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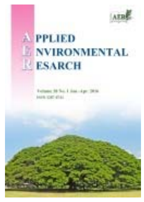

Land–Water–Population Model: Developing an Agricultural Resources Management in the Upper Part of Pranburi Watershed

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Abstract

This research proposes the application of the Land-Water-Population (LWPM) concept in the upper part of the Pranburi watershed. The objective of the study is to develop a model for agricultural resources management under the Sufficiency Economy Philosophy (SEP). The methodology is divided into three parts; 1) evaluate the soil quality in agricultural areas, 2) analyze water quality in agricultural land; and 3) assess farmer practice in agricultural resources management using a questionnaire. The study findings point to problems in soil and water conservation, suggesting that in the area should prioritize agricultural management, as advocated under the SEP, which provides guidelines for practicing agriculture under the New Theory on land and water management. Adoption of this model under the SEP will facilitate integrated natural resource management and sustainable agriculture by stakeholder participation at community level.

Keywords: Land-Water-Population concept (LWPM concept); Pranburi watershed; Agricultural Resources Management; Sufficiency Economy Philosophy (SEP)

Introduction

Watershed management is critical to integrating knowledge and perspectives of multiple human activities and natural resources into planning, policy and decision making [1-3]. In Thailand, the Department of Water Resources (DWR) formulated plans for 25 major river basins following a participatory approach. Subcommittees on water resources development were established and members appointed for each main watershed to collaborate in all aspects of planning, implementation and monitoring. The last decade has witnessed more concerted efforts in strengthening people's participation by integrating bottom-up approaches into planning within watershed. However, watershed management in Thailand is not yet sufficiently reflected in the multitude of existing planning approaches. Top-down and bottom-up approaches exist side by side, but do not yet complement one another. Three key areas supporting successful implementation of national watershed management programmes merit particular attention: 1) socio-economic and legal issues, 2) hydrological and micro-meteorological effects of land-use changes in upper watersheds, and 3) environmental and economic assessment of forest management options in upper watershed forests [4].

The Pranburi watershed forms a branch of the Prachuap Khiri Khan Coastal watershed, and covers an area of 2,991.10 km^2. The upper reaches of the river pass through steep mountains, before flowing into a plain. Its average slope is about 1:590. It covers parts of Kaeng Krachan, Tha Yang, and Cha-Am District, Phetchaburi Province and Sam Roi Yot District, Hua Hin, Pranburi, and Kui Buri District, in Prachuap Khiri Khan Province (Figure 1).

The topography of the upper Pranburi watershed comprises highland and undulating plain. The residents of this area are mostly farmers cultivating crops such as pineapple, corn, lime, durian, and vegetables. Production is mostly rainfed, with only a few small reservoirs and weirs which are inadequate for farming. The Land Development Department (2001) reports that land use in Pranburi watershed is distributed as follows: forest (66%) and agriculture (30.02%) [5].

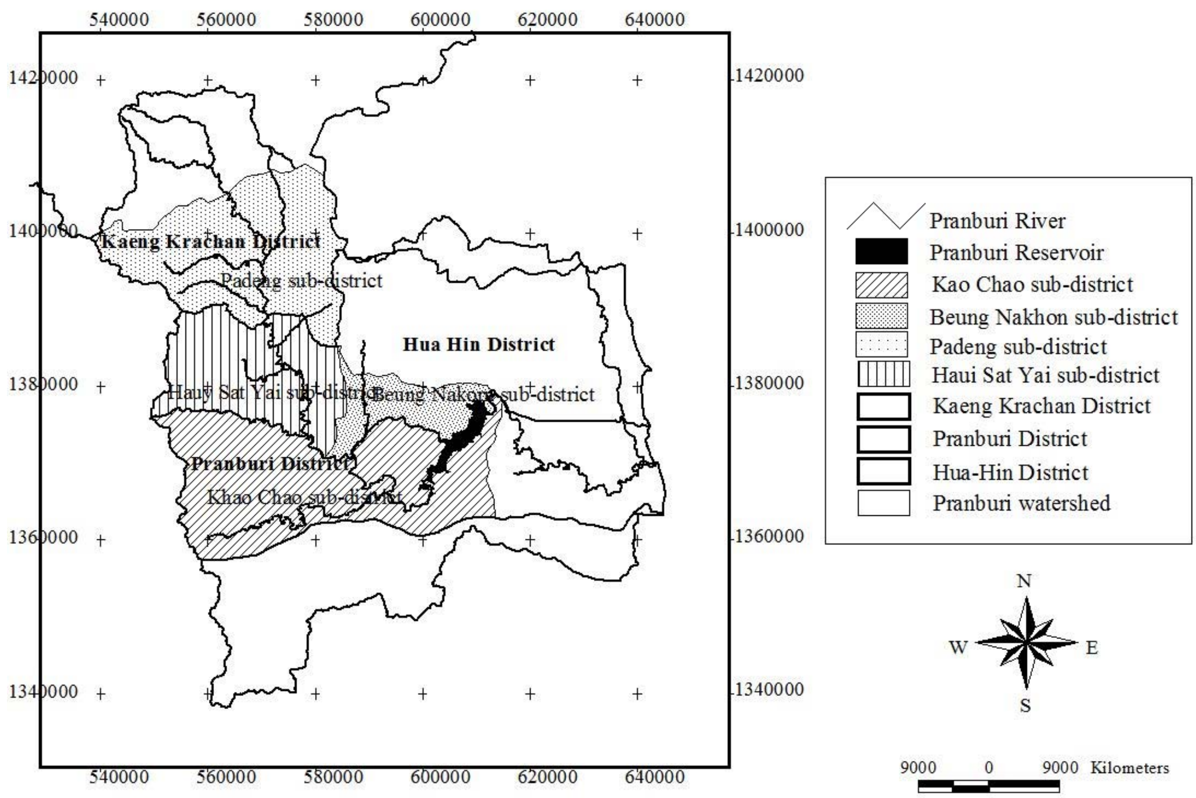

Figure 1 Study area: the upper part of Pranburi watershed.

Although the Keng Krachan National Park occupies a large part of the watershed, there is significant encroachment of forest areas for agricultural use, adversely impacting on quality of the ecosystem, especially in the watershed level 1A and 1B. Encroachment also causes land erosion, especially on steeper slopes. Farming on such slopes without suitable soil and water conservation measures leads to major soil and ecosystem loss, and degradation of soil cover and fertility. Water scarcity is also a serious problem because most agricultural areas in the upper Pranburi watershed have no irrigation systems. The existing small reservoirs are insufficient to meet demand, so that most farmers in the area depend on the rain for farming.

For these reasons, the study focused on the suitability of agricultural resource management in the upper Pranburi watershed. The philosophy of the sufficiency economy is aligned with Thailand's agricultural development policy as stated in the Eleventh National Economic and Social Development Plan (2012-2016) which stresses agricultural resources management. The plan sets out strategies for efficient and sustainable agricultural resource management and rehabilitation, and also emphasizes improvement of soil quality, appropriate land use planning in accordance with its potential, more efficient water management for agriculture, and promoting and supporting farmers to use natural resources sustainably in order to mitigate the impacts of climate change. A natural disaster prevention and mitigation plan was also established [6].

Accordingly, this study applied the concept of Sriburi (2009) on Land–Water–Population concept (LWPM) as a conceptual framework for studying the upper Pranburi watershed. The LWPM concept aims to integrate the capacity of all available natural resources including land, water and population, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem services [7].

A previous study on the LWPM concept focused on integrated water resources management in the Lam Takong watershed [8]. The study results resulted in guidelines for management of both demand and supply of water resources and land development conforming to the LWPM concept. Moreover, Chetananon, and Sriburi [9] studied integrated water management for natural resources and environment in a case study of the Royal-Initiated Lamphayang River Basin (upper part) Development Project Khao Wong district, Kalasin province. An in-depth analysis of water management in the study area under the New Theory was conducted using the LWPM concept. The study analyzed historical and current patterns of water utilization and projected the trajectory of water use in the future in order to develop appropriate water management recommendations.

Based on these studies, the current research applied the LWPM approach as a conceptual framework for the upper part of the Pranburi watershed. The objective was to develop a model for agricultural resources management under the LWPM concept, aligned with the philosophy of the sufficiency economy, initiated by His Majesty King Bhumibol Adulyadej of Thailand on 4 December 1997.

Methodology

This study was divided into three components: 1) evaluate soil quality in agricultural areas; 2) analyze water quality in agricultural soils; and 3) assess farmers' practice in utilization of agricultural resources in the upper part of the Pranburi watershed. Details of methodology are provided in the following section.

1) Population and sampling

Samples were taken from 2,494 farm households [10] who utilize soil and water resources in the upper Pranburi watershed. The sampling intensity was determined using formula [11] at a significance level of 0.02.

$$n = \frac{P(1\text{-}P)}{\left(\frac{SE}{t}\right)^2 + \frac{P(1\text{-}P)}{N}}$$

when n = number of sample, N = number of population (2,494 households) P = proportion in population (0.98) SE = standard error (0.02) and t = t-test statistic (= 1.96)

After substitution into the formula;

$$n = \frac{0.98(1\text{-}0.98)}{\left(\frac{0.02}{1.96}\right)^2 + \frac{0.98(1\text{-}0.98)}{2494}}$$

Using this formula, the number of interview samples was calculated as 175 households.

2) Research instrument

Demographic information for the study population was collected using semi-structured interviews with both closed-end and open-end questions divided to three parts as follows;

Part 1: Socio-economic information

Part 2: Practices and utilization of soil and water resources in Pranburi watershed

Part 3: Problems and guideline for development of soil and water resources.

3) Data collection method

Collection of soil, water and population data was undertaken as follows.

3.1) Soil sampling equipment and method

- Soil samples of various land use type in Pranburi watershed were collected following the method recommended by the Land Development Department (2001). The samples were analyzed for soil quality parameters and the results are shown in Table 1.
- Prepare soil sampling equipment comprising hoe, plastic bags, and plastic bucket.
- Specify sampling points distributed across various land use types in the upper Pranburi watershed, including field crops such as pineapple, corn, and sugar cane, orchards and trees including durian, rambutan, rubber and oil palm, and vegetables (Figure 2).
- Collect soil samples from each plot by digging V shape vertical hole with 15 cm depth below ground for all type of plant except soil samples from tree plot that must be collected from 30 cm depth below ground. Soil samples were collected from 1-2 point/0.0016 km^2. Mix the collected samples in the bucket then place the sample on plastic bag and well mix it again to get the composite sample representing the soil of each plot for all 23 locations.

3.2) Water quality sampling equipment and method

- Water quality measurement equipment comprised a thermometer, pH meter, DO meter, and conductivity meter and water sampling equipment including a grab sampler and rope. The water quality parameters are summarized in Table 2.
- Analyze parameters affected by agricultural land use in Pranburi watershed, including physical, chemical and biological. The results were compared with surface water quality standards in Thailand [12] and summarized in Table 3.

Table 1 Soil quality parameters and measurement

Parameter	Unit	Measurement
pH	-	Soil:H_2O (1:1)
EC_e	dS/m	EC 1:5 suspension
Organic matter	%	Walkley and Black Method
Available P	mg/kg	Bray-II Method
Exchangeable K	mg/kg	1 N NH_4OAc pH7
Exchangeable Ca	mg/kg	1 N NH_4OAc pH7
Exchangeable Mg	mg/kg	1 N NH_4OAc pH7

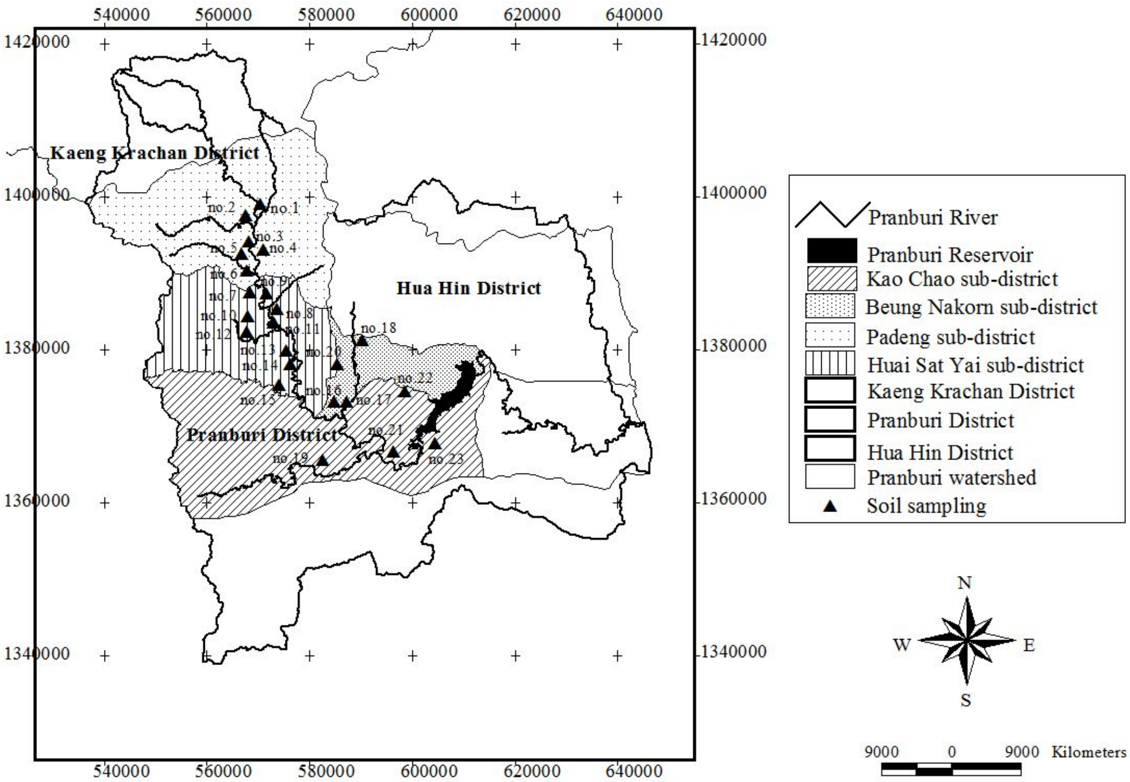

Figure 2 Soil sampling located sites in the upper part of Pranburi watershed.

Table 2 Water quality parameters and measurement

Parameter	Unit	Measurement
Temperature	°C	Thermometer
pH	-	pH meter
DO	mg/l	DO meter
Conductivity	µm/cm.	Conductivity meter
Turbidity	NTU	Nephelometric Method 2130 B.
Total solids	mg/l	Total Solids Dried AT 103-105°C 2540 B.
BOD_5	mg/l	5-Days BOD Test 5210 B.
Nitrate	mg/l	Nitrate Electrode Method 4500-NO_3^- D.
Phosphate	mg/l	Ascorbic Acid Method 4500-P E.
Total coliform	MPN/100ml	Fecal Coliform Procedure 9221E.

Table 3 Surface water quality standards in Thailand

Parameter	Unit	Standard value for classification				
		Class 1	Class 2	Class 3	Class 4	Class 5
pH	-	n	5-9	5-9	5-9	-
Dissolved Oxygen (DO)[1/]	mg/l	n	6	4	2	-
BOD (5 days, 20°C)	mg/l	n	1.5	2	4	-
Total coliform bacteria	MPN/100 ml	n	5,000	20,000	-	-

Source: Pollution Control Department (n.d.)

[1/] DO is the minimum standard

- Specify water sampling locations covering upper Pranburi watershed from upstream to the point of discharge into Pranburi reservoir (Figure 3).
- Collect water quality data as specified. Water samples were collected in two seasons: the dry period from January to April, and the wet season from June to October. After collection, water samples were sent for laboratory analysis.

Results and discussion

1) Soil analysis results

- Soil pH

Soil pH affects nutrient solubility and decomposition rates in soil and thereby has a profound effect on the availability of nutrients to plants. A slightly acidic pH of between 6 and 7 appears to provide optimal nutrient availability to plants, though there are exceptions [13]. Soil pH of the study area ranged from 5.53 to 7.23.

Almost every sub-district tested was found to have soils with pH below 7.0, especially in Ban Khao Chao district and Beung Nakorn district, where pineapple is the main economic crop. Pineapple is well-suited to acidic conditions, with an optimum range of 4.5 to 6.5. [14] and can also be grown in loam, sandy loam and sandy soils and in slope complex areas (FAO, 2015). The crop is sensitive to water logging and therefore requires a well-drained soil with good aeration [15].

- Conductivity (Ec)

Soil electrical conductivity indicates the amount of salt in the soil and its influence on plant growth and productivity. Soil conductivity is measured as the conductivity of water extracted from water-saturated soil [16].

Soil conductivity in upper Pranburi watershed area ranged from 0.41 to 0.91 dS/m. As the levels recorded were lower than 2 dS/m, it can be concluded that there is no soil salinity problem affecting plant growth in the study area.

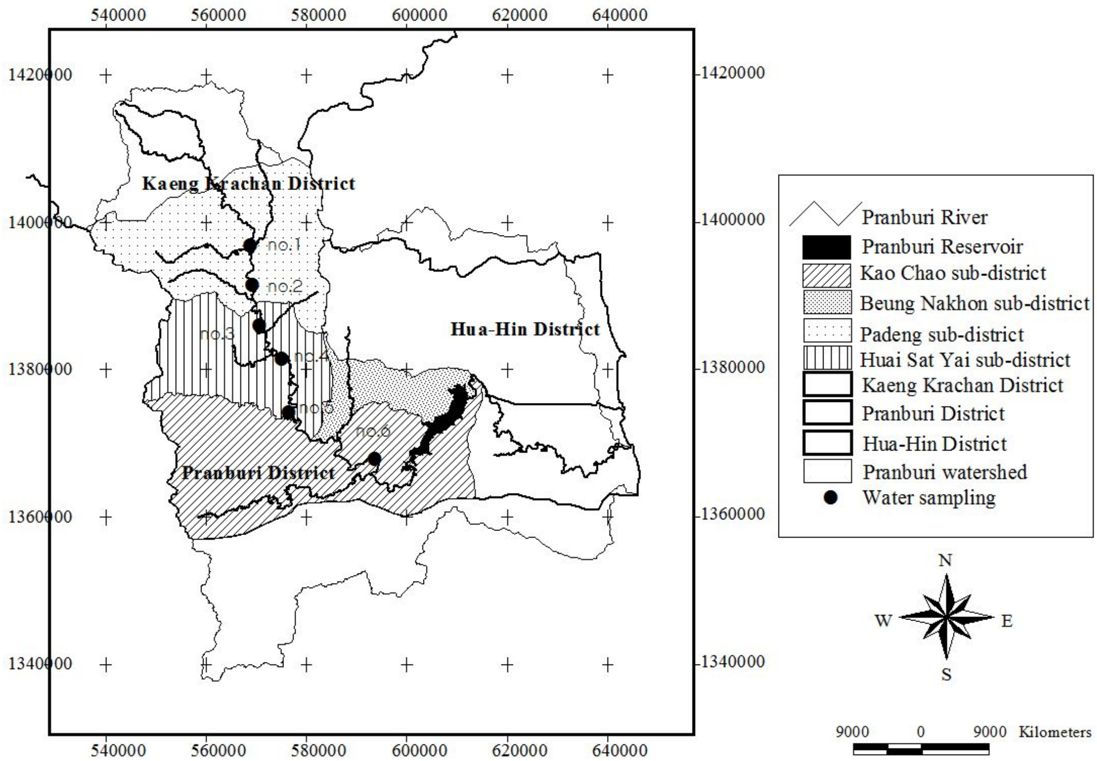

Figure 3 Water sampling locations in the upper part of Pranburi watershed.

• Soil organic matter (SOM)

Soil organic matter comprises diverse components, including, in varying proportions and many intermediate stages, an active organic fraction including microorganisms (10-40%), and resistant or stable organic matter (40-60%), also referred to as humus [17]. Soil organic matter is crucial in maintenance of long-term soil fertility, sustainable agricultural systems and productivity, and there is concern about the low levels of organic matter found in many soils [18].

The analysis showed that SOM in soil ranged from 0.57% to 2.08%. These low to moderate levels of SOM are likely to result from continuous mono-cropping and lack of soil improvement during and post cultivation. Typically, soil utilized for agriculture for a long continuous period usually contains SOM levels lower than 5%. A study by The Dang and Klinnert (2001) reported that the intensification of farming systems, characterized by annual crops, and the transformation of large areas of natural vegetation for agricultural use are primary factors leading to exhaustion of soil organic matter in Vietnam [19].

The results indicated that soils in Pranburi watershed were inadequately improved. In order to improve these soils, at least 1-2 ton/ 0.0016 km^2 needs to be added, depending on soil type, in order to improve soil structure and increase its water holding capacity [20]. Where land is not cultivated, crops such as legumes, sunhemp and sesbania can be grown to ameliorate the soil. In cultivated land, fertilizer, manure, or plant residues such as nutshells, husk, and grasses can be applied in order to increase SOM [21].

• Available phosphorus

The amount of available phosphorus in soils within the upper Pranburi watershed ranged from 5.86 to 143.43 mg/kg, with levels mostly at a high level. However, available phosphorus was found to be low in Ban Kho Nom Phatthana, Huay Sat Yai sub-district, and Ban Khao Chao and Ban Tha Wang Hin, Khao Chao sub-district [21]. In addition, before cultivation, the required amount of available phosphorus that is suitable for each type of plant should be estimated and applied. The high level of available phosphorus found in the study area resulted from overuse of phosphorus fertilizers, especially in Ban Chalermkiat Pattana and Ban Fahprathan, Huay Sat Yai sub-districts.

• Exchangeable potassium, calcium, and magnesium

Exchangeable potassium is potassium in the form of its ion (K^+). Potassium ions are found either in solution, dissolved in soil water, while the bulk of available K is found adsorbed to clay mineral particles. Fine soils such as clays tend to contain more K^+ than coarser soils such as sandy soils and sandy loams. Plant roots can take up K^+ from both sources [16], so that potassium fertilizer can be applied either by mixing it with soil or scattering over the soil surface, followed by plowing. The amount of exchangeable potassium in soils in the upper Pranburi watershed ranged from 68.49 to 393.34 mg/kg which is not lower than the specific criteria. However, high levels of potassium were observed in some aeas, especially in pineapple fields, due to overuse of potassium fertilizers.

In addition, the amount of exchangeable calcium (Ca^{2+}) was generally high, ranging from 565.50 to 3,266.87 mg/kg. Meanwhile, the amounts of exchangeable magnesium were moderate to high in the study area, ranging from 64.33 to 262.99 mg/kg.

2) Water quality characteristic in Pranburi River

2.1) Physical quality

• Temperature

The temperature of water in the upper Pranburi watershed was measured at sampling locations No. 1 to 6 ranged from 24.1 to 31.1 °C (Figure 4). The mean temperature in the dry season was 27.06 °C and 25.91 °C for the wet season. Water temperatures in April was higher than for other months since as this is the hottest month of the year; conversely, water temperatures in October was lowest due to heavy rain during this month. Water temperature is an important indicator and also influences other indicators of water quality in terms of physical and chemical parameters. Water temperature also influences turbidity because lower temperatures result in higher water density and viscosity, so that fewer suspended particles are less precipitated, increasing turbidity [23]. Therefore, the turbidity of water in the upper Pranburi watershed from June to October was higher than in the dry season.

- Turbidity

Turbidity of water in upper Pranburi watershed was measured at sampling locations No. 1 to 6, ranged from 0.99 to 103 NTU (Figure 4). The mean turbidity in the wet season was 26.6 NTU, with lower levels (2.476 NTU) in the dry season. Turbidity of water at sampling locations No. 3, 4, and 6 was higher than at other sample locations. In October, turbidity of water at sampling location No. 3 (Huay Phu Sai Creek) was 103 NTU, as the area was affected by storms resulting in high levels of suspended solids in the stream flow. The turbidity of surface water should not exceed 100 NTU [23] therefore the soil erosion control and mitigation measures such as use of vetiver grass should be implemented in this area in order to minimize turbidity.

- Total dissolved solids

The amount of total dissolved solids (TDS) in the water of the upper Pranburi watershed was measured at sampling locations No 1 to 6 is related to the amount of dissolved oxygen in water. High levels of TDS inhibit the photosynthesis processes of plants and organic matter in water. Where organic matter is decomposed by microbial activity, levels of dissolved oxygen in water will fall rapidly [23].

The amount of TDS in water in the upper Pranburi watershed ranged from 64 to 404 mg/l (Figure 4). The mean of TDS in water in dry season is 244.3 mg/l, and 164.7mg/l in the wet season. These levels comply with the water quality standard of the Food and Agriculture Organization of the United Nations (FAO) which specifies that water quality for irrigation should contain TDS lower than 450 mg/l.

- Conductivity

Conductivity of water in upper Pranburi watershed measured at sampling location No. 1 to 6 ranged from 49.7 to 579 µm/cm. (Figure 4). The mean conductivity of water in the dry season was 307 µm/cm, with 129.5 µm/cm in the wet season. Conductivity of surface water ranged from 150 to 300 µm/cm [22], indicating that conductivity of the river water increased from upstream to downstream. This is due to the increasing chemical load entering the river.

2.2) Chemical quality

- pH

pH of water in the upper Pranburi watershed, measured at sampling locations No. 1 to 6, ranged from 6.1 to 8.2. The mean dry season pH was 7.7, with 6.8 in the wet season. The pH of the water was in compliance with the Class 2 surface water quality standard.

- Dissolved oxygen (DO)

With Dissolved oxygen in the water of the upper Pranburi watershed, measured at sampling locations No.1 to 6, ranged from 5.98 to 10.59 mg/l. The mean DO of water in the dry season is 8.30 mg/l, with 7.30 mg/l. in the wet season. The DO was in compliance with Class 2 surface water quality standard, which specifies that DO of surface water should not fall below 6 mg/l. The amount of DO indicates the suitability of the water body as a habitat for aquatic organisms.

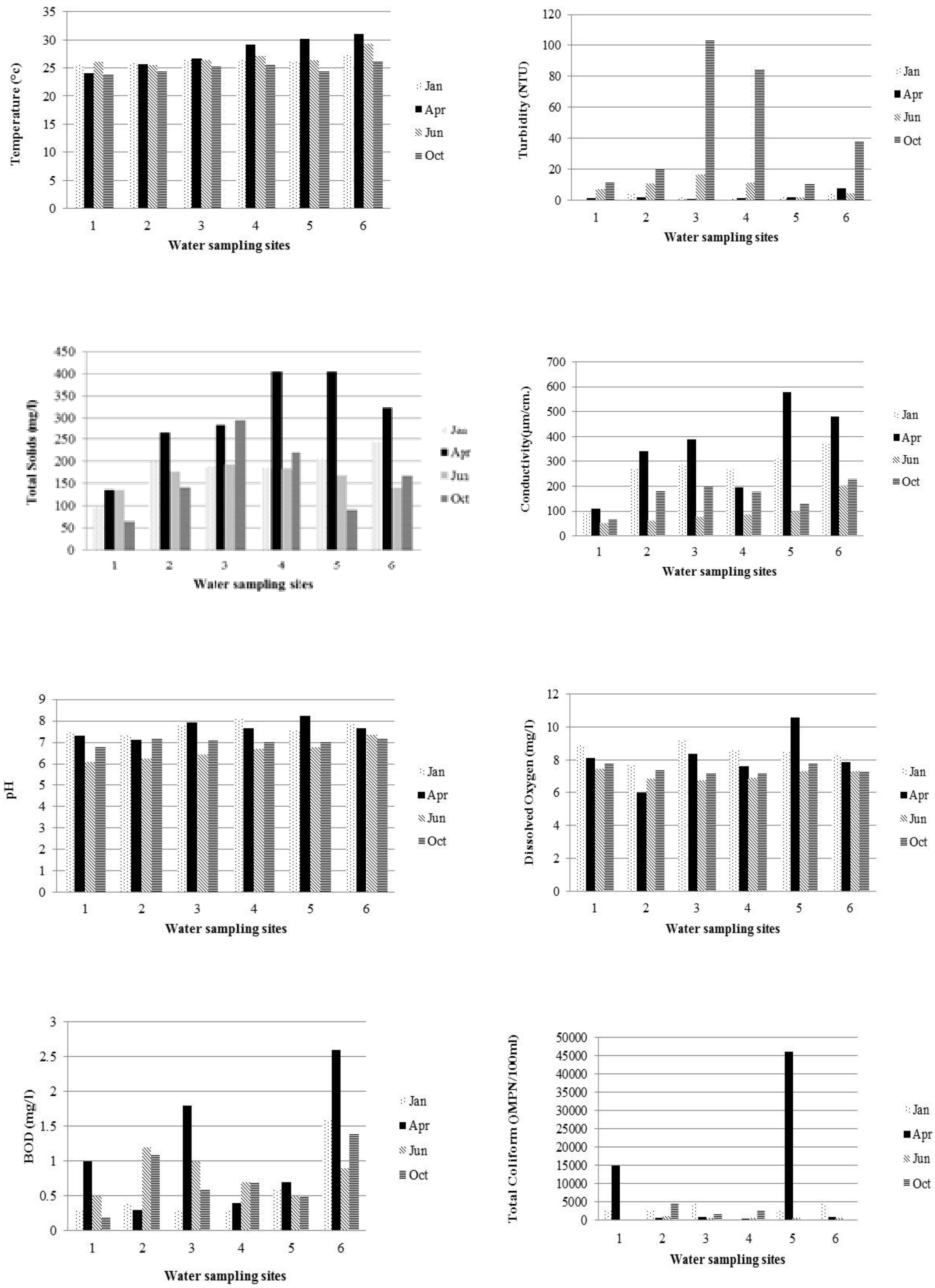

Figure 4 Results of water quality in Pranburi watershed.

• Biochemical oxygen demand (BOD)

Biochemical oxygen demand of water in upper Pranburi watershed, measured at sampling locations No. 1 to 6, ranged from 0.3 to 2.6 mg/l. The mean BOD of water in the dry season was 0.86 mg/l, with 0.78 mg/l in the wet season. The BOD was in compliance with the Class 2 surface water quality standard, which specifies that BOD of surface water should not exceed 6 mg/l. However, sampling location No 6 fell below this standard in April because it received wastewater from a nearby community.

2.3) Biological quality

• Total coliform bacteria (TCB)

Total coliform bacteria inhabit the intestines of humans and, and are also sometimes found in plants and soils. Analysis of TCB in surface water can indicate the risk of contamination or dispersion of gastrointestinal diseases such as cholera, dysentery, typhoid and diarrhea. The amount of TCB in water from the upper Pranburi watershed, measured at sampling location No. 1 to 6 ranged from 240 to 15,000 MPN/100 ml. The mean amount of TCB in water during the summer was 6,736 MPN/100 ml, with 1,041 MPN/100 ml. during the wet season. The results indicated that the majority of surface water samples complied with Class 2 surface water quality standard for TCB, except for some locations during April when the water was not fit for consumption.

3) Population

The data obtained from the 175 respondents in Pranburi watershed are structured as follows: 1) General socio-economic information on respondents; 2) Utilization of soil and water resources in Pranburi watershed; and 3) Problems and recommendations for sustainable development of soil and water resources. The findings are summarized in the following sections.

3.1) General socio-economic information on respondents

The majority of farmers were male, accounting for 64% of the sample. This is consistency with a report by the National Statistical Office [NSO] (2013), which revealed that holders of agricultural holdings were dominated by males (63.7%).

The average age of farmers was 50 years old. In terms of education, 65% had received only primary level education, with 14% going on to receive junior secondary level, 17% receiving senior secondary level, 1% receiving a vocational certificate, and 3% obtaining a bachelor degree (3%). This result is consistent with the report of NSO (2013) which reported 64.8% of the population received only primary level education. This is because prior to 2001, primary education in Thailand was only compulsory up to the age of 6 [24].

The average number of household members was 4 persons. The social status of respondents can be classified as head of household (70%), spouse of head of household (23%), child of head of household (5%), and other relatives of head of household (2%). On average, the respondents had lived in the Pranburi watershed for 26 years. Most of population, accounting for 61%, moved to this area by following their parent. 30% moved in relation to their work, and only 9% were born in the area.

The majority of respondents in the Pranburi watershed were farmers, divided as follows: vegetable farming (30%), orchard farming (32%), field cropping (27%) and livestock farming (11%).

In regard to the status of land tenure and land size, it was found that the average household owned 0.0336 km^2/household, followed by rented land (0.0048 km^2/household). Land ownership was relatively high because most respondents in the watershed had received approximately 0.032 km^2/household of land donated by the King in 1977. This finding corresponds with [24], who reported that the average area of owned-land was 0.03152 km^2.

Average income was 192,887 baht/year while the average income of farmer households in Petchburi and Prachuap Khiri Khan Province were 20,026 baht/month and 17,477 Baht/ month, respectively. Orchard farmers had higher income than field crop farmers due to the higher prices of orchard crops, especially durian.

In addition, 37% of respondents were members of a Village Fund, followed by the saving group, water usage group, farmer group, and soil group are 32%, 18%, 9%, and 3%, respectively.

3.2) Utilization of soil and water resource in Pranburi watershed

From the interviews, it can be summarized that most agricultural production (56.57%) takes place in the alluvial plain, while the rest (43.43%) were highland. The upper part of the watershed area is situated in the Kaeng Krachan National Park, and the alluvial plains in the middle area of the watershed.

In terms of agriculture, 70.86% of respondents had never tested the soil properties before cultivation. Although testing of soil properties is usually conducted by a soil group, the farmers only rarely receive the test result, so they do not know how to improve the soil. Therefore, agricultural extension officers should advise farmers on methods of soil improvement before the start of the cultivation season.

About 68.86% of respondents reported use of chemicals. However, 37.71% of respondents used organic fertilizer only, with 33.71% using inorganic fertilizer only. 28.58% reported using both organic and inorganic fertilizers together.

Most farmers (46.29%) performed mono cropping, followed by mixed cropping (21.14%), intercropping (18.86%), and rotation cropping (13.71%). However, after harvest, most farmers (60.57%) rarely improved the soil, with only 39.43% improving soil after harvest.

In terms of distance from the agricultural area to the water source, 31.43% of respondents reported water sources 101-500 metres from their farms, while 27.43% reported water sources less than 100 meters from their farms were 27.43%, a further 23.43% reported water sources 501-1,000 meters from their farms.

There are five main sources of water used for irrigation: the Pranburi River, rain water, ponds, groundwater, and reservoirs. Most respondents (46%) used water from the Pranburi River, followed by rain water (28%), and reservoirs (12%). The irrigation projects in the watershed are small-scale, including three reservoirs (Ka-Rang 3, Huay Pa Lao and Pa-Dang reservoir). The total irrigation area of these reservoirs is about 16 km^2 which is insufficient to serve the agricultural demand.

It was found that 77.14% of respondents did not participate in planning processes for water resources, because most of them used natural water sources (mainly the Pranburi River). Water users who obtained the reservoirs for their water could only participate in planning through their leadership. Only 22.86% of farmers were able to participate in water usage planning.

Most respondents (66.29) had not attended any training on soil and water conservation, while 33.71% of respondents have attended training on making bio-fertilizer, soil improvement, safe application of chemicals, soil and water conservation, and other knowledge on agricultural occupation such as dairy farming, cultivation according to the philosophy of the sufficiency economy.

The findings also revealed that many farmers still lacked knowledge in terms of integrated natural resources for watershed management. In addition, farmer required training on irrigation, soil and water conservation, methods of soil improvement, and self-soil quality testing.

3.3) Problems and recommendations for development of soil and water resources

In the interviews with 175 respondents, 70.8% reported no soil problems, while 29.1% of farmers confronted soil problems such as soil quality depletion due to excessive use of farm chemicals without soil improvement. In addition, the most serious problem relating to water resources was dry season water scarcity, accounting for 55.4%. Moreover, some farmers did not dig ponds to hold water within their cultivation areas, so that farmers dependent on rain water for cultivation have faced severe water shortages in the dry season. Nevertheless, 44.6% of farmers had not confronted water shortages since they prepared water storage ponds; also, some of them lived close to a reservoir, facilitating access to water even in the dry season.

Application of the LWPM concept and the SEP to sustainable agricultural resources management model in Pranburi Watershed

The application of the LWPM concept for watershed management leads to the following conclusions in relation to integration of natural resource management with agricultural activities.

With diverse patterns of land use and agricultural practices across the watershed, implications for natural resource management are many and varied. Soil problems in the watershed were related to low levels of soil organic matter because most farmers neglected the need for soil improvement. The study revealed that 60.57% of farmers rarely undertook any post-harvest soil intervention activity. Lack of awareness of the importance of soil organic matter was a major cause of this neglect. In addition, the prevalence of mono-cropping in the area further exacerbates the long-term decline in soil organic matter.

Agricultural extension officers should give increased emphasis to this fundamentally important aspect in their farmer training programmes [25]. In Thailand, the Philosophy of the Sufficiency Economy can help farmers to increase soil organic matter. The New Theory of agriculture is the way of life that is consistent with sustainable agriculture.

Erosion is a second key problem faced by farmers in the upper part of the watershed, affecting water turbidity and conductivity inflow to the Pranburi River. Therefore, the community should plant Vetiver grass for soil and water conservation. Vetiver grass is highly effective in binding surface soil, reducing the impacts of flash floods in the rainy season and in increaseing soil humidity in the dry season [26].

In terms of the problem of water usage, the finding also revealed the most of farmers used water from natural water resources, which is inadequate for agricultural activities. This factor has resulted in water shortages during the dry season. Therefore, the farmer should dig small water retention in the area for agricultural. The guideline of SEP can lead to soil and water conservation. The implement of the New Theory is the pattern farming that can help farmers from agricultural droughts.

In conclusion, application of LWPM can analyze the interaction between agriculture and natural resources. The goal of agricultural resources management should lead to sustainable development. The research of Mongsawad (2010) revealed that sustainable agriculture practices organic farming, which eliminates the use of chemical fertilizer and pesticides. This is be-cause chemical fertilizer is the main causes of soil degradation, which reduces crop productivity in the longer term. Chemical pesticides not only kill insects, but also endanger the environment, which in turn harms people. Instead, locally-available natural materials are used to make organic fertilizer and insecticides. Aiming to make a profit, farmers normally plant monocrops or cash crops, which are totally dependent on market prices, thereby increasing the farmers' vulnerability to external price shocks. Also, the practice can harm the environment, as farmers tend to overuse chemical substances to increase production [27].

Therefore, sustainable agriculture can thus be seen as an alternative long-term solution for small-scale farmers who wish to have a different method of farming than mainstream agriculture, which is based mainly on market forces. Agricultural resources in Thailand are diverse, and so are rural culture and traditional wisdom. Sustainable agriculture must be adjusted to suit different contexts. In Thailand, at least five main patterns of sustainable agricultural system are currently being promoted. These are integrated farming systems, organic farming, natural farming, agroforestry and new yheory farming [28].

From the findings of the LWPM concept, it may be concluded that the community in Pranburi watershed should embrace and adopt the SEP as a guideline for sustainable agricultural resource management (Figure 5).

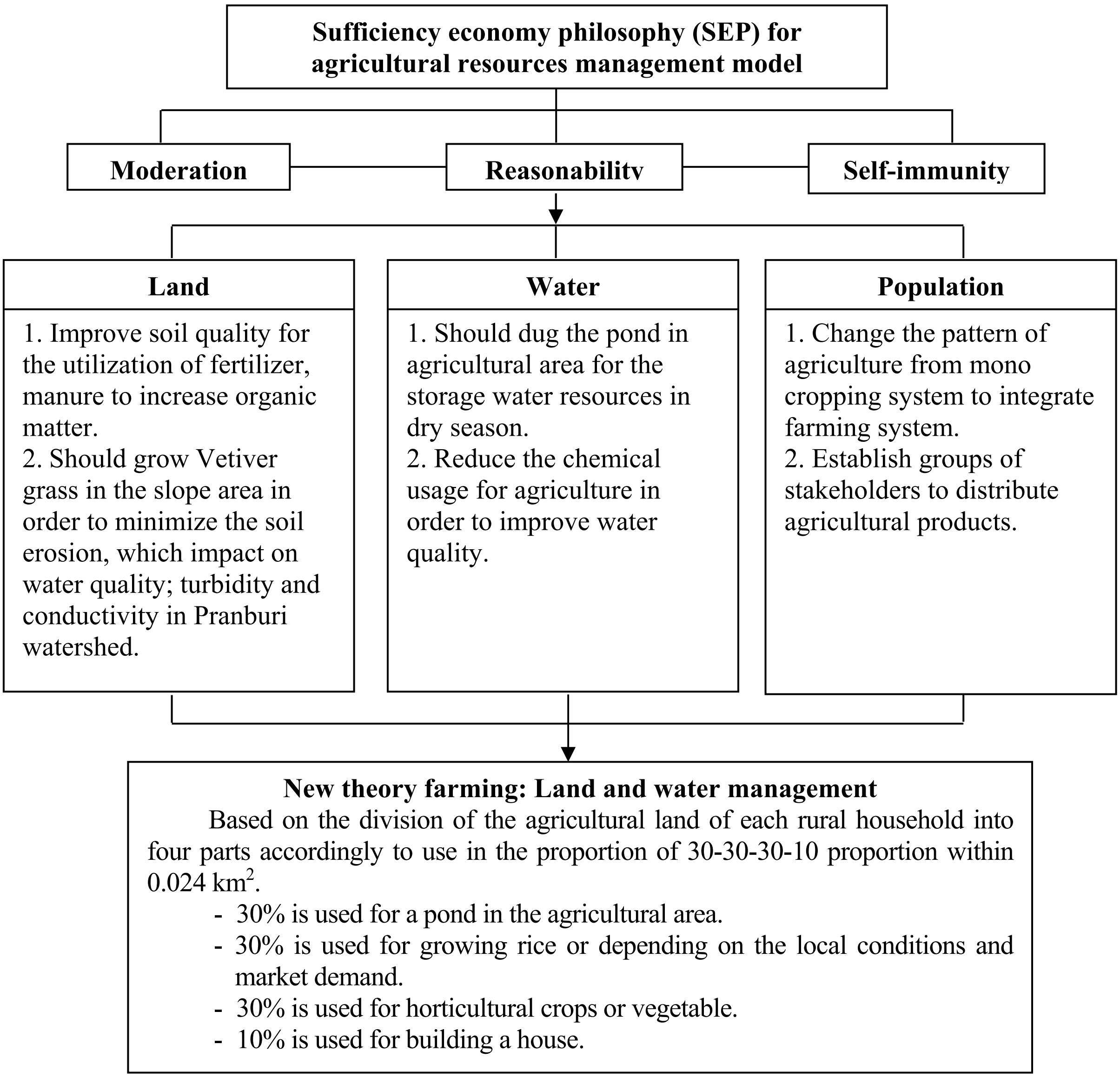

Figure 5 Sufficiency economy philosophy for agricultural resources management model.

This model comprises three components based on SEP for agricultural resource management: moderation, reasonability, and self-immunity, which together contribute to a way of life as follows [29];

- Moderation is the concept of a middle path with self-reliance in production and consumption at a moderate level.
- Reasonability is based on the decision concerning with a rational and consideration of the key factors in natural resource management that affect the sustainable allocation of resources in agriculture and other uses.
- Self-immunity emphasizes preparation to cope with likely impacts and changes in of various known threats and risks, by considering the probability of future situations in the agricultural sector, including natural disasters.

In order to improve availability of water in the watershed, farmers should dig ponds on their farms, following the principle of the new theory in order to store water during the dry season. In 1992, His Majesty the King introduced the concept of the new theory, outlining an agricultural approach which emphasizes appropriate land and water management for optimum benefits. His Majesty was well aware of several factors that had impeded productive agriculture, including limited land area, risks from adverse climate and droughts, and lack of innovative agricultural methods and systems to replace the widespread practice of monocropping [30].

Conclusion

In order to address the inter-linked problems of low soil organic matter, erosion and water scarcity in the Pranburi watershed, the philosophy of the sufficiency economy is advocated to diversify crop production, reduce use of farm chemicals, and grow green manures to restore long-term soil fertility. Furthermore, the new theory agriculture also emphasizes soil and water conservation; most farmers do not have pond for holding water, and so digging new small farm ponds should be prioritized. The recommendations of the SEP can help farmers suffering continuously from the impacts of economic crises and environmental threats. The implementation of SEP for agriculture can be applied at all levels- individual level, community and at the national level.

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