
WT5	0.00	3.00	2.80a	1.97a	0.06a	0.08a
TC1	1.50	1.50	3.10a	2.27a	0.08c	0.09b

Note: (1) Comparison on the column side Yields of different watering kale followed by the same letter were not different by DMRT at 95% confidence level.

The correlation coefficient of the field environment with the values of organic matter and macronutrients after planting. There is an extraordinarily little too little relationship as follows:

Soil moisture was less positively correlated with soil organic matter and beneficial potassium. There was extraordinarily little positive correlation between total nitrogen and phosphorus availability.

Soil temperature had extraordinarily little positive correlation with soil organic matter and total nitrogen. There is little positive association with beneficial potassium. However, there was extraordinarily little negative association with beneficial phosphorus.

Soil pH was negatively correlated with total nutrient and organic matter. There was extraordinarily little negative correlation with organic matter. Total nitrogen and beneficial potassium There was little negative association with beneficial phosphorus. Details are shown in Table 4.5.

Table 4.6 It Shows the Correlation of the Field Environment with the Amount of Organic Matter and Macronutrients after Planting

Correlation	R^2	P-Value	Correlation
Soil moisture and organic matter	0.327	0.186	Less positive correlation
Soil moisture and total nitrogen	0.043	0.865	Extraordinarily little positive correlation
Soil moisture and available phosphorus	0.221	0.379	Extraordinarily little positive correlation
Soil moisture and beneficial potassium	0.311	0.163	Less positive correlation
Soil temperature and organic matter	0.127	0.615	Extraordinarily little positive correlation
Soil temperature and total nitrogen	0.012	0.0964	Extraordinarily little positive correlation
Soil temperature and available phosphorus	-0.126	0.618	Very few negative correlation
Soil temperature and beneficial potassium	0.032	0.900	Less positive correlation
Soil pH and organic matter	-0.01	0.683	Very few negative relationships
Soil pH and total nitrogen	-0.135	0.595	Very few negative Correlation

Correlation	R^2	P-Value	Correlation
Soil pH and available l phosphorus	-0.397	0.103	Few negative Correlation
Soil pH and beneficial Potassium	-0.198	0.431	Very few negative Correlation

As for the relationship between organic matter and macronutrients after planting, it was found that organic matter content had a high positive correlation with beneficial potassium found after planting. Detail is shown in Tables 4.6 and 4.7.

Table 4.7 Correlation between Organic Matter before Planting and Macronutrient after Planting

Correlation	R^2	Correlation Level
Organic matter before planting and total nitrogen.	0.328	Less positive Correlation
Organic matter before planting and beneficial phosphorus	-0.440	Less negative Correlation
Organic matter before planting and beneficial potassium	0.741**	High positive correlation

Note: * statistically significant at the 0.05 level

** statistically significant at the 0.01 level

Table 4.8 Correlation between Organic Matter before Planting and Macronutrient Changes after Planting

Correlation	R^2	Correlation level
Organic matter before planting and the difference of total nitrogen	0.475*	Less positive correlation
Organic matter before planting and the difference in beneficial phosphorus	-0.512*	Moderate negative correlation
Organic matter before planting and useful potassium difference	-0.648**	Moderate negative correlation

Note: * statistically significant at the 0.05 level

** statistically significant at the 0.01 level

4.1.3 Results of Wood Degradation Analysis

4.1.3.1 Wood degradation values before and after planting kale.

The results of the study of the degradation of wood used in the bottom of the planting plot were to determine the relationship of the degradation of wood to the number of macronutrients found in the plot. Six experimental sets were prepared in Hügelkultur plots, namely WT1, WT2, WT3, WT4, WT5, and TC2 (TC1 typical plots). Preparing wood samples packed in net bags placed in a layer of wood before filling with other layers of planting material when using the planting plot for the 49th-day anniversary of kale planting. It was found that the mean degradation of wood in all six experimental sets was between 236.82 – 1088.94 g, with the highest degradation found in the WT1 experimental set and the lowest in the WT2 experimental set when comparing the difference in mean wood degradation by DMRT statistics. It was found that the mean values of the experimental sets at WT1 and WT2 were significantly different at the 95% confidence level and when testing the relationship of wood degradation with the changed macronutrient content. In plots with Pearson correlation coefficients statistics, it was found that wood decomposition had a slight positive correlation with organic matter values. Moreover, beneficial potassium values There was a minimal negative correlation with the total nitrogen content. Furthermore, helpful phosphorus details are shown in Figure 4.15, Table 4.9 - 4.10.

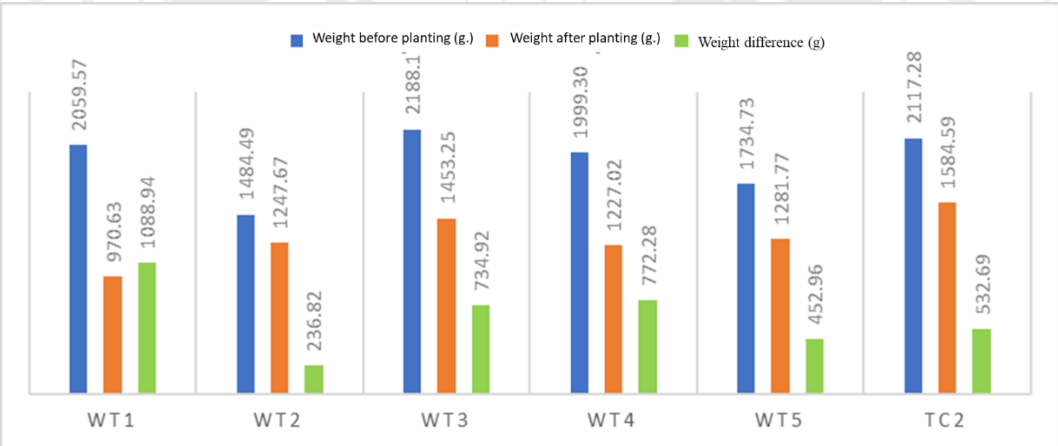


Figure 4.15 Wood Degradation Graph before and after Planting Vegetables

Table 4.9 Effects of Water Use on Wood Degradation in Planted Plots

Experiment	Water Use (lite)		Wood Degradation (%) [1]
	Morning	Evening	Weight(gram)
WT1	1.00	1.00	1088.94a
WT2	1.25	1.25	236.82b
WT3	1.50	1.50	734.92ab
WT4	3.00	0.00	722.28ab
WT5	0.00	3.00	452.96ab
TC2	1.50	1.50	532.69ab

Note: (1) Comparison on the column side Yields of different watering kale followed by the same letter were not different by DMRT at 95% confidence level.

Table 4.10 Correlation Coefficient between Wood Degradation and Changes in Macronutrients and Organic Matter

Correlation	R^2	Correlation Level
Wood degradation and total nitrogen changed	-0.231	Very few negative correlation
Wood degradation and the beneficial phosphorus changed	-0.049	Very few negative correlation
Wood degradation and the beneficial potassium changed	0.307	Less positive correlation
Wood degradation and organic matter	0.061	Less positive correlation

4.1.4 Results of the Study on the Growth and Yield of Kale

4.1.4.1 The Growth and Yield of Kale

A study on the growth and yield of kale in the Hügelkultur field was conducted every seven days once a week. Throughout the total planting period of 5 weeks, including the height of the plant. Stem diameter Counting the number of leaves, fresh weight, and dry weight, it was found that the height of TC1 was 33.84 cm. The height of the WT4 was 22.93 cm. The highest kale plant was 13.93 mm. The WT4 had the lowest kale plant diameter of 7.75 mm. Counting the number of leaves that emerged from all seven experimental sets showed weekly leaf emergence rates. Kale planted in seven experimental sets had the same number of leaves, nine leaves, and fresh-dry kale weight by drying at 70-80 °C (until dried kale). The fresh weight of the TC1 was 880.65 g. The WT4 was the least 297.91 g. The dry weight of the TC1 was the highest, 86.54 g, and the WT4 was the least, 27.89. The details of each indicator are shown in Figures 4.16 – 4.19.

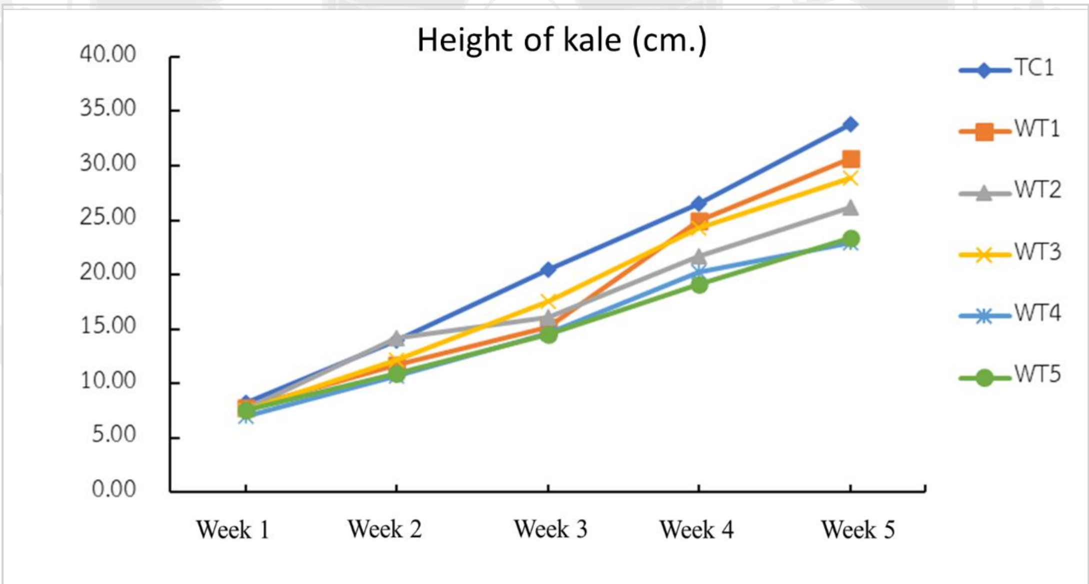


Figure 4.16 Weekly Height Changes of Kale

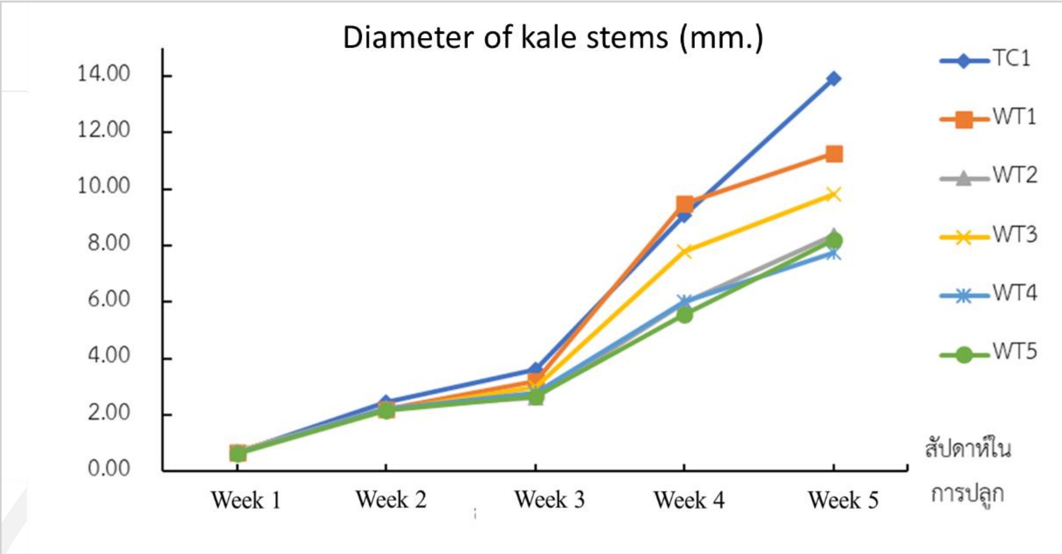


Figure 4.17 Weekly Change in Diameter of Kale

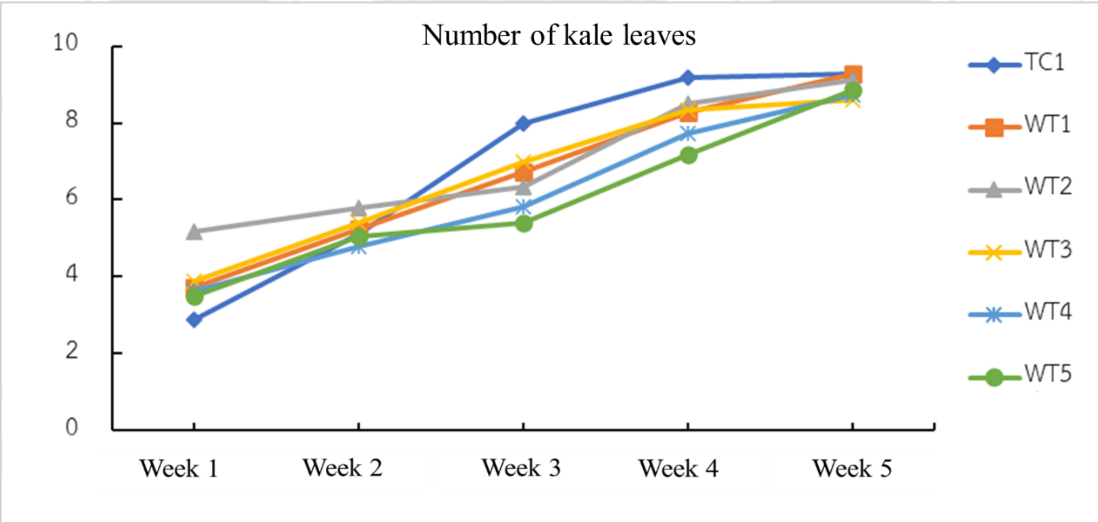


Figure 4.18 Changes in Weekly Leaf Counts of Kale

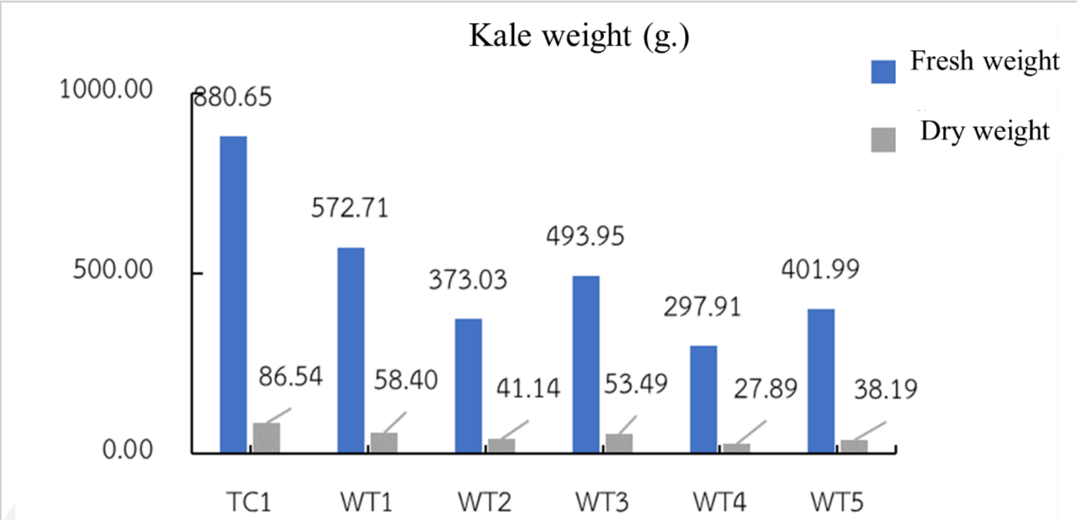


Figure 4.19 Fresh-Dry Weight of Kale

4.1.4.2 Comparison of Various Kale Growth Outcomes.

The average Kale stem diameter in the fifth week of planting was between 7.75 – 14.09 mm, with the highest value in the experimental set in the control TC1 field giving 1.5 liters of morning and cold water each time and the least in the set in the WT4 field with Hügelkultur field giving 3 liters of water in the evening. WT1 and WT3 were significantly different. The WT2, WT4, and WT5. Only TC1 was significantly different from other experimental sets. Typical plant plots with morning and evening watering gave kale a larger stem diameter. Hügelkultur plots, 1.0 liters of morning and evening irrigation resulted in kale's most prominent stem diameter. The result was not significantly different from the next one, 1.5 liters of water morning and evening, while watering one time/day, morning or evening, three liters/day gave no different results. And there is no difference from giving water two times/day at 1.25 liters in the morning and evening.

Plant height: In the TC1, typical plots were watered two times/day in the morning and evening, causing kale to have the highest plant height at 34.22 cm, significantly different from that of Hügelkultur plots. Once daily watering (morning/evening) in the WT4 WT5 was compared with the twice daily watering (morning/evening) in the WT1 and WT3, but not significantly different from the WT2.

The average number of leaves of kale in all experimental sets was similar. With an average of 8.61 – 9.30 cards, details are shown in Table 4.9.

Table 4.11 Effects of Watering on Growth in Stem Height (cm), Stem Diameter (mm) and Number of Leaves of Kale

Treatment	**Watering (lite)**		**Stem Diameter (1)**		**Stem Height (1)**		**Number of Leaves (1)**	
	Morning	**Evening**	**Average**	**± S.D.**	**Average**	**± S.D.**	**Average**	**± S.D.**
WT1	1.00	1.00	11.27c	2.70	30.63c	4.66	9.28a	1.27
WT2	1.25	1.25	8.38ab	2.24	26.14ab	5.19	9.11a	1.91
WT3	1.50	1.50	9.81bc	1.99	28.88bc	4.15	8.61a	1.79
WT4	3.00	0.00	7.75a	1.88	22.93a	4.49	8.72a	1.41
WT5	0.00	3.00	8.68ab	2.69	24.29a	6.09	8.83a	1.58
TC1	1.50	1.50	14.09d	3.48	34.22d	5.93	9.30a	2.23
F-test			**		**		ns	
C.V. %			24.98		18.26		18.92	

Note: ns, *, ** = not statistically different, statistically different at the significance level 0.05 and 0.01, respectively.

(1) Comparison on the column side Yields of different watering kale followed by the same letter No difference by DMRT at 95% confidence level.

The average fresh weight yield of kale was between 49.65 – 146.78 g/plant, with the typical plot in the experimental set where TC1 gave the highest yield. Fresh weight yield of kale was higher and significantly different from the Hügelkultur plot, with the lowest values in the WT4 experimental set and the highest in the WT1 experimental set. It differed significantly from WT4 but not significantly from WT2, WT3, and WT5 at a 95% confidence level using DMRT statistics.

Dry weight yield in normal plots, the TC1 experimental sets were not significantly different. with Hügelkultur plots in WT1 and WT3, but significantly different from those in WT2, WT4, and WT5. The dry weight of WT2 was not significantly different from those in WT4 and WT5. Details are shown in Table 4.12.

Table 4.12 Effect of Watering on Yield, Fresh Weight, and Dry Weight of Kale (g/plant)

Treatment	watering (lite)		fresh weight (1)		dry weight (1)	
	morning	evening	Average	± S.D.	Average	± S.D.
WT1	1.00	1.00	95.45 b	49.53	9.73 c	5.29
WT2	1.25	1.25	62.17 ab	43.44	6.86 ab	4.79
WT3	1.50	1.50	82.33 ab	31.76	8.91 c	3.29
WT4	3.00	0.00	49.65 a	28.27	4.65 a	2.80
WT5	0.00	3.00	67.00 ab	46.40	6.36 ab	4.78
TC1	1.50	1.50	146.78 c	88.55	14.42 c	8.01
F-test			**		**	
C.V. %			57.20		56.83	

Note: ns, *, ** = not statistically different, statistically different at the significance level 0.05 and 0.01, respectively.

(1) Comparison on the column side Yields of different watering kale followed by the same letter No difference by DMRT at 95% confidence level.

4.1.5 Correlation Between Environment and Growth and Kale Yield

The correlation coefficient (r) between kale growth and the soil's physical environment in the field was used to explain the suitability of the environmental values of each experimental set for kale cultivation. It was found that Soil moisture was less positively correlated with plant height. Stem diameter and number of leaves. Soil temperature was less positively correlated with leaf number. There was a moderate positive correlation between plant height and number of leaves. Soil pH was height positively correlated with plant height, stem diameter, and number of leaves. The details are shown in Table 4.13.

Table 4.13 The Correlation of Environmental Conditions with Kale Growth and Yield was Shown

Correlation	R^2	P-value	Correlation Level (Hinkel et al.,1998)
Soil moisture and kale height.	0.388*	0.034	Less positive correlation
Soil moisture and stem dimeter.	0.326	0.079	Less positive correlation
Soil moisture and number of leaves.	0.343	0.063	Less positive correlation
Soil moisture and fresh weight	0.81	0.051	Height positive correlation
Soil moisture and dry weight	0.783	0.66	Height positive correlation
Soil temperature and kale height	0.589**	0.001	ความสัมพันธ์ทางบวกปานกลาง
Soil temperature and stem dimeter	0.466**	0.009	Less positive correlation
Soil temperature and number of leaves.	0.618**	0.000	Moderate positive correlation
Soil temperature and fresh weight	0.728	0.101	Height positive correlation
Soil temperature and dry weight	0.752	0.084	Height positive correlation
Soil ph and kale height	0.854**	0.000	Height positive correlation
Soil ph and stem dimeter	0.792**	0.000	Height positive correlation
Soil ph and number of leaves.	0.881**	0.000	Height positive correlation
Soil ph and fresh weight	-0.325	0.530	Less negative correlation
Soil ph and dry weight	-0.436	0.387	Less negative correlation

Note: * statistically significant at the 0.05 level** statistically significant at the 0.01 level.

4.2 Results of the Study of Water Footprint and Carbon Footprint

4.2.1 Results of the Study on Water Footprint Quantity

The water footprint of kale in the Hügelkultur plot was studied from water consumption throughout the growing season. It was found that TC1 consumed water throughout the growing season 0.147 cubic meters/plot yielding 1.27 kg/square meter or 2.82 tons/rai. The water footprint was 174.75 cubic meters/ton of kale yield. WT1 uses water throughout planting equal to 0.098 cubic meters/plot yielding 1.145 kg/square meter or 1.83 tons/rai or 184.99 cubic meters per ton. WT2 uses water throughout planting is 0.1225 cubic meters/plot yielding 0.746 kg/square meter or 1.19 tons/rai. The water footprint was 349.20 cubic meters per ton. Plot WT3, WT4, and WT5 used water throughout planting equal to 0.147 cubic meter/plot yielding 0.988, 0.596, and 0.804 kg/square meter or 1.58, 0.95 and 1.29 ton/rai. As shown in the table, the water footprint was calculated as 306.75, 496.06, and 429.38 cubic meters/ton. 4.12 and Figure 4.15

Table 4.14 Amount of Water Footprint

Treatment	Watering (cubic meters /rai)	Kale Weight (tons/rai)	Water Footprint (1) (cubic meters/ton)
TC1	470.4	2.82	174.75a
WT1	313.6	1.83	184.99a
WT2	392	1.19	349.20ab
WT3	470.4	1.58	306.75ab
WT4	470.4	0.95	496.06b
WT5	470.4	1.29	429.38b

Note: (1) Compare the value column followed by the same letter. No difference by DMRT at 95% confidence level.

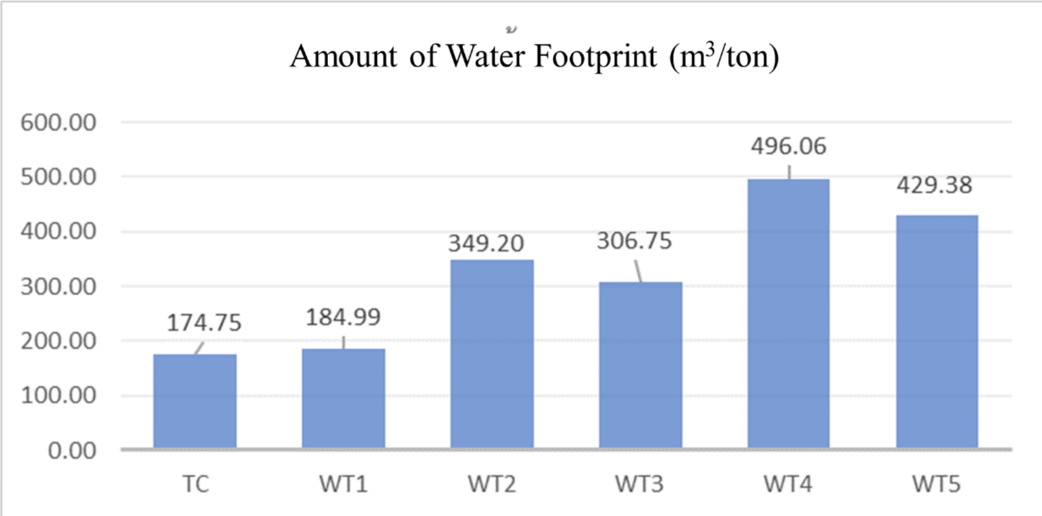


Figure 4.20 Graph Showing the Water Footprint of Kale Cultivation from All Seven Treatment

4.2.2 Carbon Footprint Study Results

Study on the carbon footprint of kale in six Hügelkultur plots. With different water supplies, by applying calculations from the product life cycle (Life cycle assessment (LCA)) using the B2C (Business-to-Consumer) carbon footprint assessment model, considering only the acquisition of raw materials and production processes. Based on calculations based on the Carbon Footprint Assessment Guidelines of Products by the Carbon Technical Committee. Product Footprint (2011), as shown in Figure 4.21 and Table A.1 in Appendix A., uses a cement pond purchased from a production shop in the trial area of about 1.5 km and transported by six small trucks using diesel fuel.

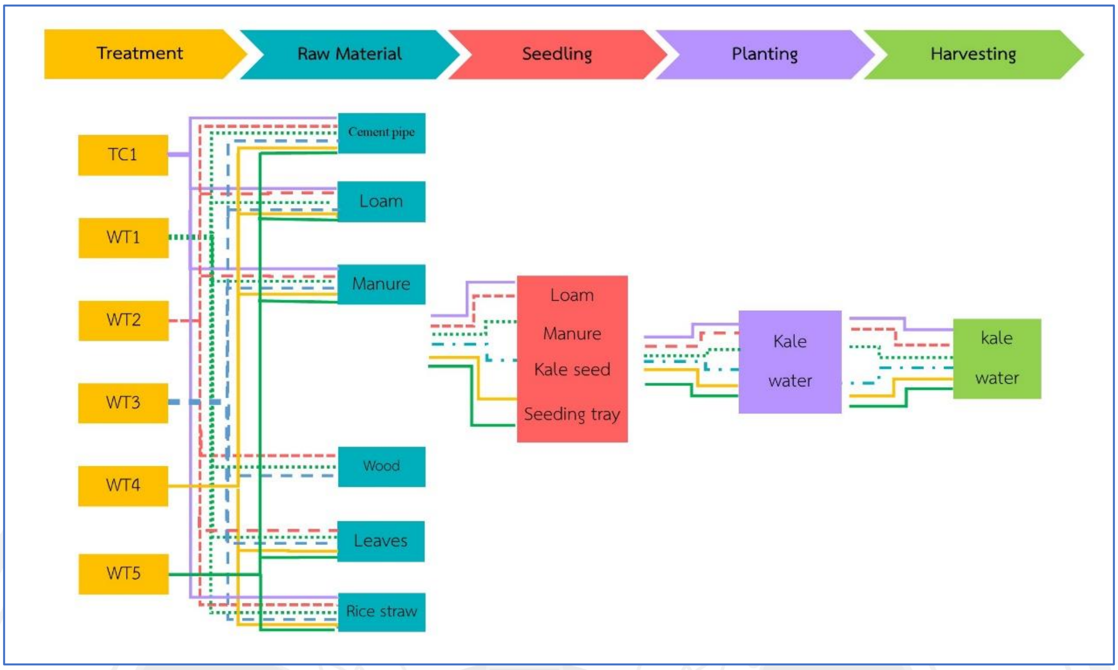


Figure 4.21 Schematic Diagram of Carbon Footprint Analysis in Hügelkultur Plot

Loam soil was used in the experimental area, 160 kg/well, mixed with 14 kg of manure in the ratio of 4:1 by volume, 60 kg of wood chips, twigs, 20 kg of leaves, 400 kg of soil mixed with 35 kg of manure in the control plot. Planting and covering the plot with 5 cm. (3 kg.) thick rice straw. Planting trays and kale seeds were purchased from the market 1.5 km from the experimental plots. Kale seedlings were planted for seeding in every plot for 21 days by watering five liters twice a day. Planted in the prepared plot for two weeks. Moreover, taking care of the kale seedlings to adapt for 14 days, then measuring the growth and environmental conditions of the field for another 35 days, including 49 days of kale care in the field and harvesting on the 50th day in the morning without watering before storage After collecting, kale was cleaned with 10 liters of water per plot before collecting the vegetables for further experiments.

The carbon footprint of kale growing in the low-water usage plots, Hügelkultur plots, was significantly lower than that of the control plots (TC) at the 99% confidence level, with plot WT1, due to low water consumption WT1 having the lowest value of 229.88 kg. CO2eq./kg. of kale, and control plots (TC) had the highest value at 352.59 kg.CO2 eq./ kg. of kale. In this regard, the use of branches and leaves as materials for building plots stores carbon in the soil, then slowly decomposes into organic matter and releases nutrients to the plants that grow instead of releasing it from landfills in landfills and burning in the open air. the lowest carbon footprint value in the WT1, followed by the WT2, WT4, WT5 and WT3, respectively. Details are shown in Figure 4.22 and Table 4.15 – 4.21.

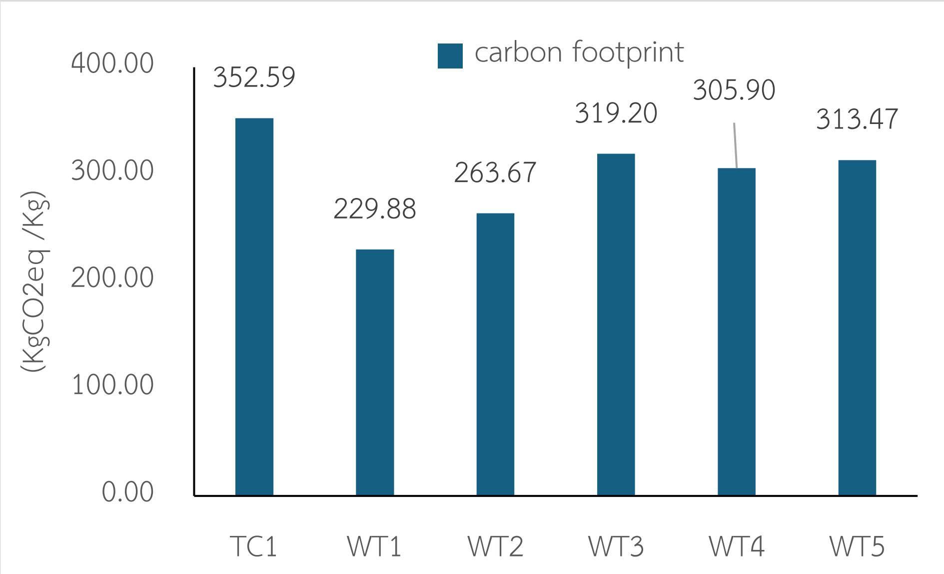


Figure 4.22 Graph Showing Carbon Footprint/Per 1 Kg of Kale Yield

Table 4.15 Greenhouse Gas Emission Data of TC1

List	Consumption	Unit	($KgCO_2eq$ /Unit)	
			EF	**Impact**
Raw materials				
Cement Pipe (1.5 km./round)	0.66	liter	0.4246	0.2802
Loam	400	kg	0.008	3.2000
Manure (Organic)	100	kg	0.1097	10.9700
*Rice Straw	5.6	kg	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	liter	0.24	0.0384
General Water	0.01	Cu.m.	0.7043	0.0704
Kale cultivation				
General Water	403.20	Cu.m.	0.7043	283.9738
Harvesting				
Kale	3,760	kg	0.0159	59.7363
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**352.5864**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, normally running 0% Loading, use gasoline to transport one time.

* Not calculated due to lack of Emission Factor.

Table 4.16 Greenhouse Gas Emission Data of WT1

List	Consumption	Unit	(KgCO2eq /Unit)	
			EF	**Impact**
Raw materials				
Cement Pipe (1.5 km./round)	0.66	liter	0.4246	0.2802
Loam	160	kg	0.008	1.2800
Manure (Organic)	14	kg	0.1097	1.5358
Wood	60	kg	0	0
Leaves	20	kg	0	0
*Rice Straw	3	kg	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	liter	0.24	0.0384
General Water	0.01	Cu.m.	0.7043	0.0070
Kale Cultivation				
General Water	268.8	Cu.m.	0.7043	183.3158
Harvesting				
Kale	2,443.56	kg	0.0159	38.85260
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**229.8830**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, running normally 0% Loading, use gasoline to transport 1 time.

* Not calculated due to lack of Emission Factor.

Table 4.17 Greenhouse Gas Emission Data of WT2

List	Consumption	Unit	($KgCO_2eq$ /Unit)	
			EF	**Impact**
Raw Materials				
Cement Pipe (1.5 km./round)	0.66	liter	0.4246	0.2802
Loam	160	kg	0.008	1.2800
Manure (Organic)	14	kg	0.1097	1.5358
Wood Chips	60	kg	0	0
Leaves	20	kg	0	0
*Rice Straw	3	kg	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	liter	0.24	0.0384
General Water	0.01	Cu.m.	0.7043	0.0070
Kale Cultivation				
General Water	336	Cu.m.	0.7043	236.6448
Harvesting				
Kale	1,597.58	kg	0.0159	25.4015
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**263.6654**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, normally running 0% Loading, use gasoline to transport one time.

* Not calculated due to lack of Emission Factor.

Table 4.18 Greenhouse Gas Emission Data of WT3

List	Consumption	Unit	(KgCO2eq /Unit)	
			EF	Impact
Raw Materials in the Plot				
Cement Pipe (1.5 km./round)	0.66	Liter	0.4246	0.2802
Loam	160	Kg.	0.008	1.2800
Manure (Organic)	14	Kg.	0.1097	1.5358
Wood Chips	60	Kg.	0	0
Leaves	20	Kg.	0	0
*Rice Straw	3	Kg.	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	Liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	Liter	0.24	0.0384
General Water	0.01	Cu.m.	0.7043	0.0070
Kale Cultivation				
General Water	403.20	Cu.m	0.7043	283.9738
Harvesting				
Kale	2,107.50	Kg.	0.0159	33.5093
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**319.1978**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, normally running 0% Loading, use gasoline to transport one time.

* Not calculated due to lack of Emission Factor.

Table 4.19 Greenhouse Gas Emission Data of WT4

List	Consumption	Unit	($KgCO_2eq$ /Unit)	
			EF	Impact
Raw materials				
Cement Pipe (1.5 km./round)	0.66	Liter	0.4246	0.2802
Loam	160	Kg.	0.008	1.2800
Manure (Organic)	14	Kg.	0.1097	1.5358
Wood	60	Kg.	0	0
Leaves	20	Kg.	0	0
*Rice Straw	3	Kg.	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	Liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	Liter	0.24	0.0384
Kale Cultivation				
General Water	403.20	Cu.m.	0.7043	283.9738
Harvesting				
Kale	1271.10	Kg.	0.0159	20.2105
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**305.8985**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, normally running 0% Loading, use gasoline to transport one time.

* Not calculated due to lack of Emission Factor.

Table 4.20 Greenhouse Gas Emission Data of WT5

List	Consumption	Unit	(KgCO2eq /Unit)	
			EF	Impact
Raw materials				
Cement Pipe (1.5 km./round)	0.66	Liter	0.4246	0.2802
Loam	160	Kg.	0.008	1.2800
Manure (Organic)	14	Kg.	0.1097	1.5358
Wood	60	Kg.	0	0
Leaves	20	Kg.	0	0
*Rice Straw	3	Kg.	-	-
Seeding				
Kale Seeds (3.7 km./round)	0.16	Liter	0.24	0.0384
Seedling Tray (3.7 km/round)	0.16	Liter	0.24	0.0384
Kale cultivation				
General Water	403.20	Cu.m.	0.7043	283.9738
Harvesting				
Kale	1,715.20	Kg.	0.0159	0.0064
General Water	0.01	Cu.m.	0.7043	0.0070
Total				**313.4714**

Remarks: 1 small 6-wheel pickup truck, normal running 0% Loading, use diesel fuel to transport one time.

2 Small 4-wheel trucks, normally running 0% Loading, use gasoline to transport 1 time.

* Not calculated due to lack of Emission Factor.

Table 4.21 Value of Water Footprint of Planted Plots

Treatment	Watering (cubic meter/rai)	Kale Weight (tons/rai)	Carbon Footprint ($KgCO_2eq$ /Kg.))
TC1	403.2	3.76	352.59a
WT1	268.8	2.44	229.88d
WT2	336.0	1.59	263.67c
WT3	403.2	2.11	319.20b
WT4	403.2	1.27	305.90b
WT5	403.2	1.72	313.47b
F-test			**
C.V. %			3.04

(1) Compare the value column followed by the same letter. No difference by DMRT at 95% confidence level.

4.3 Appropriate Model for Planting Plots That Use Less Water

The Agricultural Extension Academic Manual on Cabbage Plants Department of Agricultural Extension,2008 Provide information on the environment suitable for the growth and yield of kale as follows.

Climate: The optimum temperature is between 25 - 30 degrees Celsius. Relative humidity in the air is 60 - 80%. Photoperiod length of more than 10 hours per day. There is more than 2,000 mm of rainfall per year. Groundwater deeper than 1.00 meters, pH between 5.5 – 6.8. The soil temperature is between 25 – 35 degrees Celsius. Soil salinity (EC value) between 7,700 – 6,400 ppm or EC x103 = 12 -10. Organic matter content 2.6 – 3.5 %. Macronutrients in the soil as Nitrogen 2.80 – 3.00 %, Phosphorus 0.17 – 0.29 % and Potassium 1.80 – 2.30 %. Water used throughout the growing season is three hundred – 450 cubic meters/rai (3.4 – 5.1 liters/sqm.)

An experimental plot for planting plants that use less water is suitable in Ubon Ratchathani Province. Using the Hügelkultur technique, logs, branches, leaves, and agricultural waste are used as the plot's core. Before covering it with compost and potting soil, the plot can maintain the moisture and temperature of the plot well from the fact that the wood helps to absorb water and gradually decomposes, releasing nutrients to the plants that grow. The plot has good drainage. from the wood inserted in the planting material. For this research, kale was grown. Because it is a popular vegetable consumed in the area but needs high soil moisture and requires much water to grow. With temperature values between 30.67 - .35 degrees Celsius, relative humidity Between 60.09 - 75.00 percent, Soil condition Soil temperature 26.33 - 34.17 degrees Celsius, Soil moisture content 11.7 - 17.03 percent pH between 6.2 -7.9

Fresh weight yield of kale in descending order, TC1, WT1, WT2, WT3, WT5, WT2 and WT4, respectively, were between 297.91 – 880.65 g/plant and the dry weight yield was the same. For the growth of kale in the experimental set at TC1, the growth was the highest for plant height, stem diameter, and number of leaves. Followed by the experimental set at WT1 by plant height and stem diameter. The experimental sets TC1 and WT1 were significantly different at the confidence level of 95%, and the two experimental sets were significantly different from the t-tests WT2, WT3, WT4, and WT5.

The experimental set at TC1 had the lowest water footprint value, descending to the set at WT1, WT3, WT2, WT5, and WT4, respectively. The set at TC1, WT1, WT2, and WT3 were not significantly different at a 95% confidence level but significantly different from the set at WT4 and WT5.

The carbon footprint of the experimental set at TC1 has the highest emission value. Moreover, the values were significantly different at the confidence level of 94% with the experimental set in which WT1 – WT5 had negative release values. From using logs to convert, the release values in all experimental sets were not significantly different at the 95% confidence level.

From the environment of the plot, The number of nutrients available in the plot Growth, productivity, water footprint, and carbon footprint. It was concluded that the environmental conditions of all experimental plots were suitable for kale cultivation. The control set gave the highest value and significantly differed from the Hügelkultur plot, but the control plot. Has the highest discharge value.

When comparing typical crop plots with Hügelkultur plots from this research, Therefore, it was recommended to use the Hügelkultur plot of the experimental set

WT1, which was the plot with the least watering rate, 2 liters/day, applied twice in the morning and evening, 1 liter each time, but gave the highest yield when compared with and the plot that watered two times/day at the same time but gave a higher amount of water. The plot preparation had materials and material arrangement, as shown in Figure 4.23.

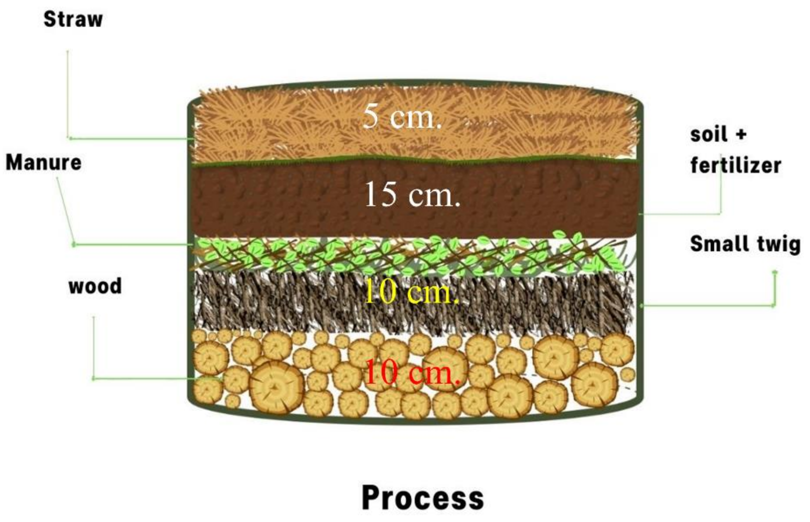


Figure 4.23 Shows Mmaterials and Arrangement of Materials to Create a Low – Water Usage Planting Plot

4.4 Guidelines for Application and Dissemination of Planting Plots That Use Less Water in Ubon Ratchathani Province

From the results of the research study, it can be concluded that The Hügelkultur plot is a plant that uses less water suitable for the Ubon Ratchathani Province area. The materials used to make plots are typical in the province and easy to find. Agricultural waste materials are used. Especially the branches and leaves, including weeds, were eliminated from the plot. Rice straw is used as a component of the planting plot to help reduce greenhouse gas emissions from having to dispose of these materials by burning. Or landfill in municipal landfills.

The constructed plots consumed less water than conventional plots, but the yields of kale were not different for dissemination of planting plots to be used in Ubon Ratchathani Province, especially in drought-prone areas.

The constructed plots consumed less water than conventional plots, but kale yields were not different for disseminating planting plots used in Ubon Ratchathani Province, especially in drought-prone areas.

Therefore, the researcher has prepared a manual for planting plots that use less water as Appendix 1 , which contains knowledge about diverse types of planting plots and plot construction methods. as well as the advantages of plots and disadvantages of diverse types of planting. To be a medium to disseminate and understand farmers and those interested in making this plot.

Concerns and suggestions for plot creation and implementation results of the interview All informants gave their opinions as follows.

4.4.1 Possibility of Using Less Water-Consuming Plots

Possibility of bringing such plots into household use. Nevertheless, it is not easy to use in growing large crops. Because it takes time to collect scrap materials and huge branches; however, in areas with orchards and rubber plantations, such as in the Nam Yuen District, Si Mueang Mai District, and Khong Chiam, pruning and pruning of para rubber can make large plots.

4.4.2 Difficulty in Conversion and Use

The construction of the plot is not complicated and easy to follow; the conversion cost is not much, and only the cost of cement can be purchased locally. Alternatively, other materials, such as old roof tiles, galvanized sheets, wooden panels, or large stones, can be substituted.

Planting plots can control the environment more efficiently than conventional plots.

The raised plot makes it easy for the elderly to use without bending too much, causing back pain.

4.4.3 Suitable Areas for Planting Plots

This water-intensive planting plot is ideal for areas with shallow soil. Moreover, areas prone to repeated drought Because it is a raised plot and cooked soil for planting, making the soil fertile. Keeping temperature, humidity, and water drainage in the plots were relatively constant.

4.4.4 Usage Concerns

Termite Concerns may come in and eat the wood; some people provide knowledge about the traditional planting of the community in the past that has pioneered the area. Older people in the old days would pile up trees and branches that were cut to open the area to burn and bring more soil to make a mound (Phon) before planting plants such as melons, yard-long beans, and corn, which those plants grow well and can grow plants for many years until the tree completely decomposes.

If there is sufficient moisture in the mound, termites will have no problem. Furthermore, the method is like that of the proposed low-water plots.

4.4.5 Recommendations for Use

There are suggestions for urban areas without large areas. Moreover, branches are from pruning trees in the house and along the public way. Especially the trees under the power lines that are trimmed throughout the year. It can be used to make a plot to grow plants like this. Causing the wood to bring the branches to leave the wasteland or wait for the municipality to collect it also helps grow organic vegetables for own consumption in the house.

4.4.6 Guidelines for Expanding Results to the Community

Provide easy-to-understand publications. The book is small and easy to carry if it is challenging to create demonstration plots in community learning resources.

CHAPTER 5

CONCLUSION AND SUGGESTIONS

The study of suitable low-water consumption planting plots in Ubon Ratchathani Province to study irrigation on the designed plots of low-water consumption crops. The experiment was completely randomized (CRD) with Hügelkultur plots and control plots. Seven sets of 3 experiments were Hügelkultur plots with soil and cow dung + twigs and leaves. Furthermore, the control plots with soil + cow dung were given three types of water at 6:00 a.m. and 5:00 p.m. and three different water levels. Prepare the plot. During 21 days of kale seedling cultivation, soil samples were collected for macronutrient analysis. The field environment was collected at 5:00 p.m., and the growth rate of kale was collected for five weeks between 22 March and 3 May 2020, totaling 49 days of kale age after planting. Harvest kale and soil samples to analyze the macronutrients and organic matter remaining after planting. In addition, the daily environmental changes of the plots were collected every 3 hours for three days for daily average values and to find the relationship between the physical environmental factors of the plots. The details of each experimental set are shown in Table 5.1.

Table 5.1 Show Details of the Composition of the Plot and Watering

Treatment	Plot	Planting Material	Plant
WT1	Hügelkultur	1	Kale
WT2	Hügelkultur	1	Kale
WT3	Hügelkultur	1	Kale
WT4	Hügelkultur	1	Kale
WT5	Hügelkultur	1	Kale
TC1	Control(typical)	2	Kale
TC2	Control (Hügelkultur)	1	No plant

Remark: 1 = Soil mixed with manure + twigs + leaves + rice straw

2 = Soil mixed with manure

Table 5.2 Watering Schedule and Amount for Each Plot

Treatment	Watering (Time)	Watering Method	Amount of Water
WT1	2	Morning – Evening	1.00 liter/time (2 liters/day)
WT2	2	Morning – Evening	1.25liter/time(2.5liters/day)
WT3	2	Morning – Evening	1.50 liter/time (3 liters/day)
WT4	1	Morning	3.00 liter/time (3 liters/day)
WT5	1	Evening	3.00 liter/time (3 liters/day)
TC1	2	Morning – Evening	1.50 liter/time (3 liters/day)
TC2	2	Morning – Evening	1.50 liter/time (3 liters/day)

Effects of watering on low water use crop plots on plot environment changes, wood degradation, macronutrient content, growth and yield of kale, water footprint, and carbon footprint of plots for planting crops that use less water can be summarized as follows:

5.1 Summary and Discussion of the Research Findings

5.1.1 The Environment of the Plots Uses Less Water

Air temperature during the experimental planting of Kale in the field between 22 March - 3 May 2020, the summer season of Ubon Ratchathani Province, the temperatures between 31.86 – 34.43 degrees Celsius, higher than the 30-year average of April that was highest during the experiment at 29.8 degrees Celsius.

Due to the high air temperature, the soil temperature in the plot was also high. The average soil temperature in the plots was between 26.33 – 35.00 °C. Relative humidity in the air was between 60.09 - 75.00 percent, soil moisture 11.7 - 20.60 percent, and sunlight. The air temperature had a negative relationship with relative humidity; when the air temperature rose, the relationship decreased.

There was a significantly high positive correlation with soil temperature. Soil moisture and temperature in all plots were not significantly different at a 95% confidence level.

Typical plots had higher average temperatures than Hügelkultur plots. For diurnal changes, soil temperatures in each plot tended to be in the same direction as climate temperature changes, i.e., highest from noon to afternoon, decreased from dusk to dawn, and increased again when there was light. Climate and soil temperatures are relatively high. Due to the summer in Thailand, which has a 30-year average temperature, the highest in April was 29.8 degrees Celsius and

Compared to the optimum temperature for the growth of Kale, Wasan Krisadarak (2001) suggested that Kale can grow well at an average temperature of 20 degrees Celsius. However, Chinese Kale is resistant to elevated temperatures.

Furthermore, produce satisfactory results at temperatures above 25 degrees Celsius.

Mean soil moisture content in the plots given different amounts of water and time. There was no significant difference at the 95% confidence level. The lowest moisture content was 14.48% in the field that was watered once a day in the evening, and the highest humidity was in the Hügelkultur TC2 field without watering twice a day, totaling three liters/day. Kale is a vegetable that requires a lot of water. Chanai Yodpetch (1999) summarized the water requirement of kale that the moisture in the soil that Chinese kale needs is about 80 percent and must receive enough water for Chinese kale to have excellent quality. If there is a lack of water, Chinese kale will halt growth. It has a lot of fiber and does not taste good. Sompong Ninphan, Srithawat Na Ayutthaya, and Narumon Chanthawatcharakorn (2001) from the useful water content study, is the soil's moisture content in the range from the moisture at the field capacity to the moisture at the permanent wilting point. Soil series 40: The soil has a coarse loam particle size layer. There is a range of water available to plants. It is a percentage by weight between 4.99 -7.99 to 22.05 - 24.75 percent, in which the Hügelkultur plot has an average moisture content between 14.48 - 15.85 percent or 64 - 65 percent of soil moisture.

Soil pH in the plots was weakly acidic in the first week and increased to slightly alkaline in the fifth week of kale cultivation, with pH values ranging from 6.2 -7.6 in plot WT3 to 6.5 -8.1 in plot TC2. The optimum pH for kale growth was between 5.5 – 6.8.

From the data analysis results, it was found that the plots used less water. There is a higher temperature. Appropriate values for the growth of kale. The average soil moisture was 64 percent of the field capacity of the cultivated soil. The soil pH was higher than the suitable value for kale cultivation.

5.1.2 Wood Degradation

Results of the study on wood degradation in all seven sets of experiments were performed in three replicates, and experiments were carried out using nylon net bags containing logs placed in cement ponds. Nylon net bags were collected after 49 days of planting to determine the change in wood weight, decay, and degradation of wood in the soil of Hügelkultur plots.

It was found that the plots that gave the minor water, one liter twice a day in the morning and evening (WT), had the highest wood degradation value of 1,088.94 grams, followed by the plots that gave water twice daily. 1.5 liters of water in the morning and evening (WT3) and 1.5 liters in the morning (WT4) were similar, 734.92 and 722.28 grams, respectively.

In plot WT5, fed three liters of water once a day in the evening, there was 452.96 g of decomposition, like plot TC2, the control plot. No vegetables are planted in the plot. Water was given two times a day, morning, and evening, 1.5 liters each time, with 532.69 grams of decomposition and 236.82 grams of the tiniest degradable plot, namely, WT2 plot that gave water two times/day, morning, and evening, 1.25 liters. The WT1 and WT2 plots had significant differences in wood degradation at the 95% confidence level, while the other plots were not significantly different.

The factor that causes the degradation of wood is the air temperature. Air relative humidity Wood degradation had a moderate positive correlation with changes in soil organic matter, moisture, and temperature. The pH value of the soil is suitable for the growth of microorganisms that help in the decomposition of wood; Trichoderma sp., together with Bacillus sp., can help reduce the decomposition time of organic material faster by 40% depending on the type of material. Carbon: nitrogen (C: N) ratio and moisture content. When decomposed, the material containing nutrients can be used to control and prevent plant diseases. While microorganisms control plant pathogens, help prevent plant diseases from fungi and bacteria. By persecuting or using the food that the germs want, it also helps to dissolve nutrients in a form that is beneficial to plants, and in suitable conditions for the decomposition and degradation of wood in the planting plot, depending on environmental factors, including temperature, humidity, pH, and soil water holding capacity The soil has good drainage. Not too hygroscopic

5.1.3 Nutrient Studies Before and After Planting Kale

Nutrients were studied before and after planting kale in the Hügelkultur plots, including Total Nitrogen, Available Phosphorus, Available Potassium, Organic Matter (OM), Electrical Conductivity (EC), and pH. (Department of Land Development, 2004) both before and after planting, both total nitrogen Beneficial Phosphorus and Beneficial Potassium Nutrients in the plots were changed as follows: total nitrogen content in control plots TC1, normal plots growing kale and TC2 plots, Hügelkultur plots without kale, and Hügelkultur plots watered once a day, WT4 and WT 5. However, in the Hügelkultur field with irrigation twice a day, morning and evening, the total nitrogen value decreased after planting and is still valued at an extremely elevated level.

Phosphorus value that is beneficial to plants. The values were extremely high both before and after planting. All plots were not significantly different at the 95% confidence level. Potassium beneficial to plants in all experimental plots was high both before and after the experiment. Kale was grown with decreasing values after all experimental batches. The Hügelkultur plots were not significantly different from the mean values. The organic matter values in the plots both before and after planting were high. After planting, every plot had a decrease in organic matter. And the mean values were not significantly different in all experimental sets. The electrical conductivity of the soil solution increased after planting.

Macronutrient tends to have exceptionally low to low levels of positive correlation with moisture and temperature in the soil. Except for the available potassium, which had a slight negative correlation with temperature and soil pH, there was a slight to insignificant negative correlation with that nutrient. When the pH value increases, the available phosphorus and benefit potassium decrease. Soil pH affects the availability of various plant nutrients. The availability of plant nutrients in the soil changes according to the pH level. The measured values are between 6.96 - 7.40, and the pH level that plants generally grow well in soil with pH 6.5 - 7.5. Nevertheless, kale requires slightly acidic soil. The optimum pH for growing kale is between 5.5 and 6.8; correspondingly, pH positively correlates with kale growth.

The Organic Matter content had a slight positive correlation with the change in Total Nitrogen content. A moderate positive correlation between available phosphorus and benefit potassium changed significantly at the 95% confidence level, but no significant correlation with wood degradation.

5.1.4 Study on Growth and Yield of Kale

Kale in typical plots showed better growth in plant height and stem diameter. There was a statistically significant difference at the 95% confidence level with the Hügelkultur plot with an average height of 34.22 cm. and an average diameter of 14.09 mm. Regarding growth in the Hügelkultur type plots, the plots fed twice a day, morning and evening, 1 liter per time had the highest plant height and diameter of 30.63 cm and 11.27 mm, which were not significantly different from the plots fed 1.5 liters 2 times/day, but significantly different from those fed 1.25 liters 2 times/day. The fresh weight and dry weight yields in the plots were given the same amount of water at 3 liters/day but at various times were not significantly different in mean fresh weight at the 95% confidence level but dry weight. The plots that gave water 1.5 liters per time, two times/day, had the highest value. It was significantly different from the plant plots that gave three liters of water once a day. That is, morning-evening watering gave better yields than watering once daily, and evening watering was better. The height of kale plants had a slight positive correlation with soil moisture. There was a moderate positive correlation with soil temperature. But soil temperature had little positive correlation with soil temperature, stem height, stem width, and leaf number were positively correlated with elevated levels and soil pH. This indicates that changes in soil moisture, temperature, and pH affect kale growth. However, from analysis of growth variance using DMRT statistics, different watering had no difference in mean moisture content, soil temperature, and soil pH of the plots, but watering three liters per day in typical plots made kale grow significantly better than that in Hügelkulturs plots. In Hügelkulturs plots watered twice daily, morning and evening, kale had higher growth but was not statistically different. In the plots fed twice daily, watering two liters/day (313.6 m3/rai) showed more incredible growth but was not significantly different from twice daily watering three liters/day (470 m3/rai).

As for the yield, fresh weight had the same effect on growth, i.e., typical plots had significantly higher fresh weight than Hügelkulturs plots. However, dry-weight plots fed twice with three liters of water twice a day were similar. Fresh weight yield and the dry weight of kale in the Hügelkulturs plot fed twice with two liters of water per day were similar in yield with plots that provide water twice daily, totaling three liters/day, and grow. It was shown that a Hügelkulturs plot that gave one liter of water twice a day had a more suitable environment for kale growth than a more considerable amount of water, thus saving up to 156.4 cubic meters per planting cycle.

5.1.5 Study of Water Footprint

The result of water footprint analysis with the process of analyzing the product's water footprint. That calculates the amount of water used both directly and indirectly from the production process to delivery to consumers. However, in this research, only water consumption in kale production from preparation of planting material to harvest was calculated. The water footprint of 1-ton kale yield in the plots was watered twice/day at 2, 2.5, and three liters/day or 313.6, 392, and 470.4 cubic meters/rai. An Average of Water Footprint There was no statistically significant difference, with an average between 174.75 – 349.20 cubic meters/tree. However, the typical and Hügelkulturs plots fed twice a day at 3 liters and two liters/day gave a lower water footprint and significantly differed from those fed once a day at 3 liters/day. Plots of low-water-use crops that gave water twice a day at the rate of two liters were more suitable than other types of watering for kale cultivation.

5.1.6 Carbon Footprint Study

The carbon footprint emission of kale cultivation in the plots using less water was found in the plot preparation by using logs and branches as planting materials and covering them with potting soil. Slowing down the immediate release of carbon into the atmosphere as farmers clean up their farmland by burning. Also, trees and leaves are pruned around the house in urban areas. It has been sent to landfills, where it is anaerobic fermentation that also releases carbon into the atmosphere. From the analysis of the product cycle from the preparation of planting material consisting of cement circles, loam soil, manure, wood chips, leaves, and rice straw, provision of seedling trays and kale seeds. Care during seedling and planting and cleaning kale at harvest time. Leaf used as planting material has a carbon credit value of 7.49 kg carbon/kg of kale yield. In the Hügelkultur field, the stored carbon is decomposed into organic matter and vegetable nutrients. The carbon footprint is 261.93 kg eq./kg of kale production. The plots that supplied water at the rate of two litters/day had the lowest carbon footprint.

5.1.7 Suitable Plots for Planting Crops That Use Less Water in Ubon Ratchathani Province

The study aimed to investigate the effect of watering rates on the environment, macronutrient content, and organic matter of planting plots. Additionally, it aimed to evaluate the water and carbon footprints of kale cultivation.

It may seem strange to water plants less frequently while providing them with two liters of water twice a day in a planting plot suitable for kale growth. However, this was an experiment conducted during the summer when the air temperature was higher than suitable for kale growth. Nevertheless, kale was able to grow and yield a high crop, comparable to the general cultivation of farmers in Ubon Ratchathani Province. The yield was 1,832.63 kg/rai with a water footprint of 184.99 cubic meters/ton.

Moreover, the carbon footprint of kale production was 352.59 kg carbon equivalent/kg, which helps in retaining carbon from conversion materials from being released into the atmosphere immediately by combustion. Alternatively, the fermentation from landfills results in farmers or people using the branches and leaves from garden cleaning to make organic household growing material.

5.1.8 Application and Dissemination of Water-Less Crops

1) From the study, community leaders agreed water-less cropping, Isarearof especially Khong Chiam district, Sri Muang Mai district, and Nam yeun district in Ubon Ratchathani province. It is easy to find prunning waste in orchords, rubber plantations and Vegetable plots. The prunning waste were used in the farm lustead of being fired, therefore it reduces carbon emission.

2) Food secerity increases as water-less and more yield possible. Farmers are able to grow different vegetable with water-less cropping. The family can the cropping dontributes better food supply to forme and communities.

5.2 Guidelines for Promoting the Use of Less Water-Consuming Crop Fields for Farmers

1) Create a manual to educate people on planting techniques that require less water and how to create household plots.

2) Share knowledge through community farmers' leaders and experts and build demonstration plots at a local learning center, which is a shared learning space for farmers in the community.

3) Target areas that are prone to repeated droughts, have shallow soil or are situated in sandstone mountains, such as Khong Chiam Nam Yuen and Si Mueang Mai District, for publication.

4) Educate farmers through community meetings, farmer groups, field trips, and workshops by providing demonstrations and hands-on learning opportunities.

5.3 Recommendations for Further Studies

1) It is recommended that the lifespan of the plot be studied in detail, as the physical changes and decomposition of wood within the plot take longer than a single production season.

2) Conduct a comparative study of crop yields obtained from planting plots during different seasons and production cycles.

3) Experiment with various plants in the plots to establish guidelines for future applications.

4) Conduct a comparative study on different methods of constructing planting plots.

5) Analyze and compare the outcomes of using various planting materials.

6) Examine the expenses associated with creating planting plots in different formats.

7) Investigate the challenges and limitations of using the prototype planting plots, including the feasibility of scaling up the results for a wider audience.

5.4 Operational Suggestions

Hugelkultur is an agricultural model that promotes the use of agricultural waste to reduce the amount of waste that goes to disposal. This includes animal manure, branches, leaves, and other such materials. By reducing the amount of agricultural waste, we can also reduce the amount of carbon emissions produced from burning these scraps for disposal. However, to successfully implement Hugelkultur in a community, relevant agencies must support and facilitate the learning and participation process. This will help create value and confidence in farmers, ensuring they understand the process and its benefits.

Research has shown that Hugelkultur can effectively promote the use of agricultural waste materials. For example, in Ban Nong Sawan, Mueang District, Nong Bua Lamphu Province (Boonla, 2011), building the potential and learning process of farmers or communities can be achieved by cooperating with various government agencies, such as the Department of Agricultural Extension and the Department of Land Development. Additionally, educational institutions can conduct research in the area and provide continuous knowledge and development of community potential. This will help support agricultural development, specifically for the Ubon Ratchathani province.

Based on this, it is recommended that policies be put in place to support the implementation of Hugelkultur in communities, including support for relevant agencies and educational institutions.

5.5 Policy Suggestions

Hugelkultur is a gardening technique that can help increase crop production at different levels – from household to organizational and large farm. This method involves using organic materials from agriculture as planting material, which gradually decomposes and releases nutrients to plants over time. The technique uses wood to create a planting bed, and the wood's properties can affect the plants' nutrient release.

There are different ways to help support the expansion of Hugelkultur planting policy. These include:

1) Creating public awareness and understanding of the benefits of Hugelkultur plantings for farmers through various channels such as mass media, farmer training programs, and public relations campaigns.

2) Promoting and developing suitable plant varieties for Hugelkultur planting, including garden vegetables, medicinal plants, and ornamental plants.

3) Providing financial support to farmers who have switched to growing Hugelkultur, such as offering low-interest loan subsidies and providing technological assistance.

4) Establishing cooperation between relevant agencies such as the Ministry of Agriculture and Cooperatives, the Ministry of Natural Resources and Environment, and the Ministry of Interior to drive the efficient use of Hugelkultur planting plots.

In addition, other approaches that can be used to support the expansion of policy results for Hugelkultur plots include developing data and information systems about Hugelkultur plots, promoting research and development of agricultural innovations, promoting trade and marketing of Hugelkultur crops, and creating a network of Hugelkultur growers. Expanding the use of Hugelkultur plots can help increase national food and economic security, reduce vulnerability to drought, and achieve the Sustainable Development Goals (SDGs) in the areas of food and water security. Examples of guidelines for expanding the policy effects of using Hugelkultur planting plots are:

1) The Ministry of Agriculture and Cooperatives should create a project to promote Hugelkultur cultivation by providing support in plant varieties, technology, and marketing to farmers.

2) The Ministry of Natural Resources and Environment should carry out projects to conserve forests and water resources to increase the amount of water available.

3) The Ministry of Interior should support the creation of reserve water sources in the community.

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APPENDICES

Appendix A

Data Sources Used to Calculate the Carbon Footprint of Planted Plots

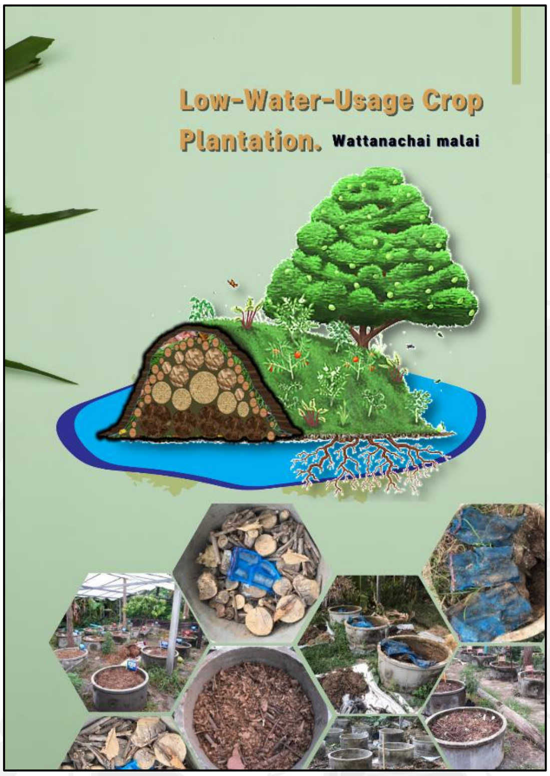
Table A.1 Data sources used to calculate the carbon footprint of planted plots.

List	Unit	EF ($KgCO_2eq$ /Unit)	Referent
Raw Materials			
Cement Pipe	liter	0.4246	Update_09Apr15
Loam	Kg.	0.008	Journal of Agri. Research & Extension
Manure (Organic)	Kg.	0.1097	Eco invent 2.0
*Rice Straw	Kg.	-	
Wood Chips	Kg.	3.33	2006 IPCC Volume 5: Waste
Leaves	Kg.	3.27	2006 IPCC Volume 5: Waste
Seeding			
Kale Seed	liter	0.24	Thai National LCI Database
Seedling Tray	liter	0.24	Thai National LCI Database
General Water	Cu.m3	0.7043	Thai National LCI Database
Kale Cultivation			
General Water	Cu.m3	0.7043	Thai National LCI Database
Harvesting			
Kale	Kg.	0.0159	Thai National LCI Database
General Water	Cu.m3	0.7043	Thai National LCI Database
Total		**3.0753**	

Appendix B

Guidelines for the Preparation of Low Water Usage Crop Plantation Plots.

Guidelines for the preparation of Low Water Usage Crop plantation plots.



contents

1

Low-Water-Usage Crop Plantation.

Ever since humans evolved from primitive times, the period when human beings changed significantly is the New Stone Age. During this period, human life began to revolve around collecting seeds for planting, marking the beginning of agriculture. Counting back thousands of years from the present, we can see that various methods of growing plants have been developed, leading to the advanced practices we have today. Different factors and considerations come into play when choosing a suitable planting method for plant.

2

1 Hugelkultur

Planting on the embankment is an agricultural method that arises from the natural observation that areas with fallen trees or branches accumulating in the forest can retain moisture better than other surrounding areas. Often, such areas have lichen, moss, or mushrooms clinging to the timber. Especially during the dry season, the soil around the timber holds more moisture than other regions. As the wood decomposes, it enriches the nearby soil, making it more fertile than other areas for an extended period of 10 years after the plant debris has completely broken down. The area eventually becomes a mound with abundant nutrients.

Hugelkultur plantation model

Pattern 1

If the topsoil is shallow and digging is complex, one can find soil elsewhere or bring it from outside. The first method is quite simple: pile up the logs until they are high, then sprinkle the obtained soil about 1-2 inches thick and cover it with mulch, such as straw.

3

Hugelkultur plantation model

Pattern 2

If you can't find soil from other places, the second option is to dig a groove (approximately 30-60 cm deep) and then pile up the logs in the groove. Afterward, shovel the excavated soil over the pile of wood again.

Pattern 3

This method is similar to Method 2, but it involves digging a trench beside the pile to allow water to flow into it during the rain. The excavated soil from this trench is then used to cover the Hugelkultur pile.

4

Characteristics of the shape of plants growing on the embankment.

Shape of Planting on the Embankment.	Description.
	Normal shape
	Slim shape.
	Triangular shape.
	Large stone border design.
	Wooden log border design.

The method uses logs or branches, leaves, and grass to pile up as a base. Furthermore, create a higher vegetable plot for planting vegetables or making other benefits of organic agriculture. The benefits of growing vegetables by this method are that The vegetables we grow get nutrients from the branches. Scraps of wood piled up and decomposed by nature. as food aid and natural humidity. Agricultural plots like this do not need to be watered. Alternatively, use very little water to water vegetables.

The Pros and Cons of Growing Hugucultur Plants

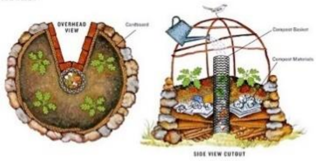
In addition to disposing of food waste, leaves, and logs, Hugelkultur plots benefit plants by promoting healthy root growth without the need for additional fertilizer. They also help conserve water, making plant care easier. These plots can be effective for up to 10 years, but they may attract termites, so it's essential to place them a good distance from the house. Maintaining adequate humidity will prevent termites from returning. Additionally, it's advisable to avoid placing the plots across waterways to prevent potential water damage.

Source: Baan Lae Suan Publishing House, (2019)

Source : thedailygarden

2 KEYHOLE

The KEYHOLE is an innovative combination of vegetable cultivation and composting in one place, specifically designed for arid regions with limited water availability. This unique concept maximizes space by serving as both a vegetable garden and a composting pit for disposing of household waste. It provides an efficient solution for growing vegetables within households."



ADVANTAGES OF KEYHOLE VEGETABLE GARDENING

1. Utilize minimal space to cultivate vegetable plots for a family of 4-5 people.
2. Conserve water by using the center hole, which provides enough moisture for all the vegetables in the pit.
3. Dispose of fresh household waste, including food scraps, fruit, and vegetable scraps, by placing them into the hole. The fermented water from the hole can be used as immediate fertilizer for the vegetables.
4. Obtain non-toxic vegetables for consumption, as a KEYHOLE vegetable plot can continuously grow vegetables to sustain the household throughout the year.
5. Require less time and effort for maintenance.
6. Serve as a beautiful and perfect garden decoration.
7. Utilize locally available materials, such as bricks, soil, and stones, to construct the vegetable plots, making it a low-cost solution.
8. Ensure food security by producing food for the household, saving on grocery expenses.
9. Assist in waste management by separating and disposing of fresh waste in the fermentation pond, contributing to a more sustainable world.
10. Reduce the expenditure on purchasing vegetables and save money in the long run.

Source: Baan Lae Suan Publishing House, (2019)

3 Raised bed

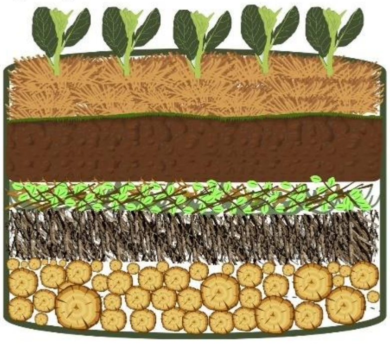
Using a vegetable planting tray offers several advantages, as we can fully observe the vegetables. Designing the width and length of the plot is simple; we only need to create a border around the soil about 20-30 centimeters high using natural materials like wood, coconut husks, coconut balls, bamboo, stones, bricks, or tree branches.

While there are many options and ideas, it's best to avoid using materials contaminated with chemicals, as they can affect the vegetables' growth. After building the tray, we fill it with planting soil mixed with our preferred fertilizer. This allows us to control the soil temperature and ensure optimal conditions for the plants. Additionally, we can plant vegetables close to each other since the soil receives full nutrients, which helps minimize weeding efforts.

The vegetables' growth will shade the soil, inhibiting grass growth, making it easier to maintain and water the plants. Proper ventilation and water flow in the tray contribute to the thriving growth of the vegetables we plant.

Appropriate plots for cultivating water-efficient crops in Ubon Province.

Water-efficient planting plots refer to plots that utilize hugelkultur techniques along with a raised bed bordered by a cement pond. The planting materials are arranged in layers, and the soil is prepared with a proper mix of manure to enhance nutrient content. These plots provide favorable environmental conditions, including suitable temperature, humidity, and drainage, promoting optimal growth for vegetable plants.



Materials and Steps for Creating

Water-Efficient Planting Plots.

Process

Equipment and material preparation

1. Sufficient logs, sticks, and branches for the desired number of plots.
2. Compost or manure, leaves.
3. Green plants or grass.
4. Potting soil.
5. Cement pond with a circle diameter of 80 cm and height of 50 cm.
6. Hoe for soil preparation.
7. Watering can for irrigation.

Plot creation process

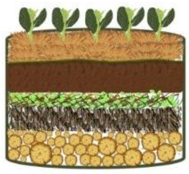
1. Determine the plot area and adjust it to a width of about 1 - 1.5 meters, adapting the size to fit the available space. Consider slightly elevating the area where the pond will be placed.
2. Start by placing the largest logs on the bottom layer, followed by smaller branches, stacking them to a height of approximately 10 cm per layer. Water the logs and branches thoroughly to ensure they are well-soaked.
3. Add leaves to the plot, using them to fill in the gaps between the branches and provide additional elements. Arrange larger, slow-degrading materials at the base of the heap, gradually progressing to smaller materials that decompose faster. This ensures a continuous supply of nutrients for the plants.
4. Cover the top layer with soil mixed with manure, reaching a thickness of about 10 cm. Then, add a layer of straw or hay on top of the soil and water it to thoroughly soak everything.

After completing the conversion, allow it to rest for 1-2 weeks before planting. This allows the organic matter to fully decompose and the sunken area to level out. However, there is no need to worry about excessive heat from the decomposition process. Since we use large logs and the materials are not tightly piled up, the heat generated in Hugelkultur plots is minimal. It's essential to let it decompose for a while to ensure that the decomposition process after planting won't negatively affect the plant roots.

Growing kale in a

water-efficient planting plot requires minimal water.

Plant kale with a spacing of 20 x 20 cm. Water the plants in the morning and evening, using 1 liter of water each time. Harvest kale at the age of 45 - 55 days.



Advantages of water-efficient planting plots:

1. Can be used for multiple plantings after preparation.
2. Provides high nutrient content.
3. Excellent moisture retention.
4. Effective drainage and ventilation.
5. Easy weed maintenance.

BIOGRAPHY

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Academic Background	Bachelor of Science (Biology) Khon Kaen University Master of Science (Environmental Management) National Institute of Development Administration
Experience	1995 - 1997 Environmental Academician. Consultants of Technology Co., Ltd. 1997 - 2005 Environmental Academician. Asdecon Corporation Co., Ltd. 2005 - 2007 Independent academician. 2007 - 2018 Employees in higher education institutions, Lecturer, Ubon Ratchathani Rajabhat University