Integrating Human and Ecotoxicological Impacts into Willingness to Pay Evaluation: Transition from Paraquat to Atrazine Use in Sweet Corn Cultivation

Miss Patharanun Toolkiattiwong

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การบูรณาการผลกระทบด้านความเป็นพิษต่อมนุษย์และระบบนิเวศในการประเมินความเต็มใจจ่าย: การเปลี่ยนผ่านจากการใช้พาราควอตไปสู่อะทราซีนในการปลูกข้าวโพดหวาน

น.ส.ภัทรนันท์ ทูลเกียรติวงษ์

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By	Miss Patharanun Toolkiattiwong
Field of Study	Industrial Toxicology and Risk Assessment
Thesis Advisor	Associate Professor PASICHA CHAIKAEW, Ph.D.
Thesis Co Advisor	CHIDSANUPHONG CHART-ASA, Ph.D.

Accepted by the FACULTY OF SCIENCE, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

.... Dean of the FACULTY OF SCIENCE
(Professor POLKIT SANGVANICH, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Assistant Professor VORAPOT KANOKKANTAPONG, Ph.D.)

.... Thesis Advisor
(Associate Professor PASICHA CHAIKAEW, Ph.D.)

.... Thesis Co-Advisor
(CHIDSANUPHONG CHART-ASA, Ph.D.)

.... Examiner
(JATUWAT SANGSANONT, Ph.D.)

.... Examiner
(SUMETH WONGKIEW, Ph.D.)

.... External Examiner
(Assistant Professor Noppol Arunrat, Ph.D.)

ภัทรนันท์ ทูลเกียรติวงษ์ : การบูรณาการผลกระทบด้านความเป็นพิษต่อมนุษย์และระบบนิเวศในการประเมินความเต็มใจจ่าย: การเปลี่ยนผ่านจากการใช้พาราควอตไปสู่อะทราซีนในการปลูกข้าวโพดหวาน. (Integrating Human and Ecotoxicological Impacts into Willingness to Pay Evaluation: Transition from Paraquat to Atrazine Use in Sweet Corn Cultivation) อ.ที่ปรึกษาหลัก : รศ. ดร.ภศิชา ไชยแก้ว, อ.ที่ปรึกษาร่วม : ดร.ชิษณุพงศ์ ชาติอาสา

การประกาศห้ามใช้พาราควอตส่งผลให้เกษตรกรผู้ปลูกข้าวโพดหวานเลือกใช้อะทราซีนในการกำจัดศัตรูพืชมากขึ้น การปรับตัวตามนโยบายดังกล่าวไม่มีผลการศึกษาที่อ้างถึงผลกระทบต่อสุขภาพของเกษตรกรและสิ่งแวดล้อม รวมถึงขาดข้อมูลสนับสนุนเรื่องมูลค่าของผลกระทบในรูปแบบที่เกษตรกรสามารถเปรียบเทียบได้และเข้าใจได้ง่าย การศึกษานี้จึงทำการประเมินผลกระทบต่อสุขภาพและความเป็นพิษต่อระบบนิเวศน้ำจืดจากพาราควอตและอะทราซีนที่สะสมในดินด้วยแบบจำลอง USEtox 2.12 และใช้หลักการความเต็มใจจ่ายอธิบายการให้คุณค่าของเกษตรกรต่อผลกระทบที่เกิดขึ้นจากการเปลี่ยนแปลงการใช้สารกำจัดศัตรูพืช นอกจากนี้ งานวิจัยนี้ยังได้ศึกษาปัจจัยจากทฤษฎีพฤติกรรมตามแผนเพื่อใช้อธิบายถึงกลุ่มปัจจัยที่มีอิทธิพลต่อความความเต็มใจจ่ายของเกษตรกร โดยอาศัยการวิเคราะห์ด้วยแบบจำลองโลจิทแบบเรียงลำดับ การศึกษานี้ใช้แบบสอบถามในการเก็บข้อมูลเกษตรกรผู้ปลูกข้าวโพดหวานในจังหวัดลพบุรี สระบุรี และนครราชสีมา ผ่านการสัมภาษณ์ทางโทรศัพท์สองครั้ง จากการศึกษาพบว่า เกษตรกร 41 คน เคยใช้พาราควอตก่อนมีประกาศห้ามใช้ ปริมาณสารออกฤทธิ์ที่ใช้คิดเป็น 0.86±0.27 กก./ไร่/ปี และเมื่อเปลี่ยนมาใช้อะทราซีน มีปริมาณสารออกฤทธิ์ คิดเป็น 0.92±0.43 กก./ไร่/ปี จากการวิเคราะห์ข้อมูลทางด้านพิษวิทยา ความเป็นพิษต่อมนุษย์จากการใช้พาราควอต ($1.33\times10^{-6}\pm4.21\times10^{-7}$ ปีที่สูญเสียสุขภาวะ) มีค่าสูงกว่าการใช้อะทราซีนเล็กน้อย ($1.30\times10^{-6}\pm6.21\times10^{-7}$ ปีที่สูญเสียสุขภาวะ) ในทางกลับกัน ความเป็นพิษต่อระบบนิเวศจากการใช้พาราควอต (68.37±21.7 สัดส่วนการสูญหายของความหลากหลายของสิ่งมีชีวิต.ลูกบาศก์เมตร.วัน) มีค่าต่ำกว่าการใช้อะทราซีนอย่างมีนัยสำคัญ (1262.67±600.83 สัดส่วนการสูญหายของความหลากหลายของสิ่งมีชีวิต.ลูกบาศก์เมตร.วัน) ค่าเฉลี่ยความเต็มใจจ่ายของเกษตรกรเพื่อลดความเป็นพิษต่อมนุษย์และระบบนิเวศจากการใช้สารกำจัดศัตรูพืชในปัจจุบันคือ 216.46±132.28 บาท/ปี และ 162.44±111.74 บาท/ปี ตามลำดับ ผลการศึกษาปัจจัยทฤษฎีพฤติกรรมตามแผนแสดงให้เห็นว่า เกษตรกรที่มีการคล้อยตามกลุ่มอ้างอิงระดับปานกลางต่อนักวิชาการการเกษตร มีแนวโน้มที่จะยินดีจ่ายเพื่อลดผลกระทบต่อระบบนิเวศน้อยกว่าเกษตรกรที่มีการคล้อยตามกลุ่มอ้างอิงเชิงบวกอย่างมีนัยสำคัญ ($p\leq0.05$) การศึกษานี้ให้ข้อมูลที่เป็นประโยชน์ต่อหน่วยงานที่เกี่ยวข้อง เพื่อปรับปรุงประสิทธิภาพของนโยบายการใช้สารกำจัดศัตรูพืชในการปลูกข้าวโพดหวานอย่างยั่งยืน

สาขาวิชา	พิษวิทยาอุตสาหกรรมและการประเมินความเสี่ยง	ลายมือชื่อนิสิต ....
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		ลายมือชื่อ อ.ที่ปรึกษาร่วม ....

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Patharanun Toolkiattiwong : Integrating Human and Ecotoxicological Impacts into Willingness to Pay Evaluation: Transition from Paraquat to Atrazine Use in Sweet Corn Cultivation. Advisor: Assoc. Prof. PASICHA CHAIKAEW, Ph.D. Co-advisor: CHIDSANUPHONG CHART-ASA, Ph.D.

The paraquat ban has led to a shift in the use of pesticides in sweet corn cultivation, atrazine as one of the alternative pesticides. This change has led to altered human-ecological impacts that have yet to be explored. The related monetary values of farmers as reflected through their willingness to pay is unknown. This study assessed the health and freshwater ecotoxicity impacts of paraquat and atrazine in soil cultivation using the USEtox 2.12 model. The value of farmers on the impact of the change was explained by willingness to pay (WTP). The theory of planned behavior (TPB) factors, a psychological theory that links beliefs to behavior was applied to consider factors that affect willingness to pay using ordered logit model. The questionnaire surveys of sweet corn farmers in Lopburi, Saraburi and Nakhon Ratchasima Provinces were interviewed twice via telephone. The study of 41 farmers indicated that farmers had used paraquat before being banned for 0.86±0.27 kg active ingredient (a.i.)/rai/year was substituted by 0.92±0.43 kg a.i./rai/year for atrazine. Based on toxicological data, human toxicities were slightly higher on the paraquat use ($1.33\times10^{-6}\pm4.21\times10^{-7}$ disability adjusted life years (DALY)) than the atrazine use ($1.30\times10^{-6}\pm6.21\times10^{-7}$ DALY). On the other hand, the corresponding ecological toxicity were significantly lower on the paraquat use (68.37±21.7 potentially disappeared fraction of species (PDF). m^3.day) than the atrazine use (1262.67±600.83 PDF.m^3.day). Farmer's average willingness to pay to reduce human and ecological toxicity from the current pesticide use was 216.46±132.28 baht/year and 162.44±111.74 baht/year, respectively. The results on TPB factors affecting willingness to pay revealed that farmers with neutral subjective norms towards agricultural scholars were less likely to be willing to pay to reduce ecotoxicity impact than farmers with positive subjective norms ($p\leq0.05$). These findings provide useful information to relevant agencies to improve the effectiveness of pesticide policies for sustainable cultivation of sweet corn.

Field of Study:	Industrial Toxicology and Risk Assessment	Student's Signature...........................
Academic Year:	2021	Advisor's Signature..........................
		Co-advisor's Signature.....................

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CHAPTER 1

INTRODUCTION

1.1 Background

The world population is expected to grow from 5.6 billion in 2009 to 7.9 billion in 2050, which is accounted to increase by over a third or 2.3 billion people. The rise of food demand will inevitably continue in response to the population growth, especially in agricultural and livestock production (Food and Agriculture Organization, 2009). Various pesticides have proved a vital role in the success of killing harmful insects and boosting intensive agricultural systems. However, using pesticides increases the likelihood of pesticide poisoning, affecting farmers' health and ecosystems. Acute and chronic poisoning from the use of pesticides causes a wide range of effects from mild to death. Parkinson's disease, cardiovascular damage, endocrine and thyroid disruption are examples of the health effects of pesticides (United States Environmental Protection Agency, 2007). Often, impacts of the chemical use are direct. Unhealthy soil and water in agriculture from overused pesticides change the food chain cycle, which in turn decrease agricultural productivity (Sabra & Mehana, 2015; Shammi et al., 2020). Despite the severe outcomes, the chronic effects of long-term exposure to pesticides are not widely recognized and documented (Nordborg et al., 2014), and the ecotoxicity impacts of the use of pesticides in the cultivation of sweet corn have received little attention (Xue et al., 2015).

A large amount of annual pesticides imports to Thailand demonstrate Thailand's high-volume pesticides use, which is the main consequence for reported cases of the toxic effects on humans and the environment (Tawatsin, 2015). The local government has put efforts into designing effective pesticide control policies to reduce the impact of pesticide (Jin et al., 2017). Sweet corn (*Zea mays L. saccharata*), one of the leading economic crops of Thailand with a large crop volume, where a large amount of pesticides is used in the planting process. According to the Ministry of Commerce Thailand (2018) reports that the amount of pesticides in global exports is 5,710 million baht. Based on the statistics of illnesses from pesticide use by the Department of Disease Control in 2019, Lopburi, Saraburi and Nakhon Ratchasima provinces are foremost producers of sweet corn in Thailand where lots of pesticides are used, in particular paraquat. Thailand banned paraquat in June, 2020 due to the toxicological hazard to living organisms, making atrazine become the main pesticide in sweet corn cultivation (Office of Agricultural Economics, 2018). Although the market values related to this pesticide shift is high, better understanding between human-ecotoxicological impacts and motivations to shifting towards suitable pesticide practices are still needed. This could be achieved through an economic analysis. The contingent valuation method (CVM), a survey-based economic technique, is widely used and suitable for evaluating individuals' preferences that are the basis for making decisions about welfare change. Health and ecotoxicity costs of pesticide use require a measure of individual preferences or willingness to pay (WTP) that are the public decision to choose the amount they are willing to pay to reduce, restore or improve the impacts that may occur (Khan & Damalas, 2015). WTP can be predicted by using concepts developed in the theory of planned behavior (TPB) to understand individual behavior as resulting from intentions, which in turn are influenced by attitudes, subjective norms, and perceived behavioral control. (Ajzen, 1991). To date, no study has not been performed to compare the changes in the use of pesticides from paraquat to atrazine in determining impact contribution to take place, including health and environmental costs.

Regarding responsible of sweet corn production, scientific data are needed for decision making to study the effect of changes in the type of pesticides used. The need to assess the impact of changes in pesticide use is essential, especially at the level of small-scale farmers whose pesticide consumption is restricted as recommended by the Department of Agriculture. The goal of this research is to integrating human and ecotoxicological impacts into willingness to pay evaluation. The amounts of pesticide uses are converted into the human and ecotoxicological impacts, and then used as the basis for evaluating the willingness to pay to minimize such impact and its influential factors. This study takes a leap from other studies to a novel aspect. The difference from previous studies is that the pesticide transition consumption is primary data collected at the small-scale farming, which provides insights into individual farmer use of pesticides. This study will provide insights into the use of pesticides from individual farmers. This research bridges the toxicological data with economic tools to create understanding and participation at the local level. This study will be useful in formulating guidelines to reduce the impact of pesticides on health and environment of sweet corn farmers as well as value on freshwater ecosystems.

1.2 Objectives

1. To assess the human and ecotoxicological impacts of pesticides for sweet corn cultivation from changes in the use of paraquat to atrazine.

2. To evaluate farmers willingness to pay to reduce human and ecotoxicological impacts transitioning from paraquat to atrazine use.

3. To identify theory of plan behavior (TPB) factors affecting willingness to pay to reduce human and ecotoxicological impacts from transition of pesticide use.

1.3 Scope and limitation of the study

The coverage study is scoped and limited to the specific small-scale farming data collected from the sweet corn farmers who are active members of the National Corn and Sorghum Research Center in Lopburi, Saraburi, and Nakhon Ratchasima provinces, Thailand. The amounts of pesticide use are self-reported through a questionnaire, which are used to estimate the human and ecotoxicological impacts as the end-point impacts on health and freshwater in the USEtox model. The willingness to pay to minimize the estimated impact are obtained through another questionnaire and an economic analysis, whereas its influential factors are determined through the statistical analysis.

CHAPTER 2

THEORETICAL BACKGROUNDS

2.1 Sweet corn cultivation

In Thailand, there is a total cultivated area of 385 km^2. Nakhon Ratchasima, Lopburi, and Saraburi provinces cover 15.88 km^2, 4.50 km^2 and 1.44 km^2 of agricultural areas (Office of Agricultural Economics, 2019). The Office of Agricultural Economics reported that in 2020, Lopburi, Saraburi and Nakhon Ratchasima provinces have a total sweet corn plantation area of 13,161 rai, accounted for 5.61% of Thailand's sweet corn planting area. In sweet corn cultivation consisting of 8 stages shown in Figure 1. Pesticides are often used in the early stages during 14-30 days, since pests began to play a role and damage sweet corn. The amount of pesticide use depends on the proportion of pesticides and water mixing determined by the Thai Department of Agriculture. In practical, pesticide consumption depends on the area, situation and farmer behavior. Spraying pesticides is the most common activity for farmers because it is time-saving and efficient way to protect the sweet corn yield from insects (Pobhirun & Pinitsoontorn, 2019)

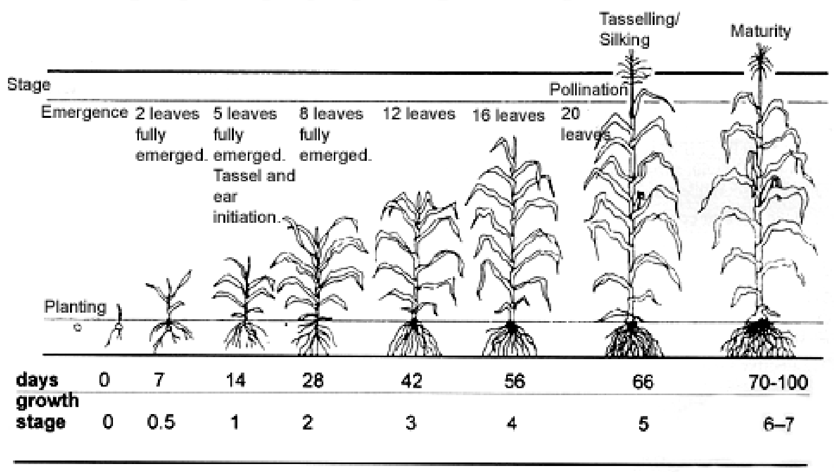

Figure 1 Sweet corn growing stages (Beckingham, 2007)

2.2 Atrazine

Atrazine (6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) is a selective herbicide in triazine group and as a pre-emergence herbicide and use to control broadleaf weeds. Although it is banned in most European countries due to a long persistence in the environment, atrazine is registered in more than 70 countries worldwide (Sinlapathorn et al., 2018). Atrazine is commonly used in Thailand in corn and millet cultivation because of its resistance to the substance by spraying into the ground, inexpensive, good performance and the effect of destroying plants inhibition of photosynthesis. Chemical properties of atrazine are determined by molecular formula $C_8H_{14}Cl\ N_5$, relative molecular mass: 215.69, melting point: 173°C, density: 1.187 g/cm^3 at 20°C, slightly soluble in water (33 mg/L at 20°C), vapor pressure 0.04 mPa at 20°C (United States Environmental Protection Agency, 2006).

2.2.1 Toxicity of Atrazine

For acute toxicity (non-cancer effect) of atrazine is mild to moderate toxicity to humans such as abdominal pain, diarrhea, vomiting, eye irritation, irritation of mucous membranes and skin reactions. Occupational exposure can occur through dermal ingestion and inhalation. It can be absorbed into the bloodstream. The long-term effects of atrazine were found to affect the immune system, cardiovascular function, central nervous system, etc. Several animal studies have shown that atrazine can bind to the androgen receptor, causing the effects to neuroendocrine system by changes in pituitary hormone levels (LH hormone and follicle stimulating hormone) (United States Environmental Protection Agency, 2007). In rats, histopathological lesions of the kidneys occurred at NOAEL = 1.0 (mg/ kg/day) (United States Environmental Protection Agency, 2006). For farmers, health information reports have shown that the use of atrazine are at risk of end-stage renal disease (kidney failure) (Lebov et al., 2016). Although the EPA classifies atrazine as unlikely to be carcinogenic to humans and International Agency for Research on Cancer (IARC) reports that atrazine is not classified as a human carcinogen (group 3), there is sufficient evidence to confirm that atrazine causes mammary fibroadenoma and breast cancer (mammary carcinoma) in rats (Pinter et al., 1990).

Several studies have found that the measured concentrations of atrazine in the environment may reach levels that are likely to cause a negative effect on sensitive species and communities. For long-term exposure to atrazine has been found to be harmful to fish in the water and amphibians. Reduction in pupation and adult emergence of *Chironomus tentans* (NOEAC = 110 ppb), reduced mean length, mean body weight in *Salvelinus tontinalis* (NOEC = 65 ppb) and reduction in adult survival of *Americamysis bahia* (NOEC = 80 ppb) (United States Environmental Protection Agency, 2006). For the atrazine impact assessment, toxicological data obtained from animal experiments were used.

2.2.2 Standard value of Atrazine

In order to control the hazards to human health, a standard value for atrazine has been established. For occupational exposure, there is a standard setting of time weight average (TWA) 5 mg/m^3 by Occupational Safety and Health Administration (OSHA) (1997). Soil quality standards (for living and agriculture) are set by the Pollution Control Department to not exceed 22 μg/kg (Pollution control department, 1992). Water quality control to prevent harm to aquatic organisms has been established a criterion maximum concentration for protection of aquatic life from acute toxicity (CMC) is 350 μg/L and criterion continuous concentration for protection of aquatic life from chronic toxicity (CCC) is 123 µg/L (United States Environmental Protection Agency, 2006). The standard values set by various agencies can be used as a guideline in assessing health and environmental impacts.

2.3 Paraquat

Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride), a common trade name Gramoxone, is classified as a non-selective herbicide. Paraquat destroys green plant tissue by translocation within the plant, inhibits photosynthesis and disrupting cell membranes. Paraquat salts are colorless or white solid and odorless. Dichloride salts are stable except under alkaline conditions. Paraquat is stable against heat when in acid or neutral solutions, but is hydrolyzed by alkali solutions. It is very soluble in water (20°C), less to no soluble in organic solvents, boiling point at 175-180° C, vapor pressure >1.0 x 10 mmHg at 25 ° C and not volatile (United States Environmental Protection Agency, 1997).

2.3.1 Toxicity of paraquat

For acute toxicity, paraquats are highly toxic by the inhalation route and are ranked in toxicity category I (the highest of four levels), moderately toxic (category II) by oral route and slightly toxic (category III) by dermal route. The lethal concentration (LC50) for inhalation in rat is 0.83-1.93 mg/kg^3. For systemic effects, paraquat alters the levels and activities of liver and kidney enzymes such as acetylcholinesterase. In addition, the amount of hemoglobin, erythrocytes, white blood cells, and serum protein decreased. In rodent studies have shown that paraquat causes proliferation and fibrosis of the bile duct (Food and agriculture organization of the United Nations, 2007). In some cases, paraquat may cause cancer. In female rodents, an increase of dose causes adenomas and carcinomas in the thyroid gland and causes tumors (pheochromocytoma) in the adrenal gland (United States Environmental Protection Agency, 1997).

In 2009, United States Environmental Protection Agency (USEPA) classified that paraquat as slightly toxic to freshwater fish. For acute toxicity, the LC50 (96hr) found in rainbow trout was 19 mg/L and 98 mg/L in mirror carp. Examples of acute toxicity in fish include excessive gulping of air, erratic swimming, and paralysis. The NOEC (chronic toxicity) in rainbow trout is 8.5 mg/L (Food and agriculture organization of the United Nations, 2007). It was also found that exposure to paraquat caused abnormalities in the toads (*Rana esculenta*), such as abdominal edema, abnormal tail development and slower head development (Quassinti et al., 2009). There are not many studies on chronic effects of paraquat because of indirect use in water. The mobility was achieved through runoff or spray drift (United States Environmental Protection Agency, 1997).

2.3.2 Standard value of paraquat

The United States Environmental Protection Agency (USEPA) has set reference dose (Rfd) for paraquat 0.0045mg/kg/day and the acceptable daily intake (ADI) 0.004 mg/kg/day. For occupational exposure, there is a standard setting by the Occupational Safety and Health Administration (OSHA), for time-weighted average (TWA) is 0.5 mg/m^3. Water quality standards for freshwater animal protection set by Pollution Control Department (1987) is 0.5 mg/L.

2.4 Assessing the impact on human health and ecotoxicity by USEtox model

Health impacts are classified into two categories: 1) direct impact - a health impact that results from direct use and causing illness, 2) indirect impact - an impact that does not directly affect health but is caused by a change in multiple health factors together that results in health changes, such as worsening health effects due to anxiety about livelihoods after natural resource degradation from herbicide use. This type of impact assessment is difficult to quantitatively analyze because of a wide variety of factors. Cumulative impact is both direct and indirect impacts from operations in the same area or population. This sometimes generates the health effects more severe than anticipated. In order to assess health impacts, a good understanding of the basic information of each area or population is required (Tonpoo, 2017).

A variety of health impact assessment tools is available. One of widely used tools in life cycle impact assessment approach is the USEtox model. With the suitable inputs, the USEtox model can quantify human health and ecotoxicity impacts in the terms that we can communicate to farmers and the community.

Xue et al. (2015) studied the ecotoxicity impact of 12 pesticides in sweet corn production in the Midwest, USA using USEtox model. The environmental fate of pesticide and human exposure has a causal link in the USEtox model. The release of pesticides into the environment was thus positively correlated with the rate of ingestion and inhalation of pesticides. The human health impact depends on the pesticide application in rates/ha/kg corn. Studies have shown that the use of atrazine at $2.56 x 10^{-4}$ kg/kg corn has the potential to cause total health effects throughout the entire life cycle 10^{-11} cases/kg pesticide (included cancer and non-cancer effect). This study showed a comprehensive overview; however, it is purely based on secondary data., In practical, each area may differ in the amounts of pesticides used in sweet corn cultivation. Another limitation is that this research employed the impacts at the midpoint level, not to the endpoint.

Juraske and Sanjuán (2011) conducted a comprehensive study of pesticide toxicity assessment in orange production in Comunidad Valenciana, Spain, based on foliar and soil application. The study found that the use of paraquat at dosages of 1.00×10^{-6} kg m^2 showed the human toxicity at 1.85×10^{-12} DALY kg^{-1} based on human intake fractions. Paraquat indicated high freshwater ecotoxicity at 9.25x10 PAF m^3 d kg^{-1}, where DALY is disability adjusted life years and PAF is potentially affected fraction of species. Impacts per kilogram commodity was used in this study to set up six scenarios based on results of human health and ecotoxicity studies. Among multiple alternative pest management plans, growing organic oranges performed the least impact on health and the ecotoxicity.

Steingrímsdóttir et al. (2018) presented the toxicity of the pesticides used in lettuce cultivation in Denmark using USEtox model and consider the toxicity-related damage costs. Application dosage toxicity (kg a.i./ha) from emissions to air, soil and residues in lettuce were used in the study. It was found that acetamiprid had the highest human toxicity potentials at 3.7×10^{-3} DALY/kg a.i. applied. Azoxystrobin show the highest ecotoxicity potential at 1.2×10^{3} PDF m^3 d/kg a.i. applied, where PDF is potentially disappeared fraction of species. In addition, damage costs were calculated from valuation factors based on the contingent valuation. It was found that acetamiprid had the highest human toxicity damage costs and azoxystrobin had the highest ecotoxicity damage costs.

2.5 Contingent valuation method (CVM)

Due to the lack of quality of life and resources reflected in monetary terms, the contingent valuation method (CVM) approach is commonly used for direct valuation (stated preference) (Adamowicz et al., 1998). Besides the environmental benefits, the CVM is recommended to evaluating health assessment. CVM uses a scenario in considering a person's willingness to pay to reduce the potential impact. One basic economic theory using in CVM is the concept of willingness to pay (WTP), which is an individual's preferences (Ditjanapongpon, 2013) of improving the quality of life and the environment (FREEMAN III, 1979).

WTP for health is a decision-making tool for individuals that refers to their willingness to spend personal money in order to obtain health benefits or to avoid wasting their health or reduce their health risks. Disability adjusted life years (DALYs) are one of the methods used to measure a person's satisfaction and well-being from their health outcomes by asking questions explaining their health care options and asking the maximum WTP for it. The price that is available to pay indicates a better living by getting goods provided at the market price. WTP is associated with ability to pay which is a key factor of demand, so individuals' willingness to pay is different. It is useful to verify that the person receives more benefits from the health program than the opportunity cost.

The aim of CVM is to get the truth from the interviewee about willingness to pay by the interviewer to use the questioning technique. There are several types of questioning techniques (Kamolcharuphisuth, 2011):

1. Open-ended question is a question that allow respondents to express their willingness to pay in an amount based on their attitudes or opinions freely and more directly in reality than close-ended questions. No starting point or first bid is required. For example, asking, "If there are improvements in preventive measures against health hazards from pesticides, are you willing to pay to support such measures?”. In the event that the interviewee answers "willing to pay", the interviewer will ask "What is the maximum amount you are willing to pay?". The disadvantage of these open-end question is that the answers obtained may be too detailed or irrelevant, and there can be pressures for the interviewee to be wronged.

2. Close-ended question is the format often used in the study of willingness to pay. This method is asking questions by setting a first bid, using bidding games technique. Games are designed to help achieve objectives. This technique is similar to a market bargain. The interviewee can negotiate the price to the actual level they are willing to pay. There are two types of bidding games.

- Single bid game

The interviewer explains in detail the scenario about quantity, quality, time, location, benefits and then asks for how much they are willing to pay for a service or product. The interviewer can specify an initial amount to guide the interviewee by using an amount that is high or low. If the interviewee is willing to pay, they will ask, "What is the maximum amount you are willing to pay?"

- Iterative bid game or converging bid game

This method is the same technique as the single bid game, but is negotiated until the interviewee responds "willing to pay", i.e., starting an interview with a high initial bid amount. Initially, the interviewee would "not be willing to pay", then keep asking by reducing the amount until the interviewee replied "willing to pay this amount". Resulting in the amount of money that is willing to pay as close to reality as possible.

This technique is convenient for research application. The bias of the first bid can be tested by dividing the interviewed into several subgroups.

3. Dichotomous choice

This method, the interviewer had the answers to choose from, "Willing to pay (yes)" and "Not willing to pay (No). For example, the interviewer asked, "Are you willing to support a project to reduce the use of pesticides for a safe ecosystem in the amount of 500 baht?". If the interviewee is willing to pay, the price will be doubled the initial amount. If the interviewee is now willing to pay in the initial amount, the interviewer will reduce the initial amount down (Hoyos & Mariel, 2010).

There are several studies evaluating WTP in preventing the use of pesticides that can have adverse effects on human health and the environment by contingent valuation method (CVM) studies.

Neamsri and Chancharoenchai (2011) studied factors affecting willingness to pay to reduce the health risks of 217 farmers using pesticides for growing pomelo in Phichit province, Thailand with the CVM technique using a converging bid game. A hypothetical scenario was created by offering an equipment that protects against harm from the base line risk 8.42 per 100,000 population. The factors that were statistically significant to the willingness to pay were gender, income, initial health level frequency of pesticide use, protection during pesticide use and awareness of the hazards of pesticides. The study concluded that bid amount, income, education, health status, consumption of pesticides and perception of pesticide hazards correlated with WTP and resulted in the willingness to pay of agriculture to reduce the health risk at 752.56 baht/household/year.

Khan and Damalas (2015) studied the effect of pesticide use of cotton farmers in cotton belt, Punjab. province by creating a scenario, how much farmers would be willing to pay for the effective pesticides that were equivalent of the current ones without the short-term and long-term health risks. The study found that farmers was willing to pay an average WTP of 8.1% of pesticide expenditures, or about $5.8 USD per year. The study concluded that farmers who are willing to pay less are concerned about insufficient funds and do not believe that pesticides have any effect on health. It was found that risk perception about pesticides, past experience, past experience of pesticide toxicity, education and income were associated with farmers' willingness to pay. The study investigated perceived risk by pesticides and thus may not have sufficient scientific data to demonstrate health effects.

Baral et al. (2007) presented the contingent valuation of critically endangered white-rumped vulture in South Asia using open-ended question and analysis by logistic regression. Of 103 households, 55.3% believe that pesticide use will cause vulture decline. The willing to pay to support vulture conservation measures: conservation breeding and habitat protection that makes it easy for a person to understand and value vultures, averaging NRs 115.2 ($1.56 USD). The willingness to pay is correlated with bid amount, age, gender and conservation attitudes, while the positive attitude towards conservation measures reflected more willing to pay. Conservation breeding are necessary in the reintroduction of vultures from the area where they disappeared and habitat measures protection will prevent the loss of local vultures.

Lazaridou and Michailidis (2020) studied farmers willingness to pay to improve water quality in Nestos watershed, Greece. This study used converging bid game and analyzed by logistic regression. Agriculture is a major contributor to the degradation of freshwater ecosystems and is associated with the use of pesticide. Studies showed that some farmers were reluctant to donate money to improve water quality, probably farmers did not recognize the real impact. However, the average total willingness to pay is €11.5- €22.0/ha/year. Education and income were positive corelated to willingness to pay in this study.

Khan et al. (2010) studied the willingness to pay for improvements in drinking water quality in Pesha water, Pakistan using contingent valuation method from 150 randomly selected households that receiving water from the government water supply through pipes and drinking water, provided by City Development and Municipal Department (CDMD). This study used a multinomial logit model to analyze willingness to pay for safe drinking water from government procurement and identify socio-economic factors that may affect willingness to pay. The study found that the highest level of education was willing to pay of Rs. 208 which was higher than uneducated households because there was awareness about the negative effects of contaminated drinking water on health and households Higher income were more willing to pay than low-income households.

Other demographic and socio-economic factors affecting farmers' willingness to pay are listed in Table 1.

Table 1 Other research on factors affecting farmers' willingness

Researchers (year)	Research topic	Data analysis	Direction of relationship with willingness to pay	
			Positive (+)	Negative (-)
Wang et al. (2018)	Farmers' willingness to pay for health risk reductions of pesticide use in China: A contingent valuation study	Binary logit regression	Education level, income, risk perception, social network, social trust	Household size, social reciprocity
Khan et al. (2018)	Willingness to pay by the farmers for safer use of pesticides	Ordered probit regression	Education level, age, health impairment, number of dosage of pesticides, risk perception, working hour	Farm size, Use of pesticides according to the recommended dose
Ahmed et al. (2015)	Exploring factors influencing farmers' willingness to pay (WTP) for a planned adaptation program to address climatic issues in agricultural sectors	Logit regression	Education level, income, household size, farm size, concern for the risk posed by climate change	-

2.6 Theory of planned behavior (TPB)

The theory of planned behavior (TPB) is a social psychological theory that focuses on the factors affecting the intentions of the actions of a person. TPB promotes the understanding of conditions and factors that helps explain problems or unwanted health behaviors. TPB is associated with the perception of individual actions which explains that "the intention of a person is one of the elements that causes a person to act or perform behavior" (Ajzen, 1991). A person's intention to act depends on three key variables: attitude toward the behavior, subjective norms, and perceived behavioral control. If a person has a positive attitude, they are more likely to conduct that behavior. On the other hand, if a person has a negative attitude, no behavior will occur. Subjective norms arise when a person has beliefs or feelings of subjection to the support of the person, they deem important, such as family, close friends, which may influence the practice or non-performing behavior. In addition, it was found that the perceived behavioral control variable was another factor that influenced the intentions of the expression or behavior of a person (Chainarong, 2018). The theoretical basic structure is shown in Figure 2.

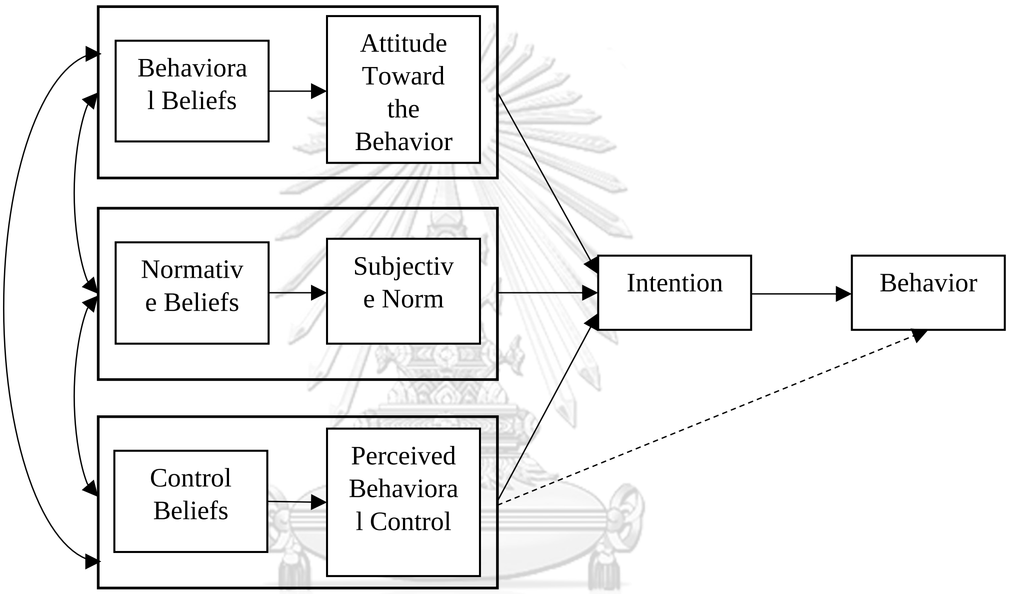

Figure 2 Theory of planned behavior (TPB) diagram

Bagheri et al. (2019) explored farmers' intentions to use pesticides in agriculture according to the TPB. A multistage cluster sampling was used to sampling 400 cereal farmers of irrigated farmlands of Moghan plain, Iran. Studies showed that farmers believed that pesticide use poses a threat to human health and wildlife, especially that overuse of pesticides leads to multiple illnesses such as cancer. For subjective norms, the use of other farmers' pesticides affects their pesticide use and on the perceived behavioral control of pesticide use, for example, having a nearby pesticide store made them accessible. In addition, subjective norms also play an important role by affecting perceived behavioral control and attitudes towards pesticides.

Several studies have used theory of planned behavior to study the tendency of a person's willingness to pay.

Rekola (2010) presented willingness to response for abatement of forest from a community-level in southern Finland in the context of theory of planned behavior (attitudes, subjective norms, and perceived behavioral control). The study predicted behavioral intention and predict factors affecting willingness to pay through logistic regression. The results showed that attitudes and perceived behavioral control predicted contingent valuation results significantly. When attitude towards the policy support was positive, the willingness to pay was high. For perceived behavioral control, it was found that respondents were aware of their budget constraints.

Obeng et al. (2019) studied the willingness to pay of US residents to restore degraded tropical rainforest watersheds using predictors from Theory Planned Behavior (TPB) by random sample of over 1000 US respondents. Data were analyzed using logistic regression with willingness to pay as the intended behavior predicted by attitudes, subjective norms and perceived behavioral control. The results showed that subjective norm was the strongest TPB predictor to predict WTP. The 55.49% of respondents said they were familiar with the rainforest, with only 22% of respondents were willing to make an annual contribution of $30 to $150 through a five-year income tax increase.

Milovantseva (2016) studied the willingness to support greening the ICT devices by paying a premium for a green cell phone (no hazardous materials and can be safely disposed of with municipal waste). This study analyzed nationally-representative U.S. data with web-based surveys. Theory of planned behavior (TPB) was used to provide data for pro-environmental consumption decision and consider factors affecting willingness to pay with generalized ordered logistic regression. The study found that respondents with higher general environmental belief scores, greater engagement in pro-environmental behavior, and positive attitudes towards recycling small electronics were more likely to be willing to pay a premium when purchasing a green cell phone compared to a conventional cell phone with similar capabilities. Average willingness to pay was between \$5.63 after accounting for uncertainty and \$29.55 under full certainty to purchase a green cell phone over a conventional cell phone with same functionalities.

CHAPTER 3

METHODOLOGY

In this research, the data were collected from two sets of questionnaires. Questions about demographic, socio-economic, pesticide information illnesses associated with pesticides, and TPB include in the questionnaire set 1. The amounts of paraquat and atrazine uses are the inputs in the USEtox 2.12 model to evaluate the health and freshwater ecotoxicity impacts from sweet corn cultivation and to compare the impacts of transitions from paraquat to atrazine, which later are compared to reflect the changes due to pesticide transition. Willingness to pay questions in the questionnaire set 2 was surveyed with the same respondents. Willingness to pay and explaining factors could help pinpoint the degree of importance towards the impacts change and provide better understanding of the driven factors to the behavioral shift.

3.1 Conceptual framework

To calculate human health and ecotoxicity impacts, pesticide usage data obtained from questionnaires are used as input to determine the emitted mass of substance x to compartment i (M). The human health impact is calculated based on intake fraction (IF) (IF are obtained from combining fate factor (FF) and exposure factor (XF)) by inhalation and ingestion route, effect factor (EF) and damage factor (DF). The increase in all of these factors resulting characterization factor (CF) increased. Then calculate the emitted mass (M) with the characterization factor (CF) to get impact score, showing human health impact expressed as disability adjusted life year (DALY). For the ecotoxicity impact, FF, XF, EF and DF were also calculated and displayed as potentially disappeared fraction of species (PDF) for impact score.

Where FF, XF, EF, and DF, are retrieved from the USEtox's database, and M are determined based on the pesticide usage data from the questionnaire. The impact score on human health and ecotoxicity was used to create a scenario to study farmers' willingness to pay. Theory of planned behavior: TPB (attitude, subjective norm and perceived behavior control) obtained from the questionnaire was used to determine factors affecting willingness to pay as shown in Figure 3.

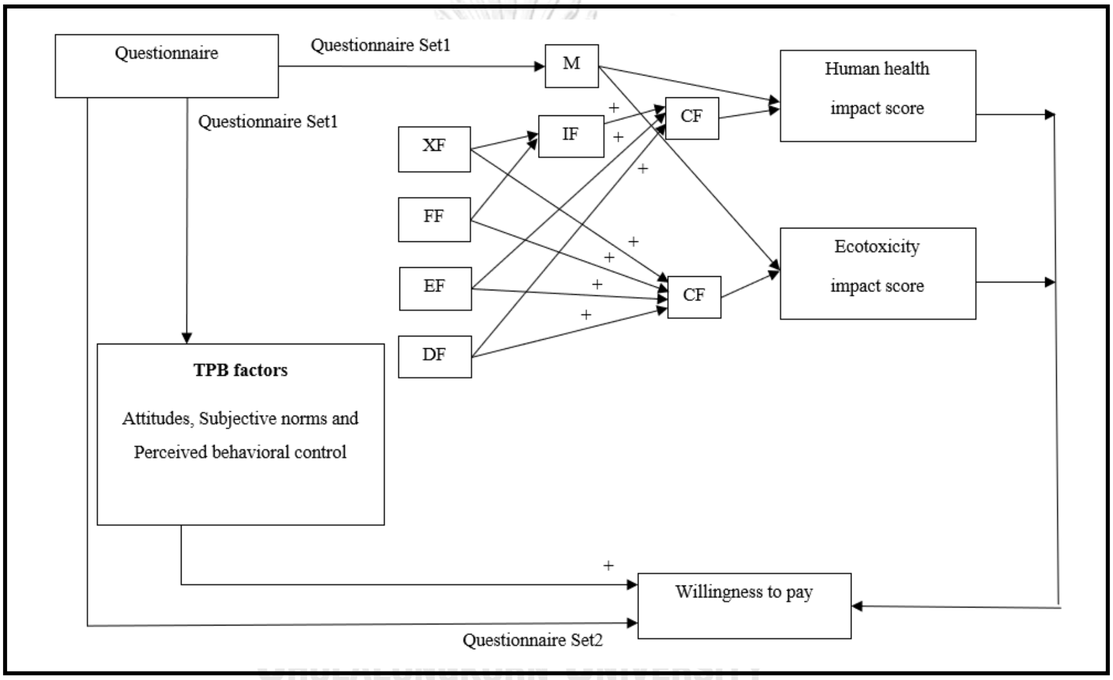

Figure 3 Conceptual framework

3.2 Study area

After Thailand banned paraquat use in 2020, some sweet corn cultivated areas have been shifted from the paraquat to atrazine application. The details of the study area are described below.

Lopburi, Saraburi (located in central Thailand) and Nakhon Ratchasima Provinces (located in the northeastern part of Thailand) are the three areas where the population's income comes from industries, wholesalers and agriculture. The major sweet corn growing areas and sweet corn commodity are found in these provinces. In Thailand, many sweet corn varieties provide good yields, nonetheless, sweet corn (organic 2) is popular for consumption and is used for processing its chain products. This study selected the areas where sweet corn is grown and large quantities of produce are shipped to the National Corn and Sorghum Research Center (Suwan farm). Three areas include:

- Klangdong and Chanthuek Sub-districts in the Pak Chong District (Nakhon Ratchasima Province)
- Lam Phaya Klang Sub-district in Muak Lek District (Saraburi Province)
- Khao Noi Sub-district in Lam Sonthi District (Lopburi Province)

3.3 Population and Sample

With the population of 98 enlisted farmers in the National Corn and Sorghum Research Center (Suwan farm), this study used purposive sampling by employed two criteria to select the sample size. Our conditions included: 1) farmers must grow sweet corn more than or equal to three years and started using atrazine in sweet corn cultivation after the paraquat ban, and 2) farmers must be over 18 years. The sample size of 41 organic variety 2 sweet corn farmers met our selection criteria and became our respondents. There were 10 farmers from Khao noi Sub-district, 4 farmers from Lam Phaya Klang Sub-district, 13 farmers from Klangdong Sub-district and 14 farmers from Chanthuek Sub-district.

3.4 Data collection

1. Primary data were obtained from the questionnaire survey based on 41 samples.

2. Secondary data were collected from textbooks, academic articles, government report journals, and USEtox model. These include study area characteristics, sweet corn cultivation data, human health and ecological impact assessment data, general pesticide consumption.

3.5 Research instruments

3.5.1 USEtox model

USEtox model (UNEP-SETAC toxicity model) is a popular scientific tool used to assess human health and ecotoxicity impacts. USEtox model are often used in life cycle assessment (LCA studies). In this study, USEtox models were used to estimate fate and transportation of pesticides use to grow sweet corn and evaluated toxicity to humans and freshwater organism (Figure 4). The results obtained from the USEtox model are two different impact score. Under the human health impact assessment, the impact score is expressed disability-adjusted life year (DALY), representing the number of years lost due to ill health, disability or early death. For the impact on the freshwater ecotoxicity impact, the impact score is expressed as estimate potentially disappeared fraction of species (PDF). PDF defines the increase in the fraction of species potentially affected as a consequence of an emission in a compartment.

The impact score obtained from the model will be analyzed by comparing the differences in health and freshwater ecotoxicity impacts of the paraquat and atrazine use among sweet corn farmers. Impact score will be used to determine the scenario to study farmers' willingness to pay for reducing health and ecotoxicity impacts.

Impact score (IS) is used to calculate the effect of pesticide consumption in conjunction with emission contribute as follows:

$$IS = \sum_i \sum_x CF_{x,i} \times M_{x,i} \qquad \text{eq.1}$$

where IS is the impact score of pesticide x, $CF_{x,i}$ is the characterization factor of pesticide x released in compartment i, and $M_{x,i}$ is the mass of pesticide x emitted to compartment i. Data on paraquat and atrazine use of farmers obtained from the questionnaire will be used as input in $M_{x,i}$ calculation. The impact score is calculated separately between paraquat and atrazine for e.g., human toxicity (disability-adjusted life years, DALY, at endpoint level). The summation holds for substances and emission compartments for the same impact category (human toxicity or freshwater ecotoxicity)

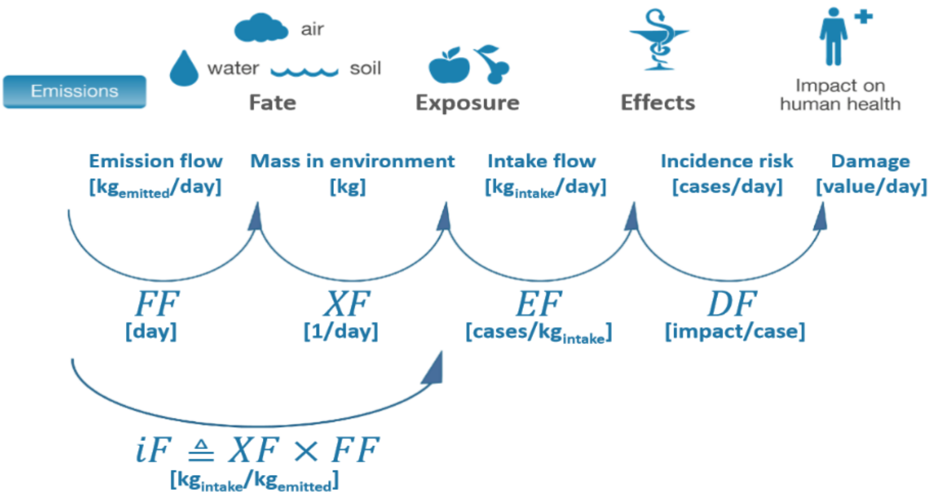

Figure 4 Emission to damage framework in USEtox model. (Bijster, 2015)

1) Human toxicity impacts

Use disability adjusted life years (DALY) as a measure of damage to human health, the human toxicological characterization factor ($CF_{H,x}$) for substance x (paraquat = p, atrazine = a). Fate factor (FF_x) link the quantity released into the environment to the chemical masses (or concentrations) in a given compartment. Exposure factor (XF_x) describe the transport from environmental compartments to the human via inhalation and ingestion, For eq.2 and eq.3 are the conceptual of USEtox model, calculated according to Huijbregts et al. (2005):

$$CF_{H,x} = IF_{H,x} \times EF_{H,x} \times DF_{H,x} \qquad \text{eq.2}$$

$$IF_{H,x} = FF_{H,x} \times XF_{H,x} \qquad \text{eq.3}$$

where $IF_{H,x}$ is the human population intake fraction ($kg_{intake}\ kg^{-1}_{emitted}$) of substance x

$FF_{H,x}$ is fate factor (day) of substance x

$XF_{H,x}$ is exposure factor (day^{-1}) of substance x

$EF_{H,x}$ is the effect factor (number of cases kg^{-1}_{intake} of substance x)

$DF_{H,x}$ is damage factor (DALY $case^{-1}$) of substance x

Intake fraction (IF_x) is to combining fate and exposure by emission-to-intake relationship expressed as kg pesticide intake per kg applied in the cultivation process, which represents the fraction of pesticide emission that humans take into the body via inhalation and ingestion of substance x (paraquat = p, atrazine = a). The intake fraction (IF) is calculated from eq.4. The values of all variables are obtained from the USEtox database.

$$IF_{H,x} = \frac{\sum_k M_k \times XP_k}{S} = \frac{Population\ Intake}{Total\ Emissions} \qquad \text{eq.4}$$

where M_k is mass in compartment k (g) of substance x

XP_k is the exposure factor via compartment k (1/day) of substance x

S is the emission rate to a compartment (g/day)

In this research we focus on inhalation and ingestion route. Therefore, the exposure factor ($XP_{H,x}$) for inhalation route defined as the proportion of mass/volume that the population receives directly daily can be obtained from this equation.

$$XP_{H,x} = \frac{Population_k \times breathing\ rate\ [\frac{m^3}{d}]}{Volume_k[m^3]} \qquad \text{eq.5}$$

According to a number of populations, human breathing rate of 13 m^3/day was considered as the exposure factors (Kounina et al., 2014).

The effect of intake dose was assessed by calculating the human effect factor (EF_i). The effect dose (ED_{50h}) and lifetime dose ($ED_{50h}^{lifetime}$) was obtained from USEtox models (using IRIS database). For body weight (BW) and lifetime of humans (LT), we used a database from USEtox model. Cancer and non-cancer effect (case/kg_{intake}) of substance x (paraquat = p, atrazine = a) can be calculated as follows:

$$Incremental\ riskIntake\ dose\ \times\ \frac{0.5}{Life\ time\ dose\ generating\ 50\%\ additional\ risks} \qquad \text{eq.6}$$

$$EF_{H,x} = \frac{0.5}{365 \times LT \times BW \times ED_{50h}} = \frac{0.5}{ED_{50h}^{lifetime}} \times 10^6 \frac{mg}{kg} \qquad \text{eq.7}$$

where ED_{50h} is the effect dose inducing response over background of 50% for humans (mg/kg day)

0.5 is the response level corresponding to the ED_{50h} (individual lifetime risk of cancer)

BW is body weight of 70 kg

LT is the lifetime of humans (70 year)

365 is the number of days per year (day/year)

$ED_{50h}^{lifetime}$ is the lifetime dose yielding 50% increase in tumor for human h (kg/lifetime)

The human health damage factor (DF_x) for cancer effects is 11.5 DALY case^{-1} and for non-cancer effects is 2.7 DALY case^{-1} based on global human health statistics on life years lost and disabled, are used according to Huijbregts et al. (2005).

2) Freshwater ecotoxicity impacts

Cause-effect chain, linking emissions to impacts through environmental fate, exposure and effect, were used to assess the toxicological effects of freshwater ecosystems. The characterization factors ($CF_{E,x}$) for freshwater ecotoxicity of pesticide x (paraquat = p, atrazine = a) expressed as potentially disappeared fraction of species (PDF) integrated with time and volume per unit mass of pesticide emitted (PDF m^3 d kg^{-1}) (eq. 8).

$$CF_{E,x} = FF_{E,x} \times XF_{E,x} \times EF_{E,x} \times DF_{E,x} \quad \text{eq.8}$$

where $FF_{E,x}$ is the fate factor describing the mass increase of pesticide x in freshwater due to emission flow (kg d^{-1}) of pesticide in the environmental compartment m (kg $_{\text{in compartment}}$/(kg$_{\text{emitted}}$ d^{-1})).

$XF_{E,x}$ is the exposure factor referring to the bioavailable fraction of pesticide in freshwater.

$EF_{E,x}$ is the effect factor expressing the expression of ecological effects by changes in PAF with increased effects (i.e. mortality) caused by changes in pesticide concentrations (PAF m^3 kg^{-1}).

$DF_{E,x}$ is damage factor for freshwater ecotoxicity (PDF/PAF), in USEtox applies a factor of 0.5 based on Jolliet et al. (2003).

The exposure factor for aquatic ecotoxicity ($XF_{E,x}$) represents the bioavailability of a substance, i.e., the fraction of the chemical dissolved in freshwater, calculated in fraction of a chemical dissolved in freshwater. The suspended matter concentration ($C_{w,susp}$), dissolved organic carbon concentration ($C_{w,doc}$) and the biota concentration ($C_{w,biomass}$) in freshwater as assumption in USEtox model. The partition coefficient suspended solids/water (K_p), the partition coefficient dissolved organic carbon/water (K_{doc}) and the bioconcentration factor in fish (BCF_{fish}) was obtained from a database of USEtox model.

$$XF_{E,x} = \frac{1}{1+(K_{doc}\times C_{w,doc}+BCF_{fish}\times C_{w,biomass})/10^6} \quad \text{eq.9}$$

where K_{doc} is the partition coefficient dissolved organic carbon/water (L/kg)

$C_{w,doc}$ is the dissolved organic carbon concentration in freshwater: 5 mg/L*

BCF_{fish} is the bioconcentration factor in fish (L/kg)

$C_{w,biomass}$ is the biota concentration in freshwater: 1 mg/L*

The effect factor ($EF_{E,x}$) for freshwater ecotoxicity (PDF m^3 kg^{-1}) can be calculated follow:

$$EF_i = \frac{0.5}{HC50} = \frac{0.5 \times PAF}{HC50_{EC50}} \qquad \text{eq.10}$$

Ecotoxicological data were based on a database from the USEtox model. $HC50$ is the hazardous concentration (kg/m^3) of a chemical at which 50% of the species in aquatic ecosystem are exposed to a concentration above their *EC50* (e.g. the concentration at which 50% of a population dies in a laboratory test). The number of species ($n_{species}$) is the value obtained from the assumption of the model. The $HC50$ formula can be expressed in eq. 11:

$$HC50 = antilog \frac{1}{n_{species}} \times \sum_{species} \log{(EC50_{species})} \qquad \text{eq.11}$$

where $n_{species}$ is number of species for which $EC50$ values are available

3.5.2 Questionnaire

This study consisted of two sets of questionnaires. The questionnaire was constructed from theoretical concepts, related research and interpreted results from

USEtox model. The purpose of the questionnaire was to obtain the data for assessing the impact of pesticides use to human and ecotoxicity from sweet corn cultivation and to study the willingness to pay and factors related to willingness to pay to reduce such impact. The current research employed TPB factors that may be associated with farmers' willingness to pay to reduce the health and ecological impacts of pesticide use.

The questionnaire was distributed twice to the same sample groups. Due to COVID-19 travel restriction, the questionnaire surveys were ministered by two telephone interviews. The first interview was conducted on 15 June 2021 and 23 September 2021 for the second interview. Two questionnaires are explained as follows:

Questionnaire set 1 mainly focuses on general information and the use of pesticides. This questionnaire was divided into five parts:

Part 1: Demographic and socio-economic data consist of gender, age, marital status, education level, income, and number of family members.

Part 2: The farm size, number of corn planting times per year and corn yield per year used to describe farmers' sweet corn cultivation patterns.

Part 3: The use of atrazine and paraquat, period of use, duration of being a farmer, number of pesticides used per 1 rai and price of pesticide. The pesticide consumption data was calculated as the active ingredient used by farmers and used as inputs to the USEtox 2.12 model as an emission to agricultural soil (kg/rai/day). The USEtox model used to compare the health and ecotoxicological impacts arising from the change in the type of pesticides used from paraquat to atrazine.

Part 4: Questions about illnesses from pesticide use. The data used to discuss the results of the health impact studies and to establish guidelines to mitigate the impacts.

Part 5: Attitude, subjective norm and perceived behavior control questions under the TPB are used to study the association between factors that cause behavioral expression and willingness to pay to reduce impacts on health and ecosystems.

Questionnaire set 2 emphasizes willingness to pay. The results obtained from the USEtox model study of the impacts on human health and freshwater ecotoxicity are used in creating scenarios to inquire about willingness to pay. This questionnaire was divided into two parts:

Part 1: Describe the results of a USEtox model study, explaining the health impacts by the use of paraquat and atrazine pesticides in sweet corn cultivation. This is expressed as the number of years lost due to ill-health (Disability-adjusted life year: DALY). The respondents were asked about their willingness to pay to reduce health impact from the current pesticide use.

Part 2: Describe the scenario about the impact of paraquat and atrazine on aquatic organism in water source. Expressed as the fraction of species potentially disappearing (PDF m^3 day). The respondents were asked for their willingness to pay to reduce the ecotoxicity impact from the current pesticide use.

3.5.3 Model of willingness to pay

The farmers' willingness to pay to reduce their health and ecotoxicity impacts, measured in baht per year. This study employed a mixed-method question design to assess farmers’ WTP. The method. The method combined bidding games technique to explore the willingness to pay, followed by dichotomous choice questions (yes or no), and the final open-ended question about maximum farmer's WTP. The initial bid was set as 110 baht for both human health and freshwater ecotoxicity impact uses the selling price of 10 kilograms of large sweet corn calculated from the sweet corn planting requirements of the National Corn and Sorghum Research Center 2021 as displayed in Figure 5.

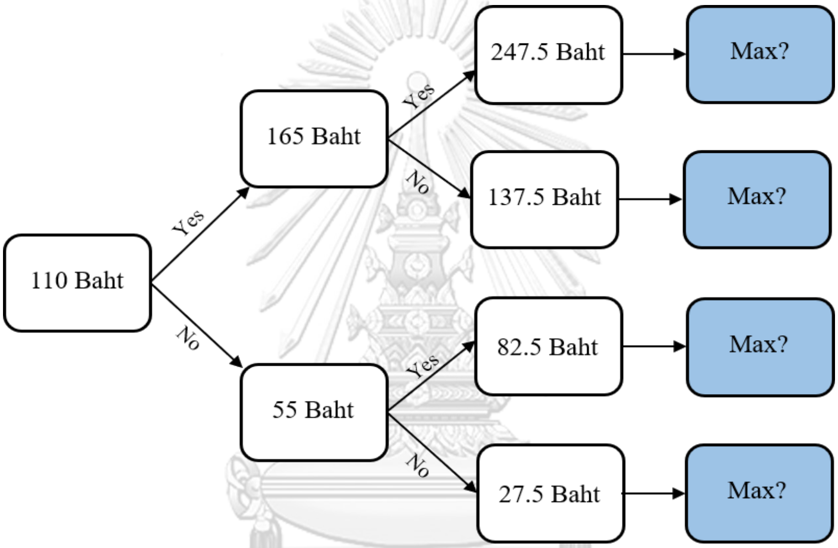

Figure 5 A mixed-method design combining a bidding game, dichotomous choice, and opened-end question for willingness to pay estimation to reduce the health impacts and freshwater ecotoxicity from transitioning paraquat to atrazine in sweet corn cultivation.

3.5.4 Factors affecting willingness to pay

TPB were used to analyze factors affecting willingness to pay to reduce human health and freshwater ecotoxicity impacts by ordinal logistic regression with the likelihood ratio test at statistically significant (α = 0.05). Factors affecting willingness to pay to reduce human health and freshwater ecotoxicity impacts were considered separately. TPB factors were considered separately for attitudes, subjective norms and perceived behavioral control. Ordinal logistic regression models were used to estimate probabilities of WTP as functions of TPB variables. Logistic regression estimated the log odds or logit P as a linear combination of the independent factors.

$$P_{(i)} = \frac{1}{1+exp^{-(Y_{(i)})}} \qquad \text{eq.12}$$

where

$P_{(i)}$ = the probability of having the outcome and P/(1-P) is the odds of the outcome.

Y = The linear regression equation showing relationships between WTP & TPB features.

i = Number of times to run the model

The WTP to reduce health impact, the model was run 3 times as follows:

$$Y_H = \beta_{0H1} + \beta_{1H1}A_1 \qquad \text{eq.13}$$

$$Y_H = \beta_{0H2} + \beta_{1H2}S_1 + \beta_{2H2}S_2 + \beta_{3H2}S_3 + \beta_{4H2}S_4 \qquad \text{eq.14}$$

$$Y_H = \beta_{0H3} + \beta_{1H3}P_1 + \beta_{2H3}P_2 \qquad \text{eq.15}$$

where Y_H is WTP to reduce health impact

For WTP to reduce freshwater ecotoxicity impact, the model was run 3 times as follows:

$$Y_E = \beta_{0E1} + \beta_{1E1}A_2 \qquad \text{eq.16}$$

$$Y_E = \beta_{0E2} + \beta_{1E2}S_1 + \beta_{2E2}S_2 + \beta_{3E2}S_3 + \beta_{4E2}S_4 \quad \text{eq.17}$$

$$Y_E = \beta_{0E3} + \beta_{1E3}P_1 + \beta_{2E3}P_2 \quad \text{eq.18}$$

where Y_E is WTP to reduce freshwater ecotoxicity impact

Scores (Likert's scale) (Likert, 1932) are divided into 3 levels: i) positive, ii) neutral and iii) negative and compared using positive baseline versus neutral, and negative. The WTP is classified into 4 groups: i) 0-99 baht, ii) 100-199 baht, iii) 200-299 baht and iv) >299 baht.

3.6 Research instruments quality testing

Examine the questionnaire with three experts to considering Content Validity with Index of Item-Objective Congruence (IOC) based on the score range from -1 to +1. The criteria for examining questions as follows:

+1 = Congruent

0 = Questionable

-1 = Incongruent

Items with scores lower than 0.5 will need to be revised, on the other hand, items with scores higher than 0.5 were reserved. This study was reviewed and edited on the advice of three experts. In this study, the index of item-objective congruence (IOC) was 1, which indicated good content validity of the survey attribute.

3.7 Data analysis

1. The impacts on health and freshwater ecotoxicity from paraquat and atrazine use was executed in the USEtox model based on the scenarios that 100% pesticides are emitted to agricultural soil.

2. The health and ecotoxicity impacts of paraquat and atrazine were compared to determine whether the effect changes positively or negatively. The impacts arising from farmers' pesticide consumption were calculated separately for each individual, considering the mean and standard deviation (S.D.) and were further statistically tested with paired sample t-test.

3. Demographic, socio-economic, TPB and other data from the questionnaire were described using descriptive statistics.

4. TPB factors related to willingness to pay to reduce health and ecotoxicity impact were analyzed by the ordinal logistic regression.

The statistical analysis was performed by SPSS v.28 and Microsoft Excel 2019.

3.8 Ethical consideration

This questionnaire survey was approved by the Research Ethics Review Committee, Chulalongkorn University, Bangkok, Thailand (No. 060.1/64). Before collecting data, a formal letter was sent to the director of the National Corn and Sorghum Research Center for permission to collect data in the area.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study were divided into 6 parts: 1) demographic and socio-economic data, 2) sweet corn cultivation 3) pesticide usage, 4) human toxicity and freshwater ecotoxicity, 5) theory of planned behavior towards paraquat to atrazine transition, and 6) WTP and factors affecting WTP.

4.1 Demographic and socio-economic data

Demographic and socio-economic data obtained from the first questionnaire consisted of gender, age, marital status, monthly income, education level and number of family members shown in Table 2 and Table 3.

Table 2 The frequency, percentage, mean and standard deviation of the samples classified by demographic characteristics

Demographic data	Frequency	Percentage
Gender		
Male	26	63.41
Female	15	36.59
Total	41	100
Age		
31-45 years	12	29.27
46-60 years	19	46.34
>60 years	10	24.39
Total	41	100
Household member		
1-3 person	7	17.10
4-6 person	32	78.00
>6 person	2	4.90
Total	41	100

The majority of farmers was males, representing 63.41 percent followed by 15 females representing 36.59 percent. The results of this study were realistic and understandable because most of the agricultural activities were carried out by men who were responsible for the purchase and spraying of pesticides in the study area.

The respondents were aged between 31-71 years. The highest percentage of age was in a range 46-60 years (46.34%), followed by 31-45 years (29.27%) and more than 60 years (24.39%), respectively. An average age was 51.73 with a standard deviation of 10.35 years. The results are similar to the study by Montgomery et al. (2020), showing that farmers aged between 54-64 years is the largest grower of sweet corn, accounting for 60.0% of sweet corn farmers and no farmers under the age of 35 years. The results are also consistent with a study by (Churachangkean et al., 2018) showing that the majority of sweet corn farmers at the National Corn and Sorghum Research Center (Suwan farm) in 2015 were aged between 46-55 years. This is consistent with a study by Wang et al. (2018) that stated the new generation or the heirs of farmers come to work in the city or not continue the farming career.

The majority of the household size consisted of 4-6 members, represented 78.00 percent. Family containing 1-3 members was 17.10 percent and more than 6 accounted for 4.90 percent. However, the farmer's household members were similar compared to the sweet corn farmer at the National Corn and Sorghum Research Center (Suwan farm) in 2015 with five household members (Churachangkean et al., 2018). The results of this study are also consistent with the data on sweet corn farmers in Si Rattana district, Sisaket Province, where most farmers have five family members (Jamsai & Tungpitukkai, 2019).

Table 3 The frequency, percentage, mean and standard deviation of the samples classified by socio-economic characteristics

Demographic data	Frequency	Percentage
Marital status		
Single	3	7.32
Married	38	92.68
Divorce	0	0.00
Total	41	100
Marital status		
Single	3	7.32
Married	38	92.68
Divorce	0	0.00
Total	41	100
Education level		
Primary school	18	43.90
Lower secondary school	7	17.07
Upper secondary school	9	21.95
Diploma	2	4.88
Undergraduate	4	9.76
Upper graduate	1	2.44
Total	41	100
Monthly income		
<10,000 baht	11	26.83
10,000-20,000 baht	15	36.59
20,001-30,000 baht	3	7.31
30,001-40,000 baht	1	2.44
>40,000 baht	11	26.83
Total	41	100

The majority of the respondents consisted of 92.68 percent of those who were married, followed by 7.32 percent who were single. The results were similar to a sample of sweet corn farmers of Jamsai and Tungpitukkai (2019) study, indicating that most of the farmers were marital.

The 43.90 percent of the respondents completed primary school, followed by 21.95 percent for the upper secondary school. The 17.07 percent achieved lower secondary school, 9.76 percent received undergraduate level, 4.88 percent had diploma and 2.44 percent was in upper graduation. When compared with sweet corn farmers at the National Corn and Sorghum Research Center (Suwan farm) in 2015, most farmers completed primary school (Churachangkean et al., 2018) as well as a sample of sweet corn farmers in Sisaket Province, most farmers completed primary school (Jamsai & Tungpitukkai, 2019).

The highest percentage of the farmer income was in a range of 10,001-20,000 baht (36.59%), followed by income less than 10,000 baht (26.83%) and more than 40,000 baht (26.83%). The 7.31 percent of respondents had income between 20,001-30,000 baht and 2.44 percent between 30,001-40,000 baht, respectively. An average income was 26,304.88 baht with a standard deviation of 20,238.85 baht. The monthly income in this study reflected the total income. Farmers were unable to determine the monthly income they received from selling sweet corn because the quota for planting sweet corn each year was different.

4.2 Sweet corn cultivation

The farmer's organic variety 2 sweet corn cultivation pattern showed that the farmers had an average cultivation area of 15.99±12.27 rai (max 50, min 3 rai/year).

During the year, farmers can plant sweet corn on an average of 3.41±2.43 cycles/year (max 13, min 1 cycles/year). However, in an area of one rai, there are no more than 3 planting cycles per year due to land preparation period required by the National Corn and Sorghum Research Center. Annually, the amount of processed sweet corn production is estimated before growing. Sweet corn planting quotas are distributed to each farmer who registered in the National Corn and Sorghum Research Center. Thus, the allocation of sweet corn quotas varies depending on the demand, if there is a small quota, it results in less planting cycle. The study also found that farmers harvested an average of 6.34±5.17 tons (max 25, min 1 tons) of sweet corn per crop cycle. All sweet corn is sold under the regulations of the research center.

4.3 Pesticide usage

Most farmers planted sweet corn at the National Corn and Sorghum Research Center between 5-10 years a (48.78%), followed by over 10 years (31.71%) and 3-5 years (19.51%). This study found that 68.29 percent of farmers used paraquat more than 5 years, 21.95 percent used paraquat for 3-5 years and 9.76 percent used paraquat for 1-3 years. The self-reported actual average pesticide application and recommended amount of pesticide usage are shown in Table 4.

Table 4 The average pesticide uses and the amount recommended on the package

Pesticide	Average pesticide use	Recommended on the package
Paraquat	0.35±0.08 kg a.i./rai	0.12-0.15 kg a.i./rai
Atrazine	0.37±0.17 kg a.i./rai	0.23-0.32 kg a.i./rai

The average amount of paraquat used by farmers before the ban was 0.35±0.08 kg a.i./rai and substituted by 0.37±0.17 kg a.i./rai for atrazine. All farmers started using atrazine after paraquat was banned between 1 and 3 years. Atrazine was used for weed control in organic 2 sweet corn cultivation in the study area. Also, the average price for a 0.9 kg atrazine is 203.41 baht and the average price for a 5-litre paraquat is 553.65 baht. The active ingredient of paraquat used by farmers was about 2.92 times greater than the amount recommended on the package (0.12-0.15 kg a.i./rai). The maximum paraquat active ingredient in one crop in this study was found to be approximately 5.5 times higher comparing to the sweet corn cultivation in New Zealand (Comendant & Davies, 2018). For atrazine, the active ingredient used by farmers was was about 1.60 times greater than the amount recommended on the package (0.23-0.32 kg a.i./rai). However, the amount of atrazine use in one crop was approximately 1.1 times greater than the sweet corn cultivation in Illinois, Minnesota, and Oregon (Arslan et al., 2016).

Over the past several decades, the Thai government has made efforts to increase agricultural productivity by enhancing land use and introducing favorable tax policies for the importation of agricultural pesticides. These actions have caused the Thai agricultural system to shift from traditional agriculture to commercial agriculture. Pesticide import also increased with increasing agricultural productivity (Sapbamrer, 2018). Pesticide was readily available for farmer purchases, most of which were purchased from local agrochemical stores, (Plianbangchang et al., 2009). Controlling the use of pesticides in Thailand has divided regulatory duties between different ministries, resulting in ineffective enforcement. Although there has been a discrepancy record between the sales and the amount of pesticide applied in the agricultural areas. Consequently, it was difficult to control farmers over the use of pesticides (Laohaudomchok et al., 2020). Studies on the use of pesticides by farmers showed that most farmers understand how to use pesticides correctly (Norkaew et al., 2010). However, in practice, farmers still perceived that large amounts of pesticide use can result in more efficient maintenance of their crops (Santaweesuk et al., 2020). It is a deep-rooted problem that has not yet been resolved. This may be explained why Thai farmers use more pesticides than the recommended amount.

In terms of negative health effects, 53.66 percent of farmers experienced adverse health effects. The self-reported symptoms as a result from the use of pesticides showed that most farmers experienced acute effects were 59.10 percent dizziness, 18.18 percent burning pain, 13.64 percent headache and others health effects such as stinging nose, sore throat, and eye irritation. Some farmers experienced sub-chronic effects: chest tightness, squeamish and vomiting.

4.4 Human toxicity and freshwater ecotoxicity

The active ingredients, primary data obtained from the first interview, were used as inputs to the USEtox 2.12 model as an emission to agricultural soil (kg/rai/day) (divided the collected data by 365 to be used as inputs in the USEtox model) and calculate human toxicity and freshwater ecotoxicity impacts at endpoint level. Disability adjusted life year (DALYs) used as a measure of overall human population damage in human toxicity and potentially disappeared fraction of species (PDF) indicating freshwater ecotoxicity.

For human toxicity, the average impact scores for human toxicity potential of paraquat ($1.33\times10^{-6}\pm4.21\times10^{-7}$ DALY) was slightly higher than atrazine ($1.30\times10^{-}$

$^{6}\pm 6.21\times10^{-7}$ DALY). For freshwater ecotoxicity, atrazine was found to create much higher impact score (1262.67±600.83 PDF m^3 day) than paraquat (68.37±21.7 PDF m^3 day) considering the worst-case scenario (Figure 6). Atrazine showed the large number of ecotoxicity impact scores because it has been demonstrated to be highly toxic to aquatic organisms, mutagenicity and genotoxicity in aquatic animals (Solomon et al., 2008). Additionally, the European Union (EU) banned atrazine in Europe in 2004 due to widespread and unpreventable water contamination. Atrazine has been banned in Germany since 1991 because of excess contamination in groundwater (Sass & Colangelo, 2006; Vonberg et al., 2014).

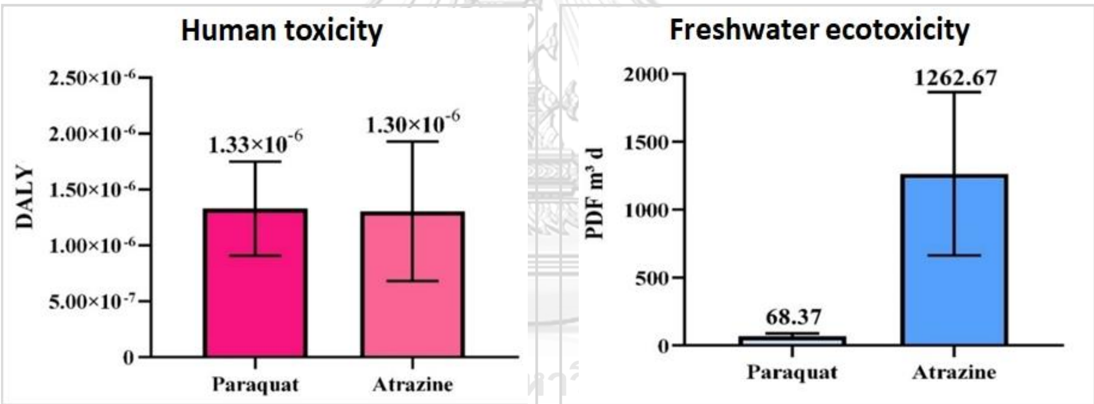

Figure 6 Comparisons of human health and ecotoxicity impact scores between the use of paraquat and atrazine in sweet corn cultivation.

The impact scores also depended on the amount of pesticide each farmer uses. Some farmers applied large amounts of paraquat but small amounts of atrazine. Some farmers applied small amount of paraquat but a large amount of atrazine. Impact scores for human toxicity were divided into two groups: i) the transition decreased human toxicity was 51.22% with the average impact scores of $1.37\times10^{-6}\pm 4.32\times10^{-7}$

DALY for paraquat and $8.89\times10^{-7}\pm2.84\times10^{-7}$ DALY for atrazine ii) the transition increased human toxicity was 48.78% with the average impact scores of $1.29\times10^{-6}\pm4.17\times10^{-7}$ DALY for paraquat and $1.74\times10^{-6}\pm5.79\times10^{-7}$ DALY for atrazine.

This study emphasized emissions to agricultural soil. According to the fate and transportation assumptions in the USEtox, the applied pesticide is remained agricultural soil or moved to other environmental compartments after application. For paraquat, the most effective mass was found in agricultural soil 99.86 percent, transferred to freshwater 0.12 percent and 0.01 percent were at other media. For atrazine emission, 83.31 percent of the mass remained in soil, 13.74 percent transferred to freshwater and 2.95 percent to other media. This proportion indicated that the likelihood of pesticides persisted or transferred in the environment after application. These data are derived from model calculations in relation to each pesticide's characteristics such as molecular mass, pKa, partitioning coefficient (Kow), partitioning coefficient between organic carbon and water (Koc), Henry's law constant, Vapor pressure, Solubility, etc. This study recommends an amount of residual pesticide in agricultural soil as the input of USEtox for more realistic estimation in a future study. The pesticide transportation calculated from the USEtox model may differ from the reality because the model considers the transportation of pesticides at steady state conditions. In fact, there are other factors affecting the pesticides transportation to various environmental media.

A comparison of mean values of human health and ecotoxicity impacts from paraquat and atrazine was tested using paired sample t-test. Differences were considered statistically significant level at 0.05. The result showed that the human health impact from paraquat and atrazine transition were not significantly different, while the ecotoxicity impact from paraquat to atrazine transition were significantly different.

Atrazine is one option recommended by the Department of Agriculture as alternatives to paraquat in sweet corn cultivation. This study indicated that the transition from paraquat to atrazine caused less pronounced health impact than ecotoxicity impact. The results of this study found that atrazine use had a markedly greater environmental impact than paraquat, raising questions about the change in pesticide use policies and the use of paraquat substitutes in sweet corn cultivation.

Nowadays, farmers are using atrazine to replace paraquat in sweet corn cultivation. Atrazine is used in combination with topramezone (herbicide) and besmor (additives). However, there are limitations of the USEtox model in terms of substance data (i.e., characteristics data and toxicological data). This study assessed the human and ecotoxicological impacts of atrazine only.

The USEtox model only considers ingestion (i.e., direct and indirect exposure) and inhalation exposure pathways. The model measures the total carcinogenic and non-carcinogenic effects of humans, in this study only considered non-carcinogenic impact to humans. This tool does not calculate the risk of specific illnesses associated with pesticides. The USEtox model estimates the effects of a single chemical at steady state and does not consider the interaction effect of many chemicals. In order to minimize both health and environmental impacts must be considered concurrent impacts. There is a likelihood of tradeoffs between health and ecotoxicity impact, as it may be difficult to achieve the risk reduction target for both impacts due to other factors such as the pesticide effectiveness and the cost of suitable pesticides to farmers.

4.5 Theory of planned behavior towards paraquat to atrazine transition

This question was constructed using Likert's scale (from 1 = strongly disagree to 5 = strongly agree) to assess different attitudes, subjective norms and perceived behavioral control. In a transition of paraquat to atrazine application, respondents showed a positive attitude towards both health and environmental impacts with both median values of 3.

The total median of subjective norms was 4. The respondents had a norm that the transition from paraquat to atrazine in sweet corn cultivation as recommended by family influences the decision to change pesticide use (median 4), followed by the recommendation from agricultural scholars (median 4), other farmers (median 4) and social media (median 3), respectively.

For perceived behavioral control, the total median was 4. The respondents believed that the atrazine is more readily available than paraquat (median 5) and the pesticide efficacy of atrazine was somewhat similar to that of paraquat (median 3) shown in Table 5.

Table 5 Descriptive data of attitudes, subjective norms and perceived behavioral control of the respondents (n=41)

TPB factors	**Scale Frequency (percentage)**					**Median**
	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	
Attitudes						
A1: Transitioning the pesticide from paraquat to atrazine has reduced sickness and diseases such as cancer.	5 (12.20%)	3 (7.32%)	13 (31.71%)	9 (21.95%)	11 (26.83%)	3

Table 5 Descriptive data of attitudes, subjective norms and perceived behavioral control of the respondents (n=41) (continued)

TPB factors	**Scale Frequency (percentage)**					**Median**
	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)	
A2: Transitioning the pesticide from paraquat to atrazine has reduced the danger to aquatic life.	4 (9.76%)	7 (17.07%)	13 (31.71%)	8 (19.51%)	9 (21.95%)	3
Subjective norms						
S1: Transitioning the pesticide from paraquat to atrazine by other farmers also influences the decision to change your pesticide use.	4 (9.76%)	5 (12.20%)	10 (24.39%)	13 (31.71%)	9 (21.95%)	4
S2: Transitioning the pesticide from paraquat to atrazine as recommended by your family also influences your decision to change your pesticide use.	4 (9.76%)	4 (9.76%)	7 (17.07%)	10 (24.39%)	16 (39.02%)	4
S3: Transitioning the pesticide from paraquat to atrazine as recommended by agricultural scholars also influences your decision to change your pesticide use.	3 (7.32%)	6 (14.63%)	9 (21.95%)	7 (17.07%)	16 (39.02%)	4
S4: Transitioning the pesticide from paraquat to atrazine from the media and social media influences your decision to change your pesticide use.	7 (17.07%)	2 (4.88%)	12 (29.27%)	8 (19.51%)	12 (29.27%)	3
Perceived behavioral control						
P1: Today, the pesticide atrazine is more readily available than paraquat.	0 (0%)	0 (0%)	1 (2.44%)	4 (9.76%)	36 (87.80%)	5
P2: The pesticide efficacy of atrazine was similar to that of paraquat.	5 (12.20%)	11 (26.83%)	18 (43.90%)	3 (7.32%)	4 (9.76%)	3

4.6 Willingness to pay and factors affecting willingness to pay

The second interview was conducted on 23 September 2021 with the same respondent group. In this interview, farmers' willingness to pay was the key question.

The health impacts of paraquat to atrazine transition calculated by the USEtox model were set as a scenario to ask willingness to pay for various measures to reduce the current health and freshwater ecotoxicity impacts separately.

An average value of 216.46±132.28 baht/year (max 500, min 20 baht/year) was farmers' WTP to reduce health impact from the current pesticide use, with the 87.80 percent (36 persons). Farmers who were willing to pay did not want the health effects to occur and they could afford the cost. For farmers who were not willing to pay, even if health problems arose, they perceived this issue beyond their responsibility for now. The latter group recognized that the legal pesticide is permitted from top-down policy. They will be willing to pay when the health effects are clearly visible.

The average WTP to reduce the ecotoxicity impact from the current pesticide use was 162.44±111.74 baht/year (max 300, min 10 baht/year), with the 85.37% (35 persons). Farmers who were willing to pay desired to maintain the ecosystem as the need for a shared responsibility because everyone is involved in the use of pesticides. The farmers who were not willing to pay argued that the impact on the ecotoxicity was not imminent and did not directly affect farmers. Some farmers claimed that it was not the responsibility of the farmers. Some farmers would like to have their split responsibility up to the amount of atrazine use and will be willing to pay only if the impact is apparent.

From data collection with questionnaires, the value of WTP to reduce human toxicity and freshwater ecotoxicity impacts per year was summarized in Tables 6 and Table 7.

Table 6 The range of willingness to pay to reduce human health impact

Value of willingness to pay (Baht/year)	Frequency	Percentage
0 - 99	7	17.1%
100 - 199	9	22.0%
200 – 299	11	26.8%
>299	14	34.1%
Total	41	100.0%

Note: Respondents who were not willing to pay accounted for 12.20%.

A study on the value of farmers' willingness to pay to reduce current health impact found that most respondents were willing to pay at a price of >299, followed by the WTP in the range of 200 - 299 baht. The respondents who were willing to pay in the range of 100 - 199 baht represented 22.0 percent, and 0 - 99 baht, represented 9.80 percent, respectively.

Consistent with other studies, Farmers in the central part of Shandong Province, China are willing to pay to reduce their health risks form pesticides use on average $65.38 (2204.84 baht (calculated from $1 = 33.72 baht)) per household per year (Wang et al., 2018). Farmers in Punjab province, Pakistan prioritizes pesticides as they are needed while they are aware of the health risks. 77% of farmers are willing to pay a fee of 20% of current pesticide costs to avoid pesticide health risks (Khan & Damalas, 2015). These demonstrate the appreciation of the health impacts of farmers.

Table 7 The range of willingness to pay to reduce freshwater ecotoxicity impact

Value of willingness to pay (Baht/year)	**Frequency**	**Percentage**
0 - 99	8	19.5%
100 - 199	16	39.0%
200 – 299	13	31.7%
>299	4	9.8%
Total	41	100.0%

Note: Respondents who were not willing to pay accounted for 14.63%.

For the study on the value of farmers' willingness to pay to reduce current freshwater ecotoxicity impact, it was found that most respondents were willing to pay at a price of 100 - 199, followed by the WTP in the range of 200 - 299 baht. The respondents who were willing to pay in the range of 0 - 99 baht represented 19.5 percent, and >299 baht represented 9.80 percent, respectively.

A study on farmers willingness to pay to improve water quality in Nestos watershed, Greece, with deterioration in part due to their pesticide use. 64.57% of farmers expressed zero responses, and the remainder were willing to pay between $12.49 - $23.89/ha/year (412.7 – 805.65 baht/ha/year (calculated from $1 = 33.72 baht)) (Lazaridou & Michailidis, 2020). A study on farmers' willingness to pay for eco-friendly agricultural waste management in which open burning of biomass is common practice after harvest, a major problem in Ethiopia. Farmers were willing to pay for $0.16 (5.40 Baht/ha/year (calculated from $1 = 33.72 baht)) (Atinkut et al., 2020). However, a comparison of willingness to pay with other studies can lead to biased conclusion because there may be different contexts and factors in different locations.

The health and environmental impacts are neither marketable nor measurable in monetary terms. This makes it difficult to interpret the extent of the damage. Assessing willingness to pay is an important way to reflect the value of a person's health and environment. In this study, farmers also value the environmental impact less than health, which is possible for farmers to focus on the direct impact they will have. Farmers in the area do not directly take advantage of the freshwater ecosystem as some farmers use tap water for watering. Freshwater resources may be an indirect use value that utilizes natural resources and the environment (Wilson & Carpenter, 1999), resulting in less emphasis and value on the environment.

Natural resources are considered a common properties regime whereby the community owns and manages the shared property (Lu, 2001). In some contexts, a lack of clarity on ownership of natural resources makes the idea of nurturing and preserving natural resources different for individuals. This may be another reason why willingness to pay for reducing environmental impact is less than reducing health impact. Public consciousness or public mind, refers to the feeling of belonging to the public in the rights and obligations of common care and maintenance. Intellectuals may play a role in educating and enhancing environmental understanding and awareness among farmers, be they academics or multidisciplinary scientists (Hsiao & Tseng, 1999).

To understand which factors affect WTP to reduce human toxicity and freshwater ecotoxicity impacts from 41 farmers, the ordinal logistic regression was used and tested at a significance level of 95%. The willingness to pay is classified into 4 groups: i) 0-99 baht, ii) 100-199 baht, iii) 200-299 baht and iv) >299 baht. Demographic and socio-economic data, including gender, age, household member, marital status, education level and monthly income, were analyzed for factors affecting willingness to pay to reduce health and ecotoxicity impacts, which were not found to be statistically significant.

The researcher further investigated TPB factors that affect WTP to reduce the human toxicity and freshwater ecotoxicity impacts. The willingness to pay is classified into 4 groups: i) 0-99 baht, ii) 100-199 baht, iii) 200-299 baht and iv) >299 baht. Once all TPB inputs were tested, the ordinal logit model did not find any factors to be statistically significance on WTP. This study therefore analyzed each group factor individually, including attitudes, subjective norms, and perceived behavioral control as explanatory variables. Respondents' WTP classes were the dependent variables. The variables and their levels used in the ordinal logit model were demonstrated in Table 8.

Table 8 The TPB variables used in the ordinal logistic regression to explain willingness to pay

Symbols	**Definitions**	**Levels description**
$WTP^{H,E}$	Willingness to pay	1 = WTP 0-99 Baht/year 2 = WTP 100-199 Baht/year 3 = WTP 200-299 Baht/year 4 = WTP >299 Baht/year
$A1^{H}$	Transitioning the pesticide from paraquat to atrazine has reduced sickness and diseases such as cancer.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)

Table 8 The TPB variables used in the ordinal logistic regression to explain willingness to pay (continued)

Symbols	Definitions	Levels description
$A2^{E}$	Transitioning the pesticide from paraquat to atrazine has reduced the danger to aquatic life.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)
$S1^{H,E}$	Transitioning the pesticide from paraquat to atrazine by other farmers also influences the decision to change your pesticide use.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)
$S2^{H,E}$	Transitioning the pesticide from paraquat to atrazine as recommended by your family also influences your decision to change your pesticide use.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)
$S3^{H,E}$	Transitioning the pesticide from paraquat to atrazine as recommended by agricultural scholars also influences your decision to change your pesticide use.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)
$S4^{H,E}$	Transitioning the pesticide from paraquat to atrazine from the media and social media influences your decision to change your pesticide use.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)
$P1^{H,E}$	On these days, the atrazine is more readily available than paraquat.	1 = Negative (score: 1-2) 2 = Neutral (score 3) 3 = Positive (score: 4-5)
$P2^{H,E}$	The pesticide efficacy of atrazine was similar to that of paraquat.	1 = Negative (score 1-2) 2 = Neutral (score 3) 3 = Positive (score 4-5)

H = Analyze with health impact; E = Analyze with ecotoxicity impact

The study found that TPB factors (attitudes, subjective norms and perceived behavioral control) had no statistically significant effect on willingness to pay to reduce health impact.

The partial analysis of TPB factors reflected its relevance to WTP in consideration of ecotoxicity impact reduction. Farmers with neutral subjective norms towards agricultural scholars in transitioning the pesticide from paraquat to atrazine were 0.128 times (*95*% CI=0.020-0.829, p = 0.031) less likely to be willing to pay to reduce ecotoxicity impact than farmers with positive subjective norms at a statistically significant 95% level (Table 9). Attitude and perceived behavioral control were not statistically significant. Our findings suggested that farmers with positive subjective norms were more likely to be willing to pay for freshwater ecosystems than farmers with moderate subjective norms. In addition, subjective norms are often linked to people's behaviors because they are defined as the social pressures a person perceives from people important to them to do or not do the behavior (Al Zubaidi, 2020). This study suggests that, in the future, if there are policies to change the use of pesticides, agricultural scholars are therefore important.

In the study area, there were agricultural scholars who publicly educated farmers about the type and appropriate amount of pesticide use in sweet corn cultivation. An annual training course was arranged to meet up and ensure farmers' understanding about the use of pesticides. Agricultural scholars will arrange a gathering of all farmers to provide knowledge by one-way communication once a year. However, due to the Covid-19 pandemic, the operation was halted for nearly three years, which was the matching period of paraquat ban and the atrazine substitution. This study suggested that agricultural academicians should be allocated to educate farmers, especially after paraquat was banned to determine the effectiveness of atrazine as a substitute for paraquat. In addition, access to agricultural scholars should be increased so that farmers can seek advice about the use of pesticides.

Table 9 Subjective norms estimated model derived by the ordinal logistic regression determining factors affecting willingness to pay to reduce ecotoxicity impact

Variables	Coefficient (β)	Sig.	Exp (β)	95% CI	
				Lower	Upper
S1 (Positive)					
S1 (Negative)	-0.643	0.706	0.526	0.019	14.774
S1 (Neutral)	-0.747	0.414	0.474	0.079	2.839
S2 (Positive)					
S2 (Negative)	2.032	0.127	7.631	0.561	103.800
S2 (Neutral)	-1.138	0.336	0.320	0.032	3.250
S3 (Positive)					
S3 (Negative)	-0.791	0.753	0.454	0.003	62.710
S3 (Neutral)	-2.057	0.031*	0.128	0.020	0.829
S4 (Positive)					
S4 (Negative)	0.012	0.995	1.012	0.020	51.742
S4 (Neutral)	-0.191	0.788	0.826	0.205	3.330
Likelihood Ratio Chi-Square		15.840	Sig.	0.045	

*$p < 0.05$

Other studies yield similar result on factors affecting willingness to pay, one study indicated that individuals with positive attitudes, a strong orientation towards biospheric and altruistic values with strong pro-environmental and subjective norms showed high visitors' willingness to pay for the conservation of a suburban park, Spain. The study suggested that a planning strategy should be implemented to bring additional environmental awareness among citizens (Lopez-Mosquera & Sanchez, 2012). The study assessed US residents' willingness to pay to restore degraded tropical rainforest watersheds using the theory of planned behavior (TPB) as a factor. The study found that the strongest factor predicting WTP was the subjective norm (Obeng et al., 2019).

However, there are studies that yield different results from this study. The study investigated the relationship between attitudes, subjective norms and perceived control behavior showed that attitudes and perceived behavioral control had significant influence on muzakki's willingness to pay his zakah (distributing wealth to the less fortunate Muslim) (Sapingi et al., 2011). Gender differences in an expanded model of the theory of planned behavior to explain the willingness to pay for the conservation of the Monfragüe national park, Spain was also assessed. The study shown that perceived behavioral control was the most significant predictors of visitors' willingness to pay (López-Mosquera, 2016).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study aimed to assess the human and ecotoxicological impacts, evaluate farmers willingness to pay to reduce human and ecotoxicological impacts and identify theory of plan behavior (TPB) factors affecting willingness to pay to reduce human and ecotoxicological impacts from transition of pesticide use in sweet corn cultivation. For health and ecotoxicity impacts assessment scenario, the active ingredient was sprayed within the corn farms and contaminated into agricultural soil. According to the toxicological assessment, paraquat showed slightly greater health effects than atrazine. ($1.33\times10^{-6}\pm4.21\times10^{-7}$ DALY for paraquat and $1.30\times10^{-6}\pm6.21\times10^{-7}$ DALY). Due to chemical properties, paraquat was highly soil-tolerant and less transfer to freshwater than atrazine. Farmers were more likely to be exposed to paraquat from agricultural soils. Long-term health effects from paraquat were not much different from atrazine. In contrast, atrazine showed a significantly greater ecotoxicity impact than paraquat when analyzed with paired sample t-test because the mass of atrazine was more likely to transfer to freshwater ecosystems (68.37±21.7 PDF m^3 day for paraquat and 1,262.67±600.83 PDF m^3 day for atrazine). The results of this study raise questions about the pesticide change policy, this change may cause unforeseen worse environmental impacts.

Our willingness to pay results indicated that the average WTP to reduce human and ecological toxicity from the current pesticide use was 216.46±132.28 baht/year and 162.44±111.74 baht/year, respectively. From the monetary perspective, farmers valued health 1.3 times over ecotoxicity impacts, although the transition from paraquat to atrazine has obvious environmental impacts. The study suggested that ecotoxicity impact should not be ignored.

A study of TPB factors affecting willingness to pay found that there was no TPB factors affecting willingness to pay to reduce health impacts. On the other hand, farmers with neutral subjective norms to agricultural scholars were 0.13 times less likely to be willing to pay to reduce ecotoxicity impact than farmers with positive subjective norms at a significant level $p<0.05$. The findings also showed that the recommendations of agricultural scholars influenced farmers' decisions to change pesticide use more than other others. Therefore, by applying a policy on the use of pesticides in sweet corn cultivation, agricultural scholars tend to create direct impact to understanding and actions among farmers.

This study bridges the toxicological data with economic tools to create understanding and participation at the local level. The health and ecotoxicity impact assessment data obtained from this study helps policy makers understand pesticide behavior to use in determining pesticide change policy decisions. Valuing farmers' impact, reflecting the implementation of current pesticide management policies in terms of health and the environment. The study of TPB factors affecting farmers' willingness to pay indicates attitudes, subjective norms and perceived behavioral controls that influence farmers' decision-making that are beneficial to policy planning on the use of pesticides for sweet corn cultivation in Thailand.

5.2 Limitations

This study was conducted to collect data during the period after Thailand announced the ban on paraquat 2 years. Some farmers have adjusted and chosen to use pesticides to replace paraquat and since the first wave of COVID-19 outbreak. Due to the unusual situation, the number of sweet corn allocation quotas has been changed. Some farmers received less quota for planting. The atrazine was not used by some farmers, resulted in relatively small sample sizes in this study.

There are some limitations for the USEtox model. The model takes into account two exposure pathway, ingestion and inhalation only. The model cannot indicate specific illnesses associated with pesticides. USEtox model estimates the effects of a single chemical at steady state to determine the impacts and does not consider the interaction effect of multiple chemicals.

5.3 Recommendations

Despite the limitations, a study should be carried out after Thailand bans paraquat at another time, for more clarity. There may be an increase in the use of the pesticide atrazine, resulting in an increase in the number of samples in the study. In addition, atrazine is one of the pesticides the Department of Agriculture recommends as a substitute for paraquat in sweet corn cultivation, which in the future may consider another substitute that should be assessed for health and ecotoxicity impacts. Moreover, a comparison of the effects of various pesticides used as substitutes for paraquat should be studied for efficiency in planning pesticide use policies that are consistent with sweet corn farmers in the area in the future.

In term of pesticide usage, farmer should limit their pesticide application to the recommended amount on the pesticide package or the guideline of the Department of Agriculture. This would help farmer save cost on pest or weed controls and also reduce adverse health and environmental consequences as well. In addition, it appeared that most farmers are willing to pay to cover the adverse outcomes from their pesticide applications. So, this implies that future relevant policies tend to receive positive cooperation from farmers if implemented properly.

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Appendix A

แบบสอบถามชุดที่ 1

เรื่อง การประเมินการใช้สารเคมีกำจัดศัตรูพืช

<u>คำชี้แจง</u>

แบบสอบถามนี้เป็นส่วนหนึ่งของการจัดทำวิทยานิพนธ์หลักสูตรวิทยาศาสตร์มหาบัณฑิต คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เพื่อประเมินผลกระทบจากสารเคมีกำจัดศัตรูพืชสำหรับการปลูกข้าวโพดหวานที่อาจส่งผลกระทบต่อมนุษย์และสิ่งแวดล้อม พร้อมกับศึกษาความเต็มใจจ่ายและปัจจัยที่ส่งผลต่อความเต็มใจจ่ายเพื่อลดผลกระทบที่คาดว่าจะเกิดขึ้นต่อสุขภาพและสิ่งแวดล้อม คำตอบที่เป็นจริงของท่านจะเป็นประโยชน์โดยการนำผลการวิจัยมาเป็นข้อมูลในการวางแผน ดำเนินการป้องกันและแก้ไขปัญหา ผลกระทบต่อการใช้สารกำจัดศัตรูพืชต่อสุขภาพมนุษย์และสิ่งแวดล้อมในอำเภอปากช่อง จังหวัดนครราชสีมา, อำเภอมวกเหล็ก จังหวัดสระบุรี และอำเภอลำสนธิ จังหวัดลพบุรีต่อไป

ผู้วิจัยจึงใคร่ขอความร่วมมือจากท่านในการตอบแบบสอบถามให้ครบทุกข้อตามความเป็นจริง คำตอบของท่านไม่มีคำตอบใดที่ผิดหรือถูก ข้อมูลและคำตอบของท่านทุกข้อจะถูกเก็บเป็นความลับ

กรุณาตอบคำถามโดยใส่เครื่องหมาย ✔ ลงในช่องว่างที่ตรงกับคำตอบของท่านและเติมคำลงในช่องว่าง

ส่วนที่ 1 ข้อมูลทั่วไป

1. เพศ

☐ 1. ชาย ☐ 2. หญิง

2. อายุ..ปี

3. สถานภาพ

☐ 1. โสด ☐ 2. สมรส/อยู่ด้วยกัน ☐ 3. หย่า/แยกกันอยู่

4. รายได้เฉลี่ยต่อเดือนของครัวเรือน..บาท/เดือน

5. ระดับการศึกษาสูงสุด

☐ 1. ไม่ได้รับการศึกษา ☐ 2. ต่ำกว่าประถมศึกษา

☐ 3. ประถมศึกษา ☐ 4. มัธยมศึกษาตอนต้น

☐ 5. มัธยมศึกษาตอนปลาย/ปวช. ☐ 6. อนุปริญญา/ปวส.

☐ 7. ปริญญาตรี ☐ 8. สูงกว่าปริญญาตรี

6. ในครอบครัวของท่านมีจำนวน...คน

ส่วนที่ 2 การปลูกข้าวโพดหวาน

1. ท่านมีพื้นที่ในการเพาะปลูกข้าวโพดหวานจำนวน................................ไร่.............................งาน

2. ในรอบปี ท่านปลูกข้าวโพดหวานได้จำนวน..ครั้ง

3. ผลผลิตข้าวโพดหวานที่เก็บเกี่ยวได้โดยประมาณ ....ตัน/ครั้ง

ส่วนที่ 3 การใช้สารเคมีกำจัดศัตรูพืช

1. ระยะเวลาที่ท่านร่วมกลุ่มเกษตรกรผู้ปลูกข้าวโพดหวานที่ศูนย์วิจัยข้าวโพดข้างฟ่างแห่งประเทศไทย (ไร่สุวรรณ)

☐ 1. น้อยกว่า 3 ปี ☐ 2. 3 - 5 ปี

☐ 3. 5 - 10 ปี ☐ 4. มากกว่า 10 ปี

2. **ปัจจุบัน**ท่านได้ใช้สารกำจัดวัชพืชอะทราซีน (Atrazine) ในการปลูกข้าวโพดหวานหรือไม่?

☐ 1. ใช้ ปริมาณการใช้.../กิโลกรัม/ไร่/ปี

เหตุผลที่ใช้...

☐ 2. ไม่ใช้ (ถ้าไม่ใช้ข้ามไปข้อ 6)

เหตุผลที่ไม่ใช้...

3. ระยะเวลาที่ใช้สารกำจัดวัชพืชอะทราซีน (Atrazine)

☐ 1. ใช้น้อยกว่า 1 ปี ☐ 2. ใช้ 1 - 3 ปี

☐ 3. ใช้ 3 - 5 ปี ☐ 4. ใช้มากกว่า 5 ปี

4. ท่านซื้อสารกำจัดวัชพืชอะทราซีน (Atrazine) 1 ถุง ขนาด.............กิโลกรัม ในราคา.............บาท

5. ในการปลูกข้าวโพดหวาน 1 ไร่ ท่านต้องใช้สารกำจัดวัชพืชอะทราซีน (Atrazine) จำนวน ....ถุง

6. **ก่อนหน้านี้**ท่านเคยใช้สารกำจัดวัชพืช พาราควอต (Paraquat) ในการปลูกข้าวโพดหวานหรือไม่?

☐ 1. เคยใช้ ปริมาณการใช้../กิโลกรัม/ไร่/ปี

☐ 2. ไม่เคยใช้

7. ระยะเวลาที่ใช้สารกำจัดวัชพืชพาราควอต (Paraquat)

☐ 1. ใช้น้อยกว่า 1 ปี ☐ 2. ใช้ 1 - 3 ปี

☐ 3. ใช้ 3 - 5 ปี ☐ 4. ใช้มากกว่า 5 ปี

8. ท่านเคยซื้อสารกำจัดวัชพืชพาราควอต (Paraquat) 1 ขวด ขนาด..............................ลิตร ในราคา..บาท

9. ในการปลูกข้าวโพดหวาน 1 ไร่ ท่านต้องใช้สารกำจัดวัชพืชพาราควอต (Paraquat) จำนวน ....ขวด

ส่วนที่ 4 ผลกระทบจากการใช้สารกำจัดศัตรูพืช

1. ท่านและคนในครอบครัวของท่านเคยมีอาการผิดปกติหรือเจ็บป่วยจากการใช้สารกำจัดศัตรูพืชหรือไม่

☐ 1. เคยมีอาการผิดปกติ (กรุณาตอบคำถามข้อ 2.) ☐ 2. ไม่เคยมีอาการผิดปกติ

2. อาการผิดปกติหรือเจ็บป่วยใดบ้างที่เคยเกิดขึ้นกับท่านหรือคนในครอบครัวของท่าน (ตอบได้มากกว่า 1 ข้อ)

กลุ่มอาการความเป็นพิษเฉียบพลัน			**กลุ่มอาการความเป็นพิษกึ่งเรื้อรัง**		**กลุ่มอาการความเป็นพิษเรื้อรัง**
☐ ไอ ☐ แสบจมูก ☐ คอแห้ง/เจ็บคอ ☐ หายใจติดขัด ☐ เวียนศีรษะ/ปวดศีรษะ	☐ คันผิวหนัง/ผิวแห้ง/ผิวแตก ☐ ผื่นคันที่ผิวหนัง/ตุ่มพุพอง ☐ ปวดแสบร้อน ☐ ตาแดง/ระคายเคืองตา	☐ อ่อนเพลีย ☐ อาการชา ☐ ใจสั่น ☐ น้ำตาไหล ☐ น้ำมูกไหล	☐ หนังตากระตุก ☐ ตาพร่ามัว ☐ เจ็บ/แน่นหน้าอก ☐ คลื่นไส้/อาเจียน ☐ ปวดท้อง	☐ ท้องเสีย ☐ กล้ามเนื้ออ่อนล้า ☐ มือสั่น ☐ เดินโซเซ	☐ หายใจติดขัด ☐ ลมชัก ☐ หมดสติ ☐ ไม่รู้สึกตัว

☐ อาการอื่น ๆ (โปรดระบุ)...

ส่วนที่ 5 ทัศนคติ การคล้อยตามกลุ่มอ้างอิงและการรับรู้ความสามารถในการควบคุมพฤติกรรมจากการใช้สารกำจัดศัตรูพืช

หมวดหมู่/คำถาม	**ความคิดเห็น**				
	เห็นด้วยอย่างยิ่ง (5)	**เห็นด้วย (4)**	**ไม่แน่ใจ (3)**	**ไม่เห็นด้วย (2)**	**ไม่เห็นด้วยอย่างยิ่ง (1)**
ทัศนคติ (Attitude)					
1. การเปลี่ยนสารกำจัดศัตรูพืชที่ท่านใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) ทำให้เกิดความเจ็บป่วยและเกิดโรคต่างๆ เช่น มะเร็ง**ลดลง**					
2. การเปลี่ยนสารกำจัดศัตรูพืชที่ท่านใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) ทำให้เกิดความอันตรายต่อสัตว์น้ำ**ลดลง**					
การคล้อยตามกลุ่มอ้างอิง (Subjective norm)					
1. การเปลี่ยนสารกำจัดศัตรูพืชที่ใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) ของ**เกษตรกรคนอื่นๆ** ส่งผลต่อการตัดสินใจในการเปลี่ยนการใช้สารกำจัดศัตรูพืชของท่านด้วย					
2. การเปลี่ยนสารกำจัดศัตรูพืชที่ใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) ตามคำแนะนำของ**คนในครอบครัว** ส่งผลต่อการตัดสินใจในการเปลี่ยนการใช้สารกำจัดศัตรูพืชของท่านด้วย					
3. การเปลี่ยนสารกำจัดศัตรูพืชที่ใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) ตามคำแนะนำของ**นักวิชาการเกษตร** ส่งผลต่อการตัดสินใจในการเปลี่ยนการใช้สารกำจัดศัตรูพืชของท่านด้วย					
4. การเปลี่ยนสารกำจัดศัตรูพืชที่ใช้จากเดิมพาราควอต (Paraquat) เป็นอะทราซีน (Atrazine) จาก**สื่อและกระแสสังคม** ส่งผลต่อการตัดสินใจในการเปลี่ยนการใช้สารกำจัดศัตรูพืชของท่านด้วย					
การรับรู้ความสามารถในการควบคุมพฤติกรรม (Perceived behavioral control)					
1. ในปัจจุบันท่านสามารถหาซื้อสารกำจัดศัตรูพืชอะทราซีน (Atrazine) ได้อย่าง**สะดวกมากกว่า**พาราควอต (Paraquat)					
2. ประสิทธิภาพในการกำจัดศัตรูพืชของอะทราซีน (Atrazine) **ให้ผลลัพธ์พอๆ กับ**พาราควอต (Paraquat)					

*** ขอบคุณทุกท่านที่สละเวลาในการตอบแบบสอบถามนี้ ***

แบบสอบถามชุดที่ 2
เรื่อง ความเต็มใจจ่ายเพื่อลดผลกระทบที่คาดว่าจะเกิดขึ้นต่อสุขภาพและสิ่งแวดล้อม

คำชี้แจง

แบบสอบถามนี้เป็นส่วนหนึ่งของการจัดทำวิทยานิพนธ์หลักสูตรวิทยาศาสตร์มหาบัณฑิต คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เพื่อประเมินผลกระทบจากสารเคมีกำจัดศัตรูพืชสำหรับการปลูกข้าวโพดหวานที่อาจส่งผลกระทบต่อมนุษย์และสิ่งแวดล้อม พร้อมกับศึกษาความเต็มใจจ่ายและปัจจัยที่ส่งผลต่อความเต็มใจจ่ายเพื่อลดผลกระทบที่คาดว่าจะเกิดขึ้นต่อสุขภาพและสิ่งแวดล้อม คำตอบที่เป็นจริงของท่านจะเป็นประโยชน์โดยการนำผลการวิจัยมาเป็นข้อมูลในการวางแผน ดำเนินการป้องกันและแก้ไขปัญหาผลกระทบต่อการใช้สารกำจัดศัตรูพืชต่อสุขภาพมนุษย์และสิ่งแวดล้อมในอำเภอปากช่อง จังหวัดนครราชสีมา, อำเภอมวกเหล็ก จังหวัดสระบุรีและอำเภอลำสนธิ จังหวัดลพบุรีต่อไป

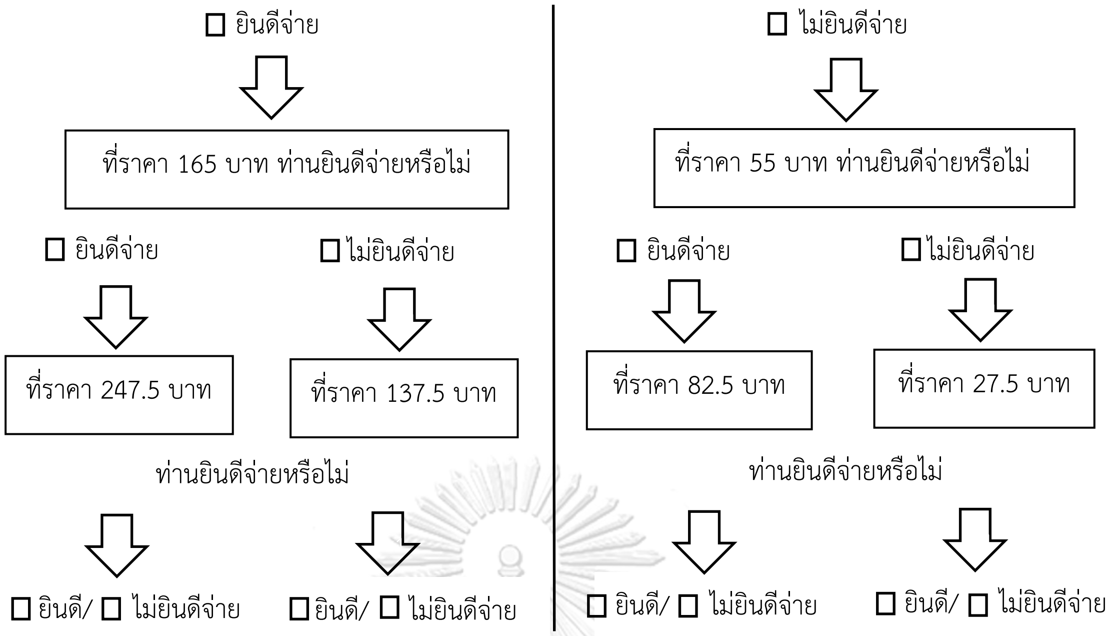
ผู้วิจัยจึงใคร่ขอความร่วมมือจากท่านในการตอบแบบสอบถามให้ครบทุกข้อตามความเป็นจริง คำตอบของท่านไม่มีคำตอบใดที่ผิดหรือถูก ข้อมูลและคำตอบของท่านทุกข้อจะถูกเก็บเป็นความลับ
กรุณาตอบคำถามโดยใส่เครื่องหมาย ✔ ลงในช่องว่างที่ตรงกับคำตอบของท่าน

ส่วนที่ 1 ความเต็มใจจ่ายเพื่อลดผลกระทบต่อสุขภาพ

สารกำจัดศัตรูพืชเป็นสารเคมีที่มีผลกระทบต่อสุขภาพทั้งในระยะสั้นและระยะยาว นอกจากผลกระทบทางด้านสุขภาพแล้วยังทำให้ต้องเสียค่าใช้จ่ายในการรักษาพยาบาล เสียโอกาสในการทำงาน ไม่สามารถดำเนินกิจวัตรประจำวันได้อย่างปกติ เป็นต้น

หากงานวิจัยสรุปว่า ในการปลูกข้าวโพดหวาน ท่านเคยใช้สารกำจัดศัตรูพืชพาราควอต (Paraquat) ที่ปริมาณการใช้............................กิโลกรัม/ไร่/ปี และได้เปลี่ยนชนิดของสารกำจัดศัตรูพืชที่ใช้เป็นอะทราซีน (Atrazine) ที่ปริมาณการใช้.............................กิโลกรัม/ไร่/ปี จะทำให้มีโอกาสเกิด ความบกพร่องทางสุขภาพหรือเกิดความเจ็บป่วย เช่น ปวดศีรษะ คลื่นไส้ ปวดท้อง แน่นหน้าอก ปวดแสบร้อนจากแผลพุพอง ฯลฯ จากเดิม......................วินาที/วัน เป็น.........................วินาที/วัน

ท่านมีความยินดีจ่ายเป็นจำนวนเงิน **110 บาท/ปี** ให้กับศูนย์วิจัยข้าวโพดข้าวฟ่างแห่งชาติในการสนับสนุนมาตรการต่างๆ เพื่อลดผลกระทบต่อสุขภาพหรือไม่



ความเต็มใจจ่ายสูงสุดของท่านคือ..บาท/ปี

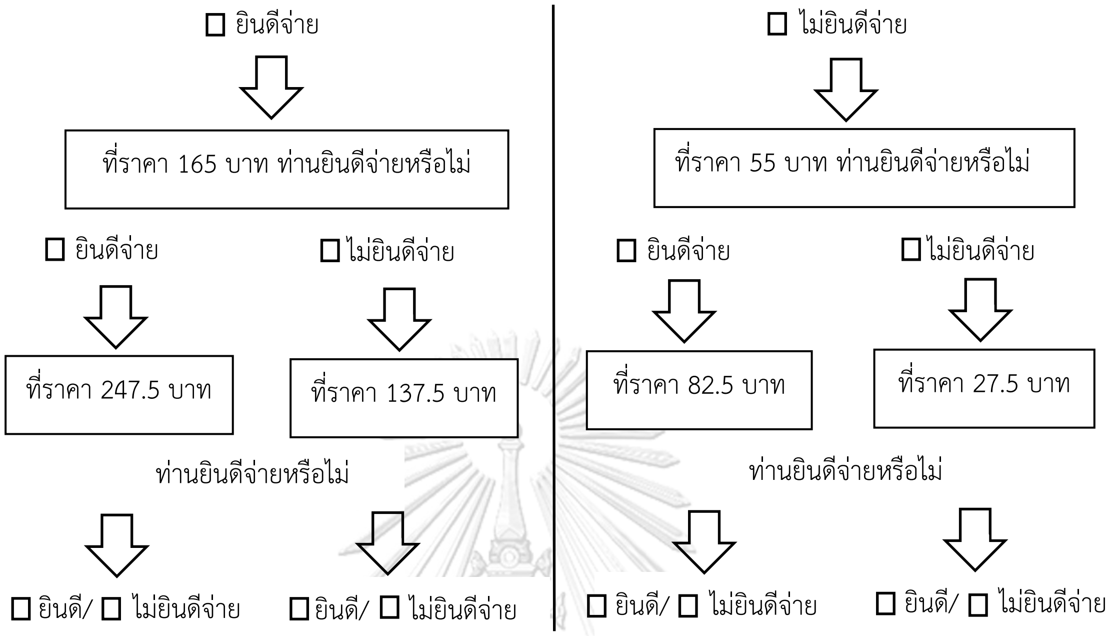
เหตุผลที่ท่านยินดีจ่ายในราคาดังกล่าว..

ส่วนที่ 2 ความเต็มใจจ่ายเพื่อลดผลกระทบต่อระบบนิเวศในน้ำ

แหล่งน้ำจืดตามธรรมชาติ เช่น คลอง แม่น้ำ เป็นที่อยู่ของสิ่งมีชีวิตไม่ว่าจะเป็นสัตว์หน้าดิน ไรน้ำ แพลงก์-ตอน ปลา ฯลฯ การเปลี่ยนแปลงของสภาพแหล่งน้ำอันเป็นผลจากสารเคมีที่ถูกปลดปล่อยลงสู่แหล่งน้ำทั้งที่ตั้งใจและไม่ได้ตั้งใจ อาจทำให้เกิดผลกระทบต่อห่วงโซ่อาหาร เช่น ไรแดงที่เป็นอาหารของปลามีจำนวนลดลง ส่งผลให้จำนวนปลาลดลงตามไปด้วย ข้อมูลข้างต้นสามารถนำมาใช้วัดผลกระทบที่เกิดขึ้นจากการใช้สารเคมีกำจัดศัตรูพืชได้

หากงานวิจัยสรุปว่า จากเดิมที่ท่านใช้พาราควอต (Paraquat) ในการปลูกข้าวโพดหวานที่ปริมาณ ....กิโลกรัม/ไร่/ปี และได้เปลี่ยนชนิดของสารกำจัดศัตรูพืชเป็นอะทราซีน (Atrazine) ปริมาณ ....กิโลกรัม/ไร่/ปี ได้ส่งผลกระทบต่อระบบนิเวศในน้ำ**มากขึ้น** ทำให้เกิดการเปลี่ยนแปลงของห่วงโซ่อาหาร จากเดิมมีผลทำให้ปริมาตรน้ำ..................................ลูกบาศก์เมตรสูญเสียสิ่งมีชีวิตทั้งหมดใน 1 วัน จากการเปลี่ยนแปลงการใช้สารกำจัดศัตรูพืชทำให้ผลกระทบเพิ่มขึ้น โดยทำให้ปริมาตรน้ำ.......................................ลูกบาศก์-เมตรสูญเสียสิ่งมีชีวิตทั้งหมดใน 1 วัน

ท่านมีความยินดีที่จะจ่ายเป็นจำนวนเงิน **110 บาท/ปี** ให้กับศูนย์วิจัยข้าวโพดข้าวฟ่างแห่งชาติในการในการใช้มาตรการต่างๆเพื่อลดผลกระทบต่อระบบนิเวศในแหล่งน้ำหรือไม่



ความเต็มใจจ่ายสูงสุดของท่านคือ..บาท/ปี

เหตุผลที่ท่านยินดีจ่ายในราคาดังกล่าว..

*** ขอบคุณทุกท่านที่สละเวลาในการตอบแบบสอบถามนี้ ***

Appendix B

A comparison of mean values of human health and ecotoxicity impacts using paired sample t-test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	HealthP	.000001328	41	.0000004213	.0000000658
	HealthA	.000001304	41	.0000006206	.0000000969
Pair 2	EcoP	68.3665	41	21.69344	3.38795
	EcoA	1262.6648	41	600.82886	93.83370

Paired Samples Correlations

		N	Correlation	Significance	
				One-Sided p	Two-Sided p
Pair 1	HealthP & HealthA	41	.430	.002	.005
Pair 2	EcoP & EcoA	41	.430	.002	.005

Paired Samples Test

		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	HealthP - HealthA	.0000000233	.0000005811	.0000000908	-.0000001601	.0000002067	.257	40	.399	.799
Pair 2	EcoP - EcoA	-1194.29836	591.82068	92.42686	-1381.10001	-1007.49670	-12.922	40	<.001	<.001

Paired Samples Effect Sizes

			Standardizer[a]	Point Estimate	95% Confidence Interval Lower	Upper
Pair 1	HealthP - HealthA	Cohen's d	.0000005811	.040	-.266	.346
		Hedges' correction	.0000005866	.040	-.264	.343
Pair 2	EcoP - EcoA	Cohen's d	591.82068	-2.018	-2.550	-1.477
		Hedges' correction	597.44220	-1.999	-2.526	-1.463

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation of the mean difference.

Hedges' correction uses the sample standard deviation of the mean difference, plus a correction factor.

Ordinal logit model estimation results

1) Attitudes and willingness to pay to reduce health impact

Categorical Variable Information

			N	Percent
Dependent Variable	WTPHN	0-99	7	17.1%
		100-199	9	22.0%
		200-299	11	26.8%
		>299	14	34.1%
		Total	41	100.0%
Factor	A1	Negative 1-2	8	19.5%
		Neutral 3	13	31.7%
		Positive 4-5	20	48.8%
		Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	2.173	4	.543
Scaled Deviance	2.173	4	
Pearson Chi-Square	2.123	4	.531
Scaled Pearson Chi-Square	2.123	4	
Log Likelihood[b]	-12.446		
Akaike's Information Criterion (AIC)	34.893		

Finite Sample Corrected AIC (AICC)	36.607		
Bayesian Information Criterion (BIC)	43.461		
Consistent AIC (CAIC)	48.461		

Dependent Variable: WTPHN

Model: (Threshold), A1

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
.404	2	.817

Dependent Variable: WTPHN

Model: (Threshold), A1

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

Source	Type III Wald Chi-Square	df	Sig.
A1	.402	2	.818

Dependent Variable: WTPHN

Model: (Threshold), A1

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval Lower	Upper	Hypothesis Test Wald Chi-Square	df	Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	Upper
Threshold	[WTPHN=1]	-1.537	.4977	-2.513	-.562	9.537	1	.002	.215	.081	.570
	[WTPHN=2]	-.397	.4297	-1.239	.446	.852	1	.356	.673	.290	1.561
	[WTPHN=3]	.715	.4461	-.160	1.589	2.567	1	.109	2.044	.853	4.899
[A1=1]		-.201	.7496	-1.670	1.268	.072	1	.789	.818	.188	3.555
[A1=2]		.291	.6464	-.976	1.558	.203	1	.652	1.338	.377	4.750
[A1=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPHN

Model: (Threshold), A1

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

2) Subjective norms and willingness to pay to reduce health impact

Categorical Variable Information

			N	Percent
Dependent Variable	WTPHN	0-99	7	17.1%
		100-199	9	22.0%
		200-299	11	26.8%
		>299	14	34.1%
		Total	41	100.0%
Factor	S1	Negative 1-2	9	22.0%
		Neutral 3	10	24.4%
		Positive 4-5	22	53.7%
		Total	41	100.0%
	S2	Negative 1-2	8	19.5%
		Neutral 3	7	17.1%
		Positive 4-5	26	63.4%
		Total	41	100.0%
	S3	Negative 1-2	9	22.0%
		Neutral 3	9	22.0%
		Positive 4-5	23	56.1%
		Total	41	100.0%

S4	Negative 1-2	9	22.0%
	Neutral 3	12	29.3%
	Positive 4-5	20	48.8%
	Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	35.294	34	1.038
Scaled Deviance	35.294	34	
Pearson Chi-Square	30.169	34	.887
Scaled Pearson Chi-Square	30.169	34	
Log Likelihood[b]	-28.540		
Akaike's Information Criterion (AIC)	79.081		
Finite Sample Corrected AIC (AICC)	88.184		
Bayesian Information Criterion (BIC)	97.930		
Consistent AIC (CAIC)	108.930		

Dependent Variable: WTPHN

Model: (Threshold), S1, S2, S3, S4

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
9.104	8	.334

Dependent Variable: WTPHN

Model: (Threshold), S1, S2, S3, S4

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

Source		Type III	
	Wald Chi-Square	df	Sig.
S1	1.102	2	.576
S2	5.109	2	.078
S3	.583	2	.747
S4	.706	2	.703

Dependent Variable: WTPHN

Model: (Threshold), S1, S2, S3, S4

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[WTPHN=1]	-2.238	.6487	-3.510	-.967	11.902	1	<.001	.107	.030	.380
	[WTPHN=2]	-.832	.5243	-1.860	.195	2.519	1	.112	.435	.156	1.216
	[WTPHN=3]	.474	.4881	-.483	1.430	.941	1	.332	1.606	.617	4.180
[S1=1]		-1.561	1.5928	-4.682	1.561	.960	1	.327	.210	.009	4.764
[S1=2]		-.521	.8349	-2.157	1.115	.390	1	.533	.594	.116	3.050
[S1=3]		0[a]	.	.	.	.	.	.	1	.	.
[S2=1]		1.665	1.2287	-.743	4.074	1.837	1	.175	5.287	.476	58.763
[S2=2]		-1.420	.9773	-3.335	.496	2.111	1	.146	.242	.036	1.642
[S2=3]		0[a]	.	.	.	.	.	.	1	.	.
[S3=1]		-1.053	2.2556	-5.474	3.368	.218	1	.641	.349	.004	29.016
[S3=2]		-.504	.7941	-2.060	1.052	.403	1	.526	.604	.127	2.864
[S3=3]		0[a]	.	.	.	.	.	.	1	.	.
[S4=1]		1.377	1.7953	-2.142	4.896	.588	1	.443	3.964	.117	133.747
[S4=2]		.385	.7066	-1.000	1.770	.296	1	.586	1.469	.368	5.868
[S4=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPHN

Model: (Threshold), S1, S2, S3, S4

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

3) Perceived behavioral control and willingness to pay to reduce health impact

Categorical Variable Information

			N	Percent
Dependent Variable	WTPHN	0-99	7	17.1%
		100-199	9	22.0%
		200-299	11	26.8%
		>299	14	34.1%
		Total	41	100.0%
Factor	P1	Neutral 3	1	2.4%
		Positive 4-5	40	97.6%
		Total	41	100.0%
	P2	Negative 1-2	16	39.0%
		Neutral 3	18	43.9%
		Positive 4-5	7	17.1%
		Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	6.038	6	1.006
Scaled Deviance	6.038	6	
Pearson Chi-Square	6.084	6	1.014
Scaled Pearson Chi-Square	6.084	6	
Log Likelihood[b]	-14.217		
Akaike's Information Criterion (AIC)	40.434		
Finite Sample Corrected AIC (AICC)	42.905		
Bayesian Information Criterion (BIC)	50.715		
Consistent AIC (CAIC)	56.715		

Dependent Variable: WTPHN

Model: (Threshold), P1, P2

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
.384	3	.944

Dependent Variable: WTPHN

Model: (Threshold), P1, P2

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
P1	.009	1	.925
P2	.377	2	.828

Dependent Variable: WTPHN

Model: (Threshold), P1, P2

Parameter Estimates

				95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter		B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.	Exp(B)	Lower	Upper
Threshold	[WTPHN=1]	-1.258	.7517	-2.731	.215	2.801	1	.094	.284	.065	1.240
	[WTPHN=2]	-.114	.7148	-1.515	1.286	.026	1	.873	.892	.220	3.620
	[WTPHN=3]	.997	.7256	-.425	2.419	1.888	1	.169	2.710	.654	11.237
[P1=2]		.145	1.5342	-2.862	3.152	.009	1	.925	1.156	.057	23.384
[P1=3]		0[a]	.	.	.	.	.	.	1	.	.
[P2=1]		.507	.8361	-1.132	2.145	.367	1	.545	1.660	.322	8.544
[P2=2]		.296	.8222	-1.315	1.908	.130	1	.719	1.345	.268	6.737
[P2=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPHN

Model: (Threshold), P1, P2

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

4) Attitudes and willingness to pay to reduce ecotoxicity impact.

Categorical Variable Information

			N	Percent
Dependent Variable	WTPEN	0-99	8	19.5%
		100-199	16	39.0%
		200-299	13	31.7%
		>299	4	9.8%
		Total	41	100.0%
Factor	A2	Negative 1-2	11	26.8%
		Neutral 3	13	31.7%
		Positive 4-5	17	41.5%
		Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	.257	4	.064
Scaled Deviance	.257	4	
Pearson Chi-Square	.257	4	.064
Scaled Pearson Chi-Square	.257	4	
Log Likelihood[b]	-11.308		
Akaike's Information Criterion (AIC)	32.616		
Finite Sample Corrected AIC (AICC)	34.331		
Bayesian Information Criterion (BIC)	41.184		
Consistent AIC (CAIC)	46.184		

Dependent Variable: WTPEN

Model: (Threshold), A2

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
.715	2	.699

Dependent Variable: WTPEN

Model: (Threshold), A2

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

Source	Wald Chi-Square	Type III df	Sig.
A2	.710	2	.701

Dependent Variable: WTPEN

Model: (Threshold), A2

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
Threshold	[WTPEN=1]	-1.638	.5400	-2.696	-.580	9.201	1	.002	.194	.067	.560
	[WTPEN=2]	.149	.4653	-.763	1.061	.103	1	.748	1.161	.466	2.891
	[WTPEN=3]	2.050	.6153	.844	3.256	11.102	1	<.001	7.769	2.326	25.950
[A2=1]		-.089	.7082	-1.477	1.299	.016	1	.900	.915	.228	3.665
[A2=2]		-.549	.6779	-1.878	.780	.656	1	.418	.578	.153	2.181
[A2=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPEN

Model: (Threshold), A2

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

5) Subjective norms and willingness to pay to reduce ecotoxicity impact.

Categorical Variable Information

			N	Percent
Dependent Variable	WTPEN	0-99	8	19.5%
		100-199	16	39.0%
		200-299	13	31.7%
		>299	4	9.8%
		Total	41	100.0%
Factor	S1	Negative 1-2	9	22.0%
		Neutral 3	10	24.4%
		Positive 4-5	22	53.7%
		Total	41	100.0%
	S2	Negative 1-2	8	19.5%
		Neutral 3	7	17.1%
		Positive 4-5	26	63.4%
		Total	41	100.0%
	S3	Negative 1-2	9	22.0%
		Neutral 3	9	22.0%
		Positive 4-5	23	56.1%
		Total	41	100.0%
	S4	Negative 1-2	9	22.0%
		Neutral 3	12	29.3%
		Positive 4-5	20	48.8%
		Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	28.311	34	.833
Scaled Deviance	28.311	34	
Pearson Chi-Square	28.627	34	.842
Scaled Pearson Chi-Square	28.627	34	
Log Likelihood[b]	-23.575		
Akaike's Information Criterion (AIC)	69.149		
Finite Sample Corrected AIC (AICC)	78.252		

Bayesian Information Criterion (BIC)	87.998		
Consistent AIC (CAIC)	98.998		

Dependent Variable: WTPEN

Model: (Threshold), S1, S2, S3, S4

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
15.840	8	.045

Dependent Variable: WTPEN

Model: (Threshold), S1, S2, S3, S4

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

	Type III		
Source	Wald Chi-Square	df	Sig.
S1	.695	2	.706
S2	4.289	2	.117
S3	4.693	2	.096
S4	.077	2	.962

Dependent Variable: WTPEN

Model: (Threshold), S1, S2, S3, S4

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval Lower	95% Wald Confidence Interval Upper	Hypothesis Test Wald Chi-Square	Hypothesis Test df	Hypothesis Test Sig.	Exp(B)	95% Wald Confidence Interval for Exp(B) Lower	95% Wald Confidence Interval for Exp(B) Upper
Threshold	[WTPEN=1]	-2.629	.7178	-4.036	-1.222	13.416	1	<.001	.072	.018	.295
	[WTPEN=2]	-.227	.5138	-1.234	.780	.195	1	.658	.797	.291	2.181
	[WTPEN=3]	1.895	.6735	.575	3.215	7.917	1	.005	6.652	1.777	24.901
[S1=1]		-.643	1.7021	-3.979	2.693	.143	1	.706	.526	.019	14.774
[S1=2]		-.747	.9134	-2.537	1.043	.668	1	.414	.474	.079	2.839
[S1=3]		0[a]	.	.	.	.	.	.	1	.	.
[S2=1]		2.032	1.3318	-.578	4.642	2.328	1	.127	7.631	.561	103.800
[S2=2]		-1.138	1.1820	-3.455	1.179	.927	1	.336	.320	.032	3.250
[S2=3]		0[a]	.	.	.	.	.	.	1	.	.
[S3=1]		-.791	2.5150	-5.720	4.139	.099	1	.753	.454	.003	62.710
[S3=2]		-2.057	.9539	-3.927	-.188	4.652	1	.031	.128	.020	.829
[S3=3]		0[a]	.	.	.	.	.	.	1	.	.
[S4=1]		.012	2.0072	-3.922	3.946	.000	1	.995	1.012	.020	51.742
[S4=2]		-.191	.7111	-1.584	1.203	.072	1	.788	.826	.205	3.330
[S4=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPEN

Model: (Threshold), S1, S2, S3, S4

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

6) Perceived behavioral control factors and willingness to pay to reduce ecotoxicity impact.

Categorical Variable Information

			N	Percent
Dependent Variable	WTPEN	0-99	8	19.5%
		100-199	16	39.0%
		200-299	13	31.7%
		>299	4	9.8%
		Total	41	100.0%
Factor	P1	Neutral 3	1	2.4%
		Positive 4-5	40	97.6%
		Total	41	100.0%
	P2	Negative 1-2	16	39.0%
		Neutral 3	18	43.9%
		Positive 4-5	7	17.1%
		Total	41	100.0%

Goodness of Fit[a]

	Value	df	Value/df
Deviance	4.835	6	.806
Scaled Deviance	4.835	6	
Pearson Chi-Square	4.174	6	.696
Scaled Pearson Chi-Square	4.174	6	
Log Likelihood[b]	-12.621		
Akaike's Information Criterion (AIC)	37.242		
Finite Sample Corrected AIC (AICC)	39.713		
Bayesian Information Criterion (BIC)	47.523		
Consistent AIC (CAIC)	53.523		

Dependent Variable: WTPEN

Model: (Threshold), P1, P2

a. Information criteria are in smaller-is-better form.

b. The full log likelihood function is displayed and used in computing information criteria.

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
1.135	3	.769

Dependent Variable: WTPEN

Model: (Threshold), P1, P2

a. Compares the fitted model against the thresholds-only model.

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
P1	.200	1	.654
P2	.998	2	.607

Dependent Variable: WTPEN

Model: (Threshold), P1, P2

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[WTPEN=1]	-.845	.7105	-2.237	.548	1.413	1	.235	.430	.107	1.730
	[WTPEN=2]	.950	.7087	-.439	2.339	1.796	1	.180	2.585	.645	10.369
	[WTPEN=3]	2.861	.8454	1.204	4.518	11.453	1	<.001	17.478	3.333	91.642
[P1=2]		-.731	1.6330	-3.932	2.469	.200	1	.654	.481	.020	11.815
[P1=3]		0[a]	.	.	.	.	.	.	1	.	.
[P2=1]		.732	.8169	-.869	2.333	.804	1	.370	2.080	.420	10.314
[P2=2]		.784	.8339	-.851	2.418	.883	1	.347	2.190	.427	11.225
[P2=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: WTPEN

Model: (Threshold), P1, P2

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

Appendix C

AF 02-12

The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University
Jamjuree 1 Building, 2nd Floor, Phyathai Rd., Patumwan district, Bangkok 10330, Thailand,
Tel: 0-2218-3202, 0-2218-3049 E-mail: eccu@chula.ac.th

COA No. 132/2021

Certificate of Approval

Study Title No. 060.1/64 : INTEGRATING HUMAN AND ECOTOXICOLOGICAL IMPACTS INTO WILLINGNESS TO PAY EVALUATION: TRANSITION FROM PARAQUAT TO ATRAZINE USE IN SWEET CORN CULTIVATION

Principal Investigator : MISS PATHARANUN TOOLKIATTIWONG

Place of Proposed Study/Institution : Faculty of Science, Chulalongkorn University

The Research Ethics Review Committee for Research Involving Human Research Participants, Group I, Chulalongkorn University, Thailand, has approved constituted in accordance with Belmont Report 1979, Declaration of Helsinki 2013, Council for International Organizations of Medical Sciences (CIOM) 2016, Standards of Research Ethics Committee (SREC) 2017, and National Policy and guidelines for Human Research 2015.

Signature: Prida Tasanapradit
(Associate Prof. Prida Tasanapradit, M.D.)
Chairman

Signature: Raveenan Mingpakanee
(Assistant Prof. Raveenan Mingpakanee, Ph.D.)
Secretary

Date of Approval : 1 June 2021

Approval Expire date : 31 May 2022

The approval documents including;

1) Research proposal
2) Participant Information Sheet and Consent Form
3) Researcher
4) Questionnaire

The approved investigator must comply with the following conditions:

1. *It's unethical to collect data of research participants before the project has been approved by the committee.*
2. *The research/project activities must end on the approval expired date. To renew the approval, it can be applied one month prior to the expired date with submission of progress report.*
3. *Strictly conduct the research/project activities as written in the proposal.*
4. *Using only the documents that bearing the RECCU's seal of approval: research tools, information sheet, consent form, invitation letter for research participation (if applicable).*
5. *Report to the RECCU for any serious adverse events within 5 working days.*
6. *Report to the RECCU for any amendment of the research project prior to conduct the research activities.*
7. *Report to the RECCU for termination of the research project within 2 weeks with reasons.*
8. *Final report (AF 01-15) and abstract is required for a one year (or less) research/project and report within 30 days after the completion of the research/project.*
9. *Research project with several phases; approval will be approved phase by phase, progress report and relevant documents for the next phase must be submitted for review.*
10. *The committee reserves the right to site visit to follow up how the research project being conducted.*
11. *For external research proposal the dean or head of department oversees how the research being conducted.*

เอกสารข้อมูลสำหรับผู้มีส่วนร่วมในการวิจัยและหนังสือแสดงความยินยอมเข้าร่วมการวิจัย

ชื่อโครงการวิจัย **การบูรณาการผลกระทบด้านความเป็นพิษต่อมนุษย์และระบบนิเวศในการประเมินความเต็มใจจ่าย: การเปลี่ยนผ่านจากการใช้พาราควอตไปสู่อะทราซีนในการปลูกข้าวโพดหวาน** (Integrating Human and Ecotoxicological Impacts into Willingness to Pay Evaluation: Transition from Paraquat to Atrazine Use in Sweet Corn Cultivation)

ชื่อผู้วิจัย **นางสาวภัทรนันท์ ทูลเกียรติวงษ์** ตำแหน่ง **นิสิตบัณฑิตศึกษาระดับปริญญาโท**
รหัสประจำตัวนิสิต **6270088723** หลักสูตร **พิษวิทยาอุตสาหกรรมและการประเมินความเสี่ยง**
ภาควิชาวิทยาศาสตร์สิ่งแวดล้อม คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
สถานที่ติดต่อผู้วิจัย
(ที่ทำงาน) ภาควิชาวิทยาศาสตร์สิ่งแวดล้อม คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
เลขที่ 254 ถนนพญาไท แขวงวังใหม่ เขตปทุมวัน กรุงเทพมหานคร รหัสไปรษณีย์ 10330
(ที่บ้าน) เลขที่ 212/259 หมู่บ้านชัยพฤกษ์พุทธมณฑลสาย5 ถนนพุทธมณฑลสาย5 ตำบลบางเตย อำเภอสามพราน จังหวัดนครปฐม รหัสไปรษณีย์ 73210
โทรศัพท์มือถือ 061-654-4947 E-mail : pathara_nun@hotmail.com

ขอเรียนเชิญเข้าร่วมการวิจัย ก่อนตัดสินใจเข้าร่วมในการวิจัย โปรดทำความเข้าใจว่างานวิจัยนี้เกี่ยวข้องกับอะไรและทำเพราะเหตุใด กรุณาใช้เวลาในการอ่านข้อมูลต่อไปนี้อย่างรอบคอบ หากมีข้อความใดที่อ่านแล้วไม่เข้าใจหรือไม่ชัดเจน โปรดสอบถามเพิ่มเติมกับผู้วิจัยได้ตลอดเวลา ผู้วิจัยจะอธิบายจนกว่าจะเข้าใจอย่างชัดเจน

1. หลักการและเหตุผล

ข้าวโพดหวานเป็นหนึ่งในพืชเศรษฐกิจของไทย ซึ่งมีรายงานการใช้สารกำจัดศัตรูพืชมาก โดยเฉพาะพาราควอต แต่ประเทศไทยมีการห้ามใช้พาราควอตในเดือนมิถุนายน 2563 เนื่องจากพิษวิทยาเป็นอันตรายต่อสิ่งมีชีวิต ทำให้อะทราซีนกลายเป็นสารกำจัดศัตรูพืชหลักในการปลูกข้าวโพดหวาน อย่างไรก็ตามก็ยังไม่ได้มีการศึกษาการเปลี่ยนผ่านจากการใช้พาราควอทเป็นอะทราซีนในการเพาะปลูกข้าวโพดหวาน ซึ่งยังไม่มีการพิจารณาเกี่ยวกับค่าใช้จ่ายด้านสุขภาพและความเป็นพิษต่อระบบนิเวศที่เกิดขึ้นจากสารกำจัดศัตรูพืชดังนั้นจึงควรที่จะมีการวิเคราะห์ทั้งผลกระทบทางด้านพิษวิทยาและเศรษฐศาสตร์ร่วมกัน

การศึกษานี้มีวัตถุประสงค์เพื่อ (1) ประเมินผลกระทบต่อมนุษย์และระบบนิเวศน์ของสารกำจัดศัตรูพืชสำหรับการปลูกข้าวโพดหวานจากการเปลี่ยนแปลงการใช้พาราควอตเป็นอะทราซีน (2)

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ประเมินความเต็มใจจ่ายของเกษตรกรและ (3) ระบุปัจจัยที่มีผลต่อความเต็มใจที่จะจ่ายเพื่อลดผลกระทบต่อมนุษย์และระบบนิเวศจากการเปลี่ยนการใช้สารกำจัดศัตรูพืชจากการเปลี่ยนการใช้พาราควอตเป็นอะทราซีนของเกษตรกรผู้ปลูกข้าวโพดหวาน ผลการศึกษาสามารถนำไปใช้ประโยชน์ในการสนับสนุนมาตรการการใช้สารกำจัดศัตรูพืชตามที่กรมวิชาการเกษตรแนะนำ เสนอแนวทางและออกแบบมาตรการการใช้สารกำจัดศัตรูพืชที่เหมาะสมเพื่อลดผลกระทบต่อมนุษย์และระบบนิเวศในการปลูกข้าวโพดหวาน

2. การให้ข้อมูลและขอความยินยอมของผู้เข้าร่วมการศึกษา

2.1 การขอความยินยอมการเข้าร่วมการศึกษา ดำเนินการดังนี้

(1) ผู้วิจัยจะจัดทำหนังสือถึงผู้อำนวยการศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติเพื่อขอความอนุเคราะห์และขออนุญาตเข้าเก็บข้อมูลในพื้นที่

(2) ผู้วิจัยได้ทำการอธิบายทางโทรศัพท์ถึงวัตถุประสงค์และวิธีการศึกษาวิจัยแก่ผู้ประสานงาน(นักวิชาการเกษตร) และส่งเอกสารข้อมูลสำหรับผู้มีส่วนร่วมในการวิจัยและขอความยินยอมให้กับผู้ประสานงาน ผู้ประสานงานจะทำการชี้แจงรายละเอียดเกี่ยวกับงานวิจัยและข้อมูลสำหรับผู้มีส่วนร่วมให้กับเกษตรกรรับทราบผ่านเครือข่ายเกษตรกรของศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติ จากนั้นผู้ประสานงานจะทำการรวบรวมรายชื่อ ไอดีไลน์ และเบอร์โทรศัพท์ของเกษตรกรที่ยินยอมการให้สัมภาษณ์ผ่านทางโทรศัพท์รวมถึงนัดหมายวันสัมภาษณ์

(3) เมื่อผู้วิจัยได้รับข้อมูลรายชื่อ ไอดีไลน์ และเบอร์โทรศัพท์ของเกษตรกร ก่อนวันนัดสัมภาษณ์ผู้วิจัยจะทำการส่งข้อความเพื่อชี้แจงข้อมูล ส่งแบบสอบถามที่จะใช้สัมภาษณ์ และเอกสารข้อมูลสำหรับผู้มีส่วนร่วมในการวิจัยและหนังสือแสดงความยินยอมเข้าร่วมการวิจัยทางไลน์และแจ้งเบอร์โทรศัพท์สำหรับสอบถามข้อมูลเพิ่มเติม

(4) ในวันนัดสัมภาษณ์ ผู้วิจัยจะทำการชี้แจงรายละเอียดอีกครั้งเกี่ยวกับข้อมูลงานวิจัย และเปิดโอกาสให้เกษตรกรซักถามเกี่ยวกับข้อปฏิบัติต่างๆของการวิจัยก่อนจะขอความยินยอมด้วยวาจาอีกครั้งหนึ่ง

2.2 การให้ข้อมูล ด้วยการสัมภาษณ์ “ถาม-ตอบ” ระหว่างผู้วิจัยและกลุ่มตัวอย่างเกษตรกรที่มีอายุตั้งแต่ 18 ปีขึ้นไป โดยผู้วิจัยจะทำการสอบถามกลุ่มตัวอย่างทีละข้อและบันทึกคำตอบลงในแบบสอบถามจนครบทุกข้อ

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3. รายละเอียดของผู้เข้าร่วมการวิจัยและคุณสมบัติ

3.1 กลุ่มตัวอย่าง

(1) เกษตรกรผู้ปลูกข้าวโพดหวานรวมทั้งสิ้น 80 คน จากข้อมูลเกษตรกรผู้ปลูกข้าวโพดหวาน (พันธุ์อินทรีย์2) ที่มีการรวบรวมจากศูนย์วิจัยข้าวโพดข้าวฟ่างแห่งชาติในปี พ.ศ.2563 โดยได้รับความอนุเคราะห์จากคุณกิตติศักดิ์ ศรีชุมพร (นักวิชาการเกษตร) เป็นผู้ประสานงาน

4. การคัดกรองผู้มีส่วนร่วมฯ ตามเกณฑ์การคัดเข้า-คัดออก

4.1 เกษตรกรเพศชายหรือหญิงผู้ปลูกข้าวโพดหวานและส่งขายให้กับศูนย์วิจัยข้าวโพดข้าวฟ่างแห่งชาติในปี พ.ศ. 2563

4.2 เป็นเกษตรกรผู้ปลูกข้าวโพดเป็นเวลาไม่น้อยกว่า 3 ปี

4.3 การคัดกรองเกษตรกรจะอ้างอิงข้อมูลสถิติเกษตรกรผู้ปลูกข้าวโพดหวานที่ถูกรวบรวมโดยศูนย์วิจัยข้าวโพดข้าวฟ่างแห่งชาติในปี พ.ศ. 2563 ซึ่งมีนักวิชาการเกษตร (คุณกิตติศักดิ์ ศรีชุมพร) เป็นผู้คัดกรอง

5. ในการเข้าร่วมงานวิจัย มีการดำเนินการกับผู้มีส่วนร่วมในการวิจัย

5.1 การเตรียมความพร้อมกลุ่มตัวอย่าง

(1) ใช้เวลาสอบถามข้อมูลด้วยแบบสอบถามผ่านทางโทรศัพท์กับกลุ่มตัวอย่างไม่เกินคนละ 20 นาที โดยจะทำการแจ้งและดำเนินการนัดหมายวันและเวลากับกลุ่มตัวอย่างเกษตรกรล่วงหน้าผ่านการประสานงานจากผู้ประสานงาน อย่างน้อย 1 วัน ซึ่งจะกระทำในรูปแบบเดียวกันทั้งการเก็บข้อมูลด้วยแบบสอบถามครั้งที่ 1 และครั้งที่ 2 โดยระยะห่างในการลงพื้นที่เก็บข้อมูลด้วยแบบสอบถามแต่ละครั้งจะห่างกันไม่เกิน 2 เดือน

(2) การตอบแบบสอบถามจะกระทำด้วยการสัมภาษณ์โดยผู้วิจัยจะเป็นผู้บันทึกข้อมูลลงในแบบสอบถามด้วยตนเอง โดยแบบสอบถามชุดที่ 1 (สำหรับการเก็บข้อมูลในครั้งแรก) มีจำนวน 28 ข้อ แบ่งเป็น 5 ส่วน ประกอบด้วย ข้อมูลทั่วไป ข้อมูลการปลูกข้าวโพดหวาน ข้อมูลการใช้สารกำจัดศัตรูพืช ผลกระทบจากการใช้สารกำจัดศัตรูพืชและทัศนคติ การคล้อยตามกลุ่มอ้างอิง (การรับรู้ของบุคคลเกี่ยวกับความต้องการ ซึ่งอาจเกิดจากกลุ่มคนใกล้ชิดของบุคคลนั้น) และการรับรู้ความสามารถในการควบคุมพฤติกรรมจากการใช้สารกำจัดศัตรูพืช โดยใช้เวลาในการสัมภาษณ์ต่อคนไม่เกิน 20 นาที และแบบสอบถามชุดที่ 2 (สำหรับการเก็บข้อมูลในครั้งที่สอง) มีจำนวน 2 ข้อ แบ่งเป็น 2 ส่วน คือ ความเต็มใจจ่ายในการสนับสนุนมาตรการต่างๆทางด้านสุขภาพ การจัดการมลพิษ เป็นต้น เพื่อลดผลกระทบต่อสุขภาพ และความเต็มใจจ่ายในการสนับสนุนมาตรการต่างๆ เช่น มาตรการการบำบัดมลพิษทางน้ำ เพื่อลดผลกระทบต่อระบบนิเวศน้ำจืด ซึ่งเป็นการสมมติสถานการณ์ขึ้นว่าจะต้องจ่ายให้กับศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติเพื่อดำเนินมาตรการต่างๆ โดยจะใช้เวลาในการสัมภาษณ์ต่อคนไม่เกิน 10 นาที

(3) ในการเก็บข้อมูลด้วยแบบสอบถามผ่านโทรศัพท์จะไม่มีการบันทึกเสียง

5.2 สถานที่ในการเก็บตัวอย่างแบบสอบถาม

ขึ้นอยู่กับความสะดวกของเกษตรกรแต่ละคน เนื่องจากเป็นการสัมภาษณ์ทางโทรศัพท์

6. ความเสี่ยง/อันตราย และความไม่สะดวกต่าง ๆ ที่อาจเกิดขึ้นจากการเข้าร่วมการวิจัย

6.1 ความเสี่ยงหรืออันตรายในการศึกษาวิจัย คือ การเก็บข้อมูลจากการสัมภาษณ์ด้วยแบบสอบถาม อาจทำให้เกิดความไม่สบายใจในการเปิดเผยข้อมูลส่วนตัวและอาจเกิดความไม่สะดวกเนื่องจากจะกลุ่มตัวอย่างเกษตรกรจะต้องสละเวลาส่วนตัว ซึ่งเป็นเวลาทำงานและอาจทำให้ขาดรายได้ในช่วงที่มาเข้าร่วมงานวิจัย

6.2 ผู้ตอบแบบสอบถามสามารถไม่ตอบคำถามข้อที่ไม่สะดวกใจได้ หรือสามารถหยุดพักหากเกิดความไม่สบายใจระหว่างให้ข้อมูล

7. ประโยชน์ในการเข้าร่วมการวิจัย

ทางศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติสามารถนำข้อมูลการเปลี่ยนผ่านจากการใช้พารา-ควอตเป็นอะทราซีนที่มีต่อสุขภาพมนุษย์และระบบนิเวศ และข้อมูลความเต็มใจจ่ายของเกษตรกรที่แสดงถึงการให้คุณค่าต่อสุขภาพและระบบนิเวศ สามารถใช้เป็นข้อมูลสนับสนุนมาตรการต่างๆที่สอดคล้องกับนโยบายการใช้สารกำจัดศัตรูพืชจากกรมวิชาการเกษตร และปรับปรุงมาตรการที่มีอยู่เพื่อประสิทธิภาพในการใช้งานสารกำจัดศัตรูพืชของเกษตรกรผู้ปลูกข้าวโพดหวานในพื้นที่อย่างยั่งยืน นอกจากนี้ยังสามารถนำข้อมูลไปใช้ประโยชน์เพื่อการปรับปรุงการใช้สารกำจัดศัตรูพืชหรือออกแบบมาตรการที่เหมาะสมต่อการปลูกข้าวโพดหวานในศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติต่อไป โดยผู้มีส่วนร่วมในงานวิจัยหรือเกษตรกรจะไม่ได้รับประโยชน์โดยตรง

8. ข้อมูลที่เกี่ยวข้องกับผู้มีส่วนร่วมในการวิจัยจะเก็บเป็นความลับ ด้วยการเก็บเป็นแฟ้มข้อมูลเฉพาะ หากอยู่ในรูปแบบไฟล์อิเล็กทรอนิกส์เอกสารทุกฉบับที่มีข้อมูลส่วนบุคคลที่จะสามารถบ่งชี้ตัวบุคคลได้จะทำการตั้งรหัสเข้าเปิดเอกสาร

สำหรับการแจ้งข้อมูลผลการศึกษาผลจากการเปลี่ยนผ่านการใช้พาราควอตเป็นอะทราซีนที่มีต่อสุขภาพมนุษย์และระบบนิเวศ รวมถึงความเต็มใจจ่ายในการลดผลกระทบที่เกิดขึ้นของเกษตรกร ผู้วิจัยจะดำเนินการคืนผลการวิเคราะห์และสรุปข้อมูลที่ได้จากการเกษตรกรกลุ่มตัวอย่างในภาพรวม (ไม่ระบุข้อมูลบ่งชี้รายบุคคล) โดยจะทำการส่งวิจัยฉบับสมบูรณ์ในรูปแบบเล่มวิทยานิพนธ์และรูปแบบอิเล็กทรอนิกส์ให้กับศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติ และหากมีการเสนอผลการวิจัยจะเสนอเป็นภาพรวม ข้อมูลใดที่สามารถระบุถึงตัวผู้มีส่วนร่วมในการวิจัยได้จะไม่ปรากฏในรายงาน

9. **เมื่อเสร็จสิ้นการวิจัยแล้ว** ข้อมูลที่เกี่ยวข้องกับผู้เข้าร่วมวิจัยทั้งหมดจะถูกทำลาย

10. การแสดงความขอบคุณผู้มีส่วนร่วมในการวิจัย

(1) แสดงความขอบคุณต่อผู้ดำเนินการในพื้นที่และศูนย์วิจัยข้าวโพดและข้าวฟ่างแห่งชาติ ด้วยการทำหนังสือแสดงความขอบคุณ และมอบค่าใช้จ่ายในการดำเนินการจำนวน 3000 บาท

(2) แสดงความขอบคุณแก่เกษตรกรกลุ่มตัวอย่าง ผู้วิจัยจะมอบคำขอบคุณที่เกษตรกรสละเวลามาร่วมงานวิจัย โดยมีการมอบค่าเสียเวลาในการเข้าร่วมงานวิจัยคนละ 70 บาทต่อครั้งโดยการโอนเงินเข้าบัญชีธนาคารของเกษตรกรโดยตรงในวันรุ่งขึ้นหลังการสัมภาษณ์ และทำการโทรศัพท์หรือส่งSMSแจ้งเมื่อทำการโอนเงินเรียบร้อย

11. การเข้าร่วมการวิจัยในครั้งนี้เป็นโดย**สมัครใจ** สามารถ**ปฏิเสธ**ที่จะเข้าร่วมหรือ**ถอนตัว**จากการวิจัยได้ทุกขณะ **โดยไม่ต้องให้เหตุผล ไม่สูญเสียประโยชน์ที่พึงได้รับ และไม่มีผลกระทบใดๆ ต่อผู้เข้าร่วมวิจัย**

12. หากมีข้อสงสัย โปรดสอบถามเพิ่มเติมจากผู้วิจัยได้ตลอดเวลา และหากผู้วิจัยมีข้อมูลเพิ่มเติมที่เป็นประโยชน์หรือโทษเกี่ยวกับการวิจัย ผู้วิจัยจะแจ้งให้ท่านทราบอย่างรวดเร็วเพื่อให้ผู้เข้าร่วมการวิจัยทบทวนว่ายังสมัครใจจะอยู่ในงานวิจัยต่อไปหรือไม่

13. หากได้รับการปฏิบัติไม่ตรงตามข้อมูลดังกล่าวสามารถร้องเรียนได้ที่ คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน กลุ่มสหสถาบัน ชุดที่ 1 จุฬาลงกรณ์มหาวิทยาลัย 254 อาคารจามจุรี 1 ชั้น 2 ถนนพญาไท เขตปทุมวัน กรุงเทพฯ 10330 โทรศัพท์ 0-2218-3202, 0-2218-3409 E-mail: eccu@chula.ac.th

ข้าพเจ้าได้รับการอธิบายจากผู้วิจัย **และเข้าใจข้อมูลดังกล่าวข้างต้นทุกประการแล้ว จึงลงนามเข้าร่วมการวิจัยนี้ด้วยความสมัครใจ** และได้รับเอกสารไว้ 1 ชุดแล้ว

ลงชื่อ	**ลงชื่อ** ....
(..)	(..)
ผู้วิจัยหลัก	**ผู้เข้าร่วมการวิจัย**
วันที่ ..../............../..........	**วันที่** ..../............../..........

เลขที่โครงการวิจัย 060.1/64

วันที่รับรอง 1 มิ.ย. 2564

วันหมดอายุ 31 พ.ค. 2565

5.

ลงชื่อ ....

(...)

พยาน

วันที่ ..../....................../.................

เลขที่โครงการวิจัย 060.1/64

วันที่รับรอง - 1 มิ.ย. 2564

วันหมดอายุ 3 1 พ.ค. 2565

VITA

NAME	Miss Patharanun Toolkiattiwong
DATE OF BIRTH	5 May 1997
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Bachelor of Environmental Science and Technology, Faculty of Environment and Resource Studies, Mahidol University
HOME ADDRESS	212/259 Chaiyapruek Village, Bangtoei Sub-District, Sampran District, Nakhon Pathom Province, 73210
PUBLICATION	Toolkiattiwong, P., Chaikaew, P. and Chart-asa, C. (2022). Comparative Human-Ecotoxicological Impacts and Willingness to Pay: A Case of Pesticide Transition from Paraquat to Atrazine in Sweet Corn Cultivation in Thailand. EnvironmentAsia 15 (Special Issue) 50-55.
AWARD RECEIVED	The best oral presentation award in "Environmental and Occupational Health/Environmental Challenges and the Covid-19 Crisis Session", The 6th EnvironmentAsia Virtual International Conference