MOST-DFG Joint Research Project

APPLICATION FORM

1. General Information

1.1. Title of Research Project

Title in English:	Fugacity analysis of the agricultural behavioral impact on nitrate and pesticide in Taiwan and German water resources
Title in Mandarin:	以逸能分析探究農業行為對台灣與德國的水資源中硝酸鹽與殺蟲劑污染物的影響
Title in German:	Analyse von Fugazität und Einflüsse des Verhaltens von Landwirten auf Nitrat und Pestizide in taiwanesischen und deutschen Wasserressourcen

1.2. Principal Investigators of project

Taiwanese PI

Name (Chinese): 陳威翔	Name (English): Wei-Hsiang Chen
Institution: National Sun Yat-sen University	Department: Institute of Environmental Engineering
Position: Associate Professor	Tel: +886-7-5252000#4421 Email: whchen@mail.nsysu.edu.tw
Signature: Wei-Hsiang Will Chen	

German PI

Last Name: Sauer	Given Name: Johannes
Institution: Technical University of Munich	Department: Agricultural Production and Resource Economics (PuR)
Position: Full professor	Tel: + 49 8161 71 2410 Email: jo.sauer@tum.de
Signature:	

1.3. Which best describes the fields of this project:

- ☐ Natural Sciences
- ■ Engineering and Applied Sciences
- ☐ Life Sciences
- ☐ Humanities and Social Sciences
- ☐ Science Education

1.4. Key words

Diffuse pollution; Agricultural practices and farmer behavior; Water pollution; Multimedia transfer; Farmer perception, Nitrate; Pesticide

2. Abstract of Integrated Research Project

Please describe briefly the proposed research project first, including the aims, executive plan, expected results, potential benefits and impacts to both sides from this collaboration within two pages.

Water pollution from unsustainable agricultural practices is a global challenge. Studies have been carried out to identify the proper agricultural practices for different farming systems to mitigate the associated water pollutions, as effective and efficient measures require tight cooperation amongst farmers, landowners, and policymakers, etc. Since most of the sustainable agricultural measures remain voluntary, the attitude and knowledge of farmers are critical factors to define the successful development of appropriate land-use management. Assessing and predicting the influences of different mitigation approaches and the farmers' attitudes, which could significantly affect the agricultural practices and farmer behaviors and the associate impacts, on receiving water environments becomes an interesting and important global issue concerning sustainable water resource management.

In this study, Taiwan and Germany were selected as two interesting and comparable examples from the Eastern and Western societies. Although the agricultural characteristics and cultural-societal structures are different between Taiwan and Germany, both countries are facing the same challenge that the valuable water resources are decreasing and are negatively affected by increasing agricultural activities. After the communications between the Taiwanese and German research groups in the last few months, we propose a collaborative research project that will investigate the co-effects of different mitigation approaches (e.g., economic incentives and conservation measures) and agricultural production behaviors (e.g., farmers' attitudes and degree of cooperation) on the receiving water environments. We apply an integrated perspective in both water and agriculture by using a transdisciplinary approach and applying cutting-edge methods that consider approaches from environmental science and engineering as well as agricultural and resource economics at a transnational level. The project will be simultaneously carried out in Taiwan and Germany over three years. Nitrate and the most relevant pesticides in Taiwan and Germany will be selected as the target compounds. This project aims to provide scientific support to underpin Taiwanese and German policy development on controlling diffuse water pollutions from agriculture and mitigating the impacts of intensified agricultural production on aquatic ecosystem degradation by investigating farmers' attitudes towards different mitigation measures and their behavioral adaptations in response to specific economic incentives and conservation measures.

In the first stage, a survey designed by Prof. Sauer's research team will be employed to understand the responses of the agricultural practices and farmer behaviors (i.e., farmers' attitudes and knowledge) toward motivations and barriers for the adoption of different approaches to mitigate the use of nitrate and pesticides with respect to agricultural activities. A discrete choice experiment model (DCE) will be used to investigate the farmer's perception of trade-offs between water conservation and agricultural

production by surveying individual farmers whether they would be willing to accept a specified monetary value to reduce agrochemical uses for better receiving water quality. Best-worst scaling (BWS) will be applied to analyze the relative preferences (the most and least preferred) for different conservation measures. Subsequently structural equation modeling (SEM) is applied to refine the conceptual basis for developing an understanding of the relationships between farmers' attitudes and behaviors towards agricultural production and water pollution. Prof. Chen's research team will develop a fugacity model system to investigate the concentration distribution of nitrate and selected pesticides in different spaces and environmental media at different time scales. The system will be represented by a three-dimensional equation matrix with the mass balance. In the second stage, with the results of the survey, different scenarios that release nitrate and pesticides of interest into the environment will be identified. The scenario information will feed into the fugacity model system to provide the potential concentration distributions and transport fluxes of nitrate and selected pesticides between different environmental media (e.g., water and sludge) and locations (e.g, upstream or downstream). The field sampling and monitoring will support the demonstration and modification of the fugacity model system. In the last stage, by adjusting the initial and boundary conditions of the fugacity model system, the impacts of different pollution intensities (such as different levels of pollution reduction) and management approaches (such as different agricultural responses to regulatory restrictions or economic incentives) will be predicted. The comparison of the results from the assumptions of different scenarios will quantify the effects of different agricultural practices and farmer behaviors on the environmental emission of nitrate and selected pesticides in the water environments of Taiwan and Germany.

Overall, the whole idea of this MOST-DFG joint research project, which is based on a collaboration between Prof. Chen's team in Taiwan and Prof. Sauer's team in Germany, is expected to provide valuable insights into how different agricultural practices and farmer behaviors affect the kinetic transfer and equilibrium distribution of nitrate and selected pesticides in water environments. As the agricultural practices and farmer behaviors will respond to different regulatory and economic incentives, the relationship between the agricultural practices and farmers' attitudes as well as the governmental policies and incentives become critical information for proper decision-making to alleviate the negative impacts of agrochemicals such as nitrate and pesticides on the ecosystem and public health. The findings of this study will be a reference resource for the respective governmental agencies (including the Environmental Protection Agency (EPA) and Council of Agricultural in Taiwan and the Water Framework Directive (WFD) in Germany) introducing and encouraging more coherent and diverse decision-making for the use of nutrients and pesticides and the reduction of associated water pollutions by the international collaboration between Taiwan and Germany research groups.

3. Participants of project

Taiwanese side:

Name	Position	Institution/Department	Role in the project
Wei-Hsiang Chen	Associated Professor	National Sun Yat-sen University Institute of Environmental Engineering	Principal investigator
To be determined	Ph.D. student	National Sun Yat-sen University Institute of Environmental Engineering	Project management, experiment execution, data analysis, and report and journal preparation
To be determined	Master student	National Sun Yat-sen University Institute of Environmental Engineering	Experiment execution, data analysis, and report and journal preparation

German side:

Name	Position	Institution/Department	Role in the project
Johannes Sauer	Full professor	Technical University of Munich Agricultural Production and Resource Economics	Principle investigator
Fabian Frick	Postdoctoral researcher	Technical University of Munich Agricultural Production and Resource Economics	Data analysis, and report and journal preparation
Philipp Menning	Ph.D. student	Technical University of Munich Agricultural Production and Resource Economics	Data analysis, and report and journal preparation
Sheng-Han-Erin Chang	Ph.D. student	Technical University of Munich Agricultural Production and Resource Economics	Project management Data analysis, and report and journal preparation

4. Budget requested for entire term of project:

Taiwanese side:

Categories	First year from 10/21 to 09/22 (MM/YY)	Second year from 10/22 to 09/23 (MM/YY)	Third year from 10/23 to 09/24 (MM/YY)	Budget Requested (NTD)
General Expenses (Personnel and Consumables)	913,000	913,000	913,000	2,739,000
Experimental Equipment	100,000	100,000	100,000	300,000
Travel Expenses	80,000	80,000	80,000	240,000
Overhead	0	0	0	0
Total	1,093,000	1,093,000	1,093,000	3,279000

German side:

Categories	First year from 10/21 to 09/22 (MM/YY)	Second year from 10/22 to 09/23 (MM/YY)	Third year from 10/23 to 09/24 (MM/YY)	Budget Requested (euros)
General Expenses (Personnel and Consumables)	129,550	99,550	99,550	328,650
Experimental Equipment	-	-	-	-
Travel Expenses	15,000	15,000	15,000	45,000
Overhead	31,801	25,201	25,201	82,203
Total	176,351	139,751	139,751	455,853

5. Research Proposal

5.1 Aims and targets

The nitrate and pesticide contamination in freshwater heavily affects human health and ecological systems on a global scale. Among many origins of these water contaminants, agricultural activities represent one important source that contributes a significant portion of the concentrations in the environments. Although different approaches are available to mitigate the pollutions of nitrate and pesticides due to the agricultural activities, the farmers' behaviors could be changed given different mitigation approaches, possibly due to the regulatory and/or economic incentives, positively or negatively affecting the effectiveness and efficiency of the mitigation approaches employed. Taiwan and Germany are two countries economically reliant on agriculture, as agriculture contributes to the food safety, rural development, and conservation of the two countries.

Water pollution from agricultural practices is a critical challenge for sustainability in Taiwan, Germany, and many countries in the world. Given this concern, we propose a collaborative research project that will investigate the co-effects of different mitigation approaches (e.g., those motivated by different regulatory and economic incentives) and agricultural practices and farmer behaviors (e.g., different attitudes and degrees of cooperation of the farmers and land-users) on the receiving water environments. This co-work will be carried out in an integrated perspective in both water and agriculture by using a transdisciplinary approach that considers the environmental science and engineering, agricultural and resource economics at a transnational level.

With the research experiences of two teams in Taiwan and Germany, Prof. Sauer's research group will help develop the survey system that understands and investigates the agricultural practices and farmer behaviors under different scenarios such as different governmental policies and mitigation approaches, as Prof. Chen's team will support the simulation and prediction of the contaminants (e.g., nitrate and selected pesticides) released through different agricultural practices and farmer behaviors into the environment and the associated negative impacts. This transnational collaboration provides a valuable opportunity for two research groups to share knowledge regarding innovative practices and technologies, which could be beneficial for sustainable agricultural development in Taiwan and Germany.

To meet the Target 6 (Clean Water and Sanitation for All) and 6.3 (Improving Water Quality by Reducing Pollution) in the United Nations' Sustainable Development Goals (SDG), this project aims:

1) To investigate the agricultural practices and farmer behaviors such as the perceptions, attitudes, opinions, values, preferences, and choices of farmers and stakeholders in response

to different regulatory policies or economic incentives for mitigation of water pollution due to agricultural activities.

2) To develop a mathematical model that simulates and predicts the fates and transfers of pollutants emitted by different agricultural practices and farmer behaviors in the receiving water environments.

3) To stimulate the innovation and exchange of the knowledge to facilitate sustainable agricultural practices and farmer behaviors for their negative impacts on the water environments through the research collaboration between Taiwan and Germany.

4) To provide critical information for the decision-making to alleviate the negative impacts of agrochemicals such as nitrate and pesticides on the ecosystem and public health.

5.2 Current status

In recent decades, agricultural productivity has increased greatly, partially due to the increased availability of fertilizers (both mineral and organic) and pesticides. However, excessive use of fertilizers and pesticides has also resulted in significant soil and water pollution. The Food and Agriculture Organization (FAO) of the United Nations (EU) (2018) identified agriculture as the greatest source contributing to water pollution. Although there are numerous studies targeting policy instruments to treat pollutants, knowledge from different scientific perspectives remains fragmented. Evans et al. (2019) reviewed studies concerning water pollution originating from agriculture and indicated the need for future research including the modeling of the fates of contaminants, harmonization of data collection, calculation of economic costs of agricultural water pollution, and adoption of good practices for pollution mitigation.

Generally speaking, there are three approaches to mitigate water pollution caused by agriculture, namely regulations, economic incentives, and extension services. The research concerning these approaches is typically conducted at a regional or national level. However, many studies have suggested that the combination of strategies in different perspectives including regulations, economic incentives, and extension services lead to better outcomes than the consideration of any individual perspective alone (OECD 2012; OECD 2017).

5.2.1 The German perspective

In 2013, the EU commission sent Germany a letter raising the concerns about a failure to meet various obligations under the Nitrate Directive as Germany has been identified as having inadequate rules to limit the application of fertilizers. Since Germany was still in breach of the Nitrates Directive, in 2019, the EU Commission urged Germany to comply with the judgment of EU rules on nitrates. According to the German Environmental Agency (2017), an assessment of the chemical status of groundwater in Germany in 2016 showed that 34.8% of all groundwater bodies had poor chemical status (means that no concentrations of priority substances exceed the relevant Environmental Quality Standards (EQS) established in the EQS Directive). This was mainly attributable to the diffuse pollution with nitrates (27.1%) and pesticides (2.8%), indicating the release of nitrate and pesticides from a range of activities that, individually, may not affect the water environment, but, at the scale of a catchment, can have a significant effect. Szöcs, et al. (2017) also found that regulatory acceptable concentrations (RACs) of pesticides were exceeded at 26% of the sampled streams in Germany.

In 2018, a report from *Friends of the Earth Germany* found that 92% of the surface water in Germany is contaminated with agrochemicals as a direct result of agricultural activity, putting freshwater species at risk. Furthermore, there is an obvious coincidence between high livestock density and nitrogen surplus at high levels in North-Rhine Westphalia, Lower Saxony, Schleswig-Holstein, and Bavaria. According to Kirschke et al (2019), “Some federal states with important agricultural sectors have a low share of water protection areas like Bavaria (5%) and Schleswig-Holstein (4%); the share in Lower Saxony (17%) is about the German average.” The study from Kirschke et al. (2019) demonstrated that Germany’s governance instruments in the water and agricultural sectors have had an effect on solving problems and suggests a need for stronger integration of water and agricultural policies, as well as better use of economic instruments for enhancing water quality in the future. Moreover, information about farmers’ behavioral changes in the applications of pesticides or fertilizers is desirable for policymaking. However, this type of information is hardly available in Germany due to the lack of adequate control mechanisms (Kirschke et al., 2019).

Germany has been warned by the EU for a long time that the national regulations for nitrogen pollution are not being fulfilled sufficiently (BUND 2017). The German government is planning more stringent regulations in this regard, for example, uniform fertilization planning mandatory for all farmers in the country (Landwirtschaft, 2020). This is to ensure that only the amounts of fertilizers needed and absorbable by plants are applied on the farms. If an area was known to be nitrate-polluted, a stricter rule will be available in 2021 after which these polluted areas must reduce the current amount of the fertilizers used by one-fifth. However, this tightening policy regarding the use of fertilizers has led to farmer protests.

5.2.2 The Taiwan perspective

In Taiwan, a study to evaluate and classify the river pollution level has been conducted (Putri et al. 2018). However, linkages between water contamination from agriculture and the impacts thereof are not well understood. Similar to Germany, information about farmers' behavior changes under different regulatory and incentive schemes is also not available in Taiwan. It is increasingly important to identify and understand the heterogeneity of farmer behaviors for supporting policymaking.

Under the efforts of rural regeneration policies initiated by the government in the last decades, agricultural communities in Taiwan have undergone a successful transformation and gradually upgraded to enterprise-based management. As the increasing number of young farmers joining the agricultural communities, a new generation of ideas has begun to sprout. The agricultural communities are now aiming towards the improvement of living quality and industrial environment as well as the ecological conservation of their surroundings. The balance between agricultural development and nature conservation has become the next important challenge for agricultural regeneration in Taiwan, changing the existing relationship between agriculture and water. For example, in the past, agricultural policies in Taiwan have typically focused on the subsidies for fertilizers, with the original purpose of helping the lives of farmers. Nevertheless, the side-effects such as the lack of infrastructure, aging, and emigration of the population arose. More importantly, it turned out that chemical fertilizers and pesticides were over-used to maximize crop yields. To face these challenges, the subsidies for fertilizer and pesticides are being replaced by the investment of environmentally-friendly infrastructure systems in rural communities. Farmers are now encouraged to reduce the usage of these chemicals in fields, changing the impacts of agrochemicals on the water environment.

Livestock production in Taiwan is another environmental issue of concern due to its wastewater and wastes generated in the processes. However, these wastewaters and wastes could be a potential alternative for the nutrient source of crop yields in agricultural activities. In response to the environmental concerns of the general public for livestock production, governmental policies that reuse the manure and slurry from livestock production for agricultural activities are being developed and employed to reduce the potential adverse impacts of the livestock production industry on the environment. This policy creates a cooperative model between the agricultural community and livestock production, alleviating the great number of chemical fertilizers originally needed in agricultural activities. However, the challenges remain. For example, the pig's husbandries in Taiwan are typically small-scale and distributed, elevating the cost and difficulty of efficient collection and centralized treatment of their wastewater and wastes. The options for proper destinations of composting of wastes from livestock production are limited. The technologies of treating and purifying the manure and slurry are improvable given high metal and nitrogen concentrations frequently reported to be present in the final products and receiving water bodies, respectively. These challenges affect the motivation of farmers to cooperate with livestock production in their agricultural activities. A study that provides the information regarding the influences of farmers' behaviors due to different management approaches (e.g., subsidy policy or wastewater reuse) on the environmental quality will help efficient integration of relevant policies from governmental and different industrial partners and face the local challenge of a quickly increasing desire to minimize the environmental impacts by agro-chemicals.

From both German and Taiwanese perspectives, although the average farm size and crop diversity differs greatly between the two countries, they have in common that most of the farms are family-run and gradually upgraded to enterprise-based management. Moreover, the diffuse pollution from agriculture is a complex and persistent environmental challenge for both Germany and Taiwan. As two highly developed examples of East Asian and Western societies, the Taiwanese and the German contexts provide an ideal comparison for agricultural practices and farmer behaviors and policy implementations, as well as the related impacts on the water environment, given their very different cultural-societal structures.

5.3 Methodology

The Taiwanese-German collaboration will be a highly representative example for East Asian and Western societies, comparing their challenges and policy frameworks on water contaminations. The Agricultural Production and Resource Economics group at the Technical University of Munich (PuR-TUM, Germany) will provide economic and statistical evidence to support policy design by investigating farmer's behaviors based on the Theory of Planned Behavior and by designing economic incentives to mitigate water pollution. This will assist policymakers to select systematically policy instruments that can influence farmer's behaviors. The Institute of Environmental Engineering at the National Sun Yat-sen University (IEE-NSYSU, Taiwan) will build a state-of-the-art multi-media fugacity transmission model that simulates the environment. This model can be developed for Taiwan and/or Germany, by adjusting the initial and boundary value settings (i.e. simulating different policies, pollution or reduction programs), by looking at the mass distribution or concentration changes of nitrate and selected pesticides in different media (water, sludge, or soils) in the environment, and by predicting the resulting impact of the policy or program on the environment and public health.

5.3.1 Theory of planned behavior

As the IEE-NSYSU in Taiwan will support the multimedia transmission modeling to assess water quality variations under different regulatory and incentive scenarios, the German partner (PuR-TUM) will lead the part on investigating the behaviors and attitudes of farmers under different schemes by conducting field surveys and using stated-preference methods (e.g., the discrete choice experiment (DCE) and the best-worst scaling (BWS)), incorporating psychometric data with structural equation modeling. The Theory of Planned Behavior is well-known and a frequently used framework for explaining and predicting human behaviors, guiding measurement of the social-psychological constructs that comprise the theory.

The DCE investigates the farmers' trade-offs between environmental conservation and agricultural production by asking individual respondents whether they would be willing to accept a specified monetary value to maintain or to conserve particular environmental goods. For example, to limit the nitrate levels in downstream water environments, the DCE could examine features of the payment mechanism to farmers' willingness to accept the reduction in agrochemical use for the achievement of better water quality. BWS is a multi-attribute approach to measure preferences which could avoid the weaknesses of rating or ranking by allowing respondents to choose twice (the best and worst) in a choice set. The BWS aims to analyze the relative preferences for a set of attributes, assuming that respondents can make judgments on the best and the worst (or the most and the least preferred/important) out of several elements of a choice-set, for example, different conservation measures.

5.3.2 Multimedia fugacity modeling

A major incentive to understand the fates of the agrochemicals of interest, namely nitrate and pesticides, emitted from different agricultural practices and farmer behaviors, including advection, dispersion, reaction, evaporation, deposition, and/or decay in different environmental media, is the protection of public health and environmental safety. The fugacity model, which is an approach commonly used to describe the behaviors of compounds in a complex array of multiple environmental compartments by the accounting of the potentials of transferring amongst the media with multimedia mass balance, was used in this study, as explained in Eq. 1.

$$V_i Z_i \frac{df_i}{dt} = E_i + \sum\left(D_{ji} f_j\right) - D_{ti} f_j \qquad \text{Eq.1}$$

where V_i represents the volume of a given environmental medium i (m^3); f represents the fugacity, namely the potential of a compound for escaping from the medium i (Pa); Z represents the fugacity capacity of the medium i (mole/m^3-Pa); E_i represents the emission rate of the compound (mole/hr); D_{ji}

represents the transport coefficient of the compound from another medium j to the medium i (mole/hr-Pa); D_{ti} represents the decay rate of the compound in the medium i (mole/hr-Pa).

There are several reasons for focusing on the multimedia transmission model. Contaminants including nitrate and pesticides of interest in this study often occur between multimedia media. Risks to destination environments such as different water bodies arise from exposure to contaminants through multiple pathways that encompass different environmental media. Laws for management and regulation of fertilizers and pesticides of concern are founded on an integrated assessment of the overall environmental risks posed by contaminants in multiple media.

The concentrations of nitrate and pesticides at equilibrium after the emission from different agricultural practices and farmer behaviors and activities in different environmental media (e.g., water, sludge, soil, and biota) will be estimated. To develop the model, in the initial stage, a certain area or location in Germany and Taiwan will be selected as the study site, with the environmental properties of the areas being applied as the model input. A complex and realistic model by coupling various processes modules appropriate for the system being considered will be developed. Level III fugacity model that takes into account continuous emission, transformation, active transport, and compartment-specific emissions is adequate for fate assessment of contaminants in this case (Mackay & Paterson, 1991). The process principles that govern contaminant transport and transformation in multimedia environments will be understood, with the emphasis on the parallels and linkages between different media. For instance, a three-dimensional fate and transport system that contains X-, Y- (different locations/regions) and Z-dimensions (considering the depth of multimedia such as air-, water-, soil-, and other phases) could be applied to evaluate the interactions of nitrate and selected pesticides with the biosphere. All the environmental media in the model were connected and considered homogeneous.

Knowledge of different data sources for the modeling will include compiled data and site-specific lab or field testing carried out by the research groups in PuR-TUM and IEE-NSYSU and parameter estimation techniques from which input parameters for the multimedia transmission model will be estimated. The field monitoring will support the demonstration and modification of the model. Lastly, by adjusting the initial and boundary conditions, the impacts of different management approaches and pollution intensities will be predicted. The comparison of the results from the assumptions of different scenarios will quantify the effects of different agricultural activities on the environmental risks of these contaminants of concern in water environments. The whole idea of the system is expected to provide insights into how farmers' behavioral changes in the applications of fertilizers and pesticides affect the chemical fates of nitrate and pesticides in water environments, alleviating the negative impacts of these chemicals on the ecosystem and public health.

5.3.3 Exposure analysis and risk assessment

Besides the negative environmental impact of nitrate, the toxic effect of pesticide exposure could be one issue of public interest. The pesticide concentrations predicted in the water, sludge, and soil phases could be further used to investigate the health risk variations among different agricultural practices and farmer behaviors and pesticide applications. The major exposure pathways may include inhalation, ingestions of water, soil particles, different food types, and dermal exposure to soils. The equations used to estimate the pesticide exposures through these pathways are available in our and other previous publications (CalEPA, 1999, 2015; Chen, Chen, & Lin, 2019; Chen, Huang, & Wang, 2018).

Simply speaking, the pathways including absorption via leaves and roots in a vegetable plant and absorption via roots in the grass and hay silage will be considered to predict the overall concentration in a vegetable plant, grass, or hay silage. The concentration absorbed via roots in a vegetable plant will be estimated. The concentrations in meat, dietary food, or eggs will also be quantified. The ingestion rates used for exposure analysis will consider the findings in the local exposure analyses such as those in Taiwan (HRSAC 2008, TWMHW 2008). The constants used throughout this section will be collected from the local agencies such as the Nutrient and Health Survey in Taiwan prepared by the Taiwan Ministry of Health and Welfare (TWMHW 2008), similar to the National Health and Nutrition Examination Survey done by the Center for Disease Control and Prevention of the U.S. Department of Health and Human Services. The risk of an individual likely to acquire negative health outcomes due to the exposure to pesticides emitted from different agricultural practices and farmer behaviors and pesticide applications in different pathways during the lifetime can thus be calculated and discussed.

5.4 Executive plan

At the initial stage of the study, a comprehensive overview of existing agricultural regulatory policies, agricultural practices and farmer behaviors, mitigation approaches, as well as the corresponding pollutions in the receiving water environments, in both Taiwan and Germany is critical. Next, the links between the farmers' attitudes and the above issues will be studied. These results will provide information regarding the potential of altering the agricultural practices and farmer behaviors by changing the farmers' beliefs and underlying attitudes, thus possibly employing different mitigation approaches for more effective and efficient pollution alleviation. Four inter-related work packages (WP) will be carried out, considering the current overviews in Germany and Taiwan, as well as the case studies in two countries to evaluate farmer’s attitudes towards agricultural nonpoint-source pollution and the implementation of reduction approaches in line with the requirements of the EU Water Framework Directive (Germany) and the Taiwan Environmental Protection Agency (Taiwan).

In Germany, the study area will be carried out in Bavaria and/or Lower Saxony, as Tainan, Kaohsiung, or Pingtung in southern Taiwan in which agriculture is the important industrial type (e.g., Tainan, Kaohsiung, or Pingtung) will be the area of concern in this study. The following stakeholders are expected to provide additional information to support this transnational collaboration:

- Germany Bavaria: the Bavarian Environmental Agency (LfU), the Bavarian State Research Center for Agriculture (LfL), Bavarian Farmer Association (Bayerischer Bauernverband), SWM (Stadtwerke München, urban utility as a universal service provider for electricity, natural gas, district heating, water for Munich). Lower Saxony: Chamber of Agriculture of Lower Saxony) Landwirtschaftskammer Niedersachsen), State Agency for Water, Coast and Environmental Protection of Lower Saxony (Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN), Farmer Association of Lower Saxony (Landvolk Niedersachsen), Water Association Oldenburg-Ostfriesland (Oldenburgisch-Ostfriesicher Wasserverband, OOWV)
- Taiwan: The Environmental Protection Agency of the Executive Yuan; The Council of Agriculture of the Executive Yuan; and the Tainan, Kaohsiung, or Pingtung City Environmental Protection Bureau, as Prof. Chen is frequently a review committee member for the projects supported by these institutes.

Work Package 1 (WP1): State of the Art of Agricultural Conservation Measures for Water Resources and Risk Assessment in Germany and Taiwan

1.1 To compare the standards for nitrate and selected pesticides in surface water and groundwater and to identify the current baseline levels of practice for non-point source diffuse pollution mitigation in two countries.

1.2 To interview experts in the authorities, farmers’ associations, and water resource suppliers for the issues concerning water pollution from agriculture.

1.3 To review the efficiencies of fertilizer (nitrogen) uses for different crops and possible yield loss when applying less fertilization and fewer pesticides.

1.4 To review the literature on farmers’ adoption of water pollution mitigation measures to reveal their attitudes towards various mitigation measures and adoption thereof. This provides insights into whether policy interventions have had limited success to date.

Work Package 2 (WP2): Data Collection and Analysis

2.1. To survey a sufficient number of the farms for database establishment (at least 500 in Germany and representative numbers in Taiwan). The survey will consist of about 50 questions (25 scenario questions, 10 socioeconomic questions, 15 farmer attitudes questions).

2.2. To use the information from the surveys for

   a. investigating whether farmers are overusing fertilizers and pesticides in the study areas;
   b. understanding the farmers' awareness and knowledge that fertilizers, pesticides, and livestock production wastes can pose risks to the environment;
   c. examining the farmers' attitudes to environmental protection and socio-economic barriers towards adopting the conservation measures;
   d. studying the farmers' current attitudes and motivation towards conservation measures;
   e. exploring farmers' attitudes towards future uptake of measures (for example, adopting field heap storage of solid manure, incorporating manure into the soil, reducing fertilizer application rates, using cover crops, and so on);

2.3 To study the fertilizer, namely nitrogen (nitrate), and pesticide issues based on two basic assumptions:

   a. decreasing the amount of fertilizer and pesticide application;
   b. ensuring the minimum requirement of the fertilizer and pesticide uses.

Point 2.3 can be achieved, for example, with catch crops that cover the arable soil even in the cold season. The crops use the fertilizer nutrients in the soil for their growth and thus avoiding the nutrients from being lost in the groundwater. Another example is non-tillage farming. Since this limitedly damages the natural soil structure, reducing the risk of superficial nutrient loss due to wind or water erosion. It is important to understand the farmers' current attitudes towards conservation measures and how likely they are to adopt them.

2.4 To run a preliminary survey to ensure the questions support the data collection on the subjective norm, farmers' attitudes, and perceived behaviors.

Work Package 3 (WP3): Strategy Development for Farmers and other Stakeholders to Address Mitigation Measures

3.1. To selected nitrate and certain pesticides of representativeness in Taiwan and Germany for the following environmental fate and distribution modeling.

3.2. To develop a fugacity model system that will be represented by a three-dimensional equation matrix with the mass balance.

3.3. To identify different scenarios that release nitrate and pesticides of interest into the environment with the results of the surveys mentioned above, as the scenarios assume the potential transport fluxes of nitrate and selected pesticides from different environmental media (e.g., water or soil) and locations (e.g, upstream or downstream).

3.4. To investigate the concentration distributions of nitrate and selected pesticides in different spaces and environmental media at different time scales under different scenarios.

3.5. To support the demonstration and modification of the fugacity model system by the field sampling and monitoring.

Work Package 4 (WP4): Identification and Formulation of Clear Policy Recommendations

4.1. To predict the impacts of different pollution intensities (e.g., different levels of pollution reduction) and management approaches (e.g., different agricultural responses to regulatory restrictions or economic incentives) by adjusting the initial and boundary conditions of the fugacity model system.

4.2. Formulation of complete policy framework to support management if sustainable and effective water resources.

Based on the results from WP1-4, this international collaboration will compare not only German and Taiwanese farmers' attitudes and preferences towards mitigation measures but also governmental policies in the respective country. This work package aims to provide policy recommendations based on an analytical framework, thereof enabling decision-makers to align or adjust their mitigation measures with the consideration of agricultural water pollutions. The policy recommendations are expected to not only provide useful recommendations for the cases in Germany and Taiwan but reference information for other countries that are facing similar agricultural challenges of nitrate and pesticide pollution in water environments.

5.5 Expected results

The understanding of the agricultural practices and farmer behaviors and the associated impacts on the quality of the receiving water environments are essential for sustainable agricultural development. The expected results may include:

- Given the survey results, a baseline of current agricultural practices, as well as insights into farmers' attitudes towards the adoption of mitigation measures and an understanding of the motivations and barriers towards implementing specific measures.
- Given the expert interviews and literature review, the potential alternatives of mitigation measures in Germany and Taiwan and the associated mechanisms (e.g. regulations or monetary incentives) for the feasibility and performances of different measures.
- A mathematical multimedia transfer model that predicts the fate and transport of nitrate and

pesticides after their emissions from different agricultural practices and farmer behaviors.

- Recommendations with the simulation of the potential outcomes that could be used to consider what needs to be changed to influence agricultural (e.g., farmers') adoption of specific mitigation measures to improve the receiving water quality.
- Policy recommendations to redesign/adjust existing water resource management measures to increase effectiveness and sustainability.

5.6 Potential benefits and impacts

This integrated project will support the integration of the Taiwanese partner into the German science arena and will provide unique opportunities for the research groups to form a new partnership in German and Asia. This transnational collaboration will be used to enrich the mutual exchange of knowledge from two scholars and the associated research teams with different professional focus enhancing the scientific know-how. More importantly, given the research goals, study processes, and likely findings from this research, this collaboration is expected to provide insights for both research groups into the risk management of water pollutions from the intensive use of fertilizer, namely nitrate, and pesticides in agricultural activities. Local and/or regional policies in Taiwan and Germany are expected to be improved through learning "good practices" from each other as well as gaining knowledge of innovative policies and technologies used by both participants in the transnational network.

The impact of this project will be important due to the following reasons. First, the Taiwanese-German collaboration will act as an example of East Asian and Western societies, not only comparing their challenges and policy frameworks on water contamination caused by agriculture but also investigating whether cultural differences have a significant influence on farmer's attitudes and perceptions towards various mitigation measures. Besides, Prof. Chen has been the principal investigator of several research projects that were funded by the MOST in Taiwan and studied similar issues. He was also the author of the publications that discussed the associated findings. The experiences of Prof. Chen will provide valuable support for both teams in Taiwan and Germany to successfully implement the project.

- Formation potentials of nitrogenous disinfection byproducts, nitrosamines, haloacetamides, and haloacetonitriles, from pharmaceuticals widely used in Taiwan and their environmental fates in drinking water treatment processes, MOST 109-2811-E-110-507, 2020/09/01-2021/07/31
- Removal of pharmaceuticals and carcinogenic byproduct-formation potentials by anaerobic ammonium oxidation enhanced by graphene oxide composite, MOST 106-2621-M-110-003,

2017/08/01-2018/07/31

- Treatment of municipal wastewater containing pharmaceuticals by using graphene oxide composite coupled with anaerobic fluidized membrane bioreactor and anaerobic ammonium oxidation, MOST 105-2633-E-110-001, 2016/08/01-2017/07/31
- Formation of nitrosamines during disinfection of pharmaceuticals and personal care products, MOST 103-2221-E-110-007-MY2, 2014/08/01-2016/07/31
- Occurrence and fate of N-nitrosamines in drinking water pretreatment and biosolids, NSC 101-2221-E-110-055-MY2, 2012/08/01-2014/07/30
- Formation of N-nitrosamines from urea herbicides during disinfection, NSC 100-2218-E-110-013-, 2011/12/01-2013/05/30
- **Wei-Hsiang Chen***, Ya-Hong Wang, and Teng-Hsiang Hsu (March 2021) "The competitive effect of different chlorination disinfection methods and additional inorganic nitrogen on nitrosamine formation from aromatic and heterocyclic amine-containing pharmaceuticals", *Chemosphere*, 267, 128922 (SCIE; 2019 Impact Factor = 5.778; Ranking 29/265 in Environmental Sciences)
- **Wei-Hsiang Chen***, Tsung-Hsien Huang, and Chung-Ya Wang (January, 2018) "Impact of pre-oxidation on nitrosamine formation from a source to drinking water: A perspective on cancer risk assessment", *Process Safety and Environmental Protection*, 113, 424-434, https://doi.org/10.1016/j.psep.2017.11.016 (SCIE; 2019 Impact Factor = 4.966; Ranking 23/143 in Chemical Engineering)
- **Wei-Hsiang Chen***, Chung-Ya Wang, and Tsung-Hsien Huang (October, 2016) "Formation and fates of nitrosamines and their formation potentials from a surface water source to drinking water treatment plants in Southern Taiwan", *Chemosphere*, 161, 546-554, DOI:10.1016/j.chemosphere.2016.07.027 (SCIE; 2019 Impact Factor = 5.778; Ranking 29/265 in Environmental Sciences)
- **Wei-Hsiang Chen***, Ya-Ciao Yang, Ya-Hong Wang, Chi-Min Li, Kun-Yi Lin, and Jie-Chung Lou (December, 2015) "Effect of molecular characteristics on formation of nitrosamines during chlor(am)ination of phenylurea herbicides", *Environmental Science: Processes & Impacts*, 17(12):2092-2100, DOI: 10.1039/C5EM00308C (SCIE; 2019 Impact Factor = 3.238; Ranking 25/86 in Chemistry, Analytical)

Prof. Sauer at TUM has led many international projects and his research group focuses on the productivity and efficiency of farming operations both at farm and sectoral levels including the factors for technology adoption and diffusion, implications of various forms of risk for farm management and development, effects of food supply chain developments on-farm operations, challenges and opportunities from biotechnological innovations, bioeconomic modelling and the analysis of sustainable resource uses, implications of climate change for agricultural production and resource use, agri-environmental behavior and schemes, food security in developing areas, the contribution of farming to rural development. Both conventional and organic forms of agricultural production are considered where the concept of sustainability plays a prominent role. Regarding agricultural water pollution, thanks to the team in the project for agri-environmental scheme, and previous study in farmers' preferences for chemical fertilizer reduction in Taiwan, their experience could be an asset for this project. Below are selected projects and publication.

- 2009-2014 GENESIS: Groundwater and Dependent Ecosystems: New Scientific and Technological Basis for Assessing Climate Change and Land-use Impacts on Groundwater. *EU FP7*
- 2016-2023 Evaluation of Bavarian Agri-Environment Schemes of the Rural Development Programme 2014-2020. *StMELF, Germany*
- 2019-2022 EFFECT: Contract-Based Agri-Environmental Policy
- 2019-2022 SIGMA NEXUS: Water Management in the Mediterranian. *EU H2020*
- 2020-2024 PONDERFUL: Pond Ecosystems for Resilient Landscapes in Changing Climate. *EU H2020*
- Sauer, J., and A. Wossink. 2013. Marketed outputs and non-marketed ecosystem services: The evaluation of marginal costs. *European Review of Agricultural Economics* **40**: 573–603.
- Sauer, J., and U. Latacz-Lohmann. 2015. Investment, technical change and efficiency: Empirical evidence from German dairy production. *European Review of Agricultural Economics* **42**: 151–175.
- Chang, S.-H.-E., Wuepper, D., Heissenhuber, A., and J. Sauer. 2017. Investigating rice farmers' preferences for an agri-environmental scheme. Is an eco-label a substitute for payments? *Land Use Policy* **64**: 374–382.
- Mennig, P. and J. Sauer (2020). The impact of agri-environment schemes on farm productivity: a DID-matching approach. *European Review of Agricultural Economics*, 47(3), 1045-1093.
- Frick, F. and J. Sauer. 2017. Deregulation and Productivity: Empirical Evidence on Dairy Production. *American Journal of Agricultural Economics* **100**: 354-378.

6. Outputs of collaborations

Please explain the proposed output of the research, and the plans for publication or other dissemination. Please also state the policy agreed between the two groups concerning publication of results and the attribution and exercise of Intellectual Property Rights (IPR).

As a transnational collaboration project, the intended contribution covers several academic fields such as agricultural science, environmental engineering, sustainability science, ecological economics, mathematical and statistical modelling among others. The potential outputs of the collaborations between the research teams in Taiwan and Germany in this transnational project include publishing the results in leading academic forums and informing the key target groups (i.e., farmers, agricultural communities, and central and local governments) with the findings of this project. The deliverables of each WP will include written reports and articles published in scientific journals and oral presentations for academic audiences, target groups, and general public:

1) The dissemination of results will target high impact (disciplinary and interdisciplinary) journals (at least two publications) to ensure the academic impact of this project.
2) Besides academic forums (i.e. at least three international or national conferences), both teams will actively present the results in professional management forums for the relevant authorities.
3) Community and stakeholder meetings (at least two meetings) will provide opportunities for community engagement, discussion, and dissemination of the results of the study.
4) Research staff exchanges are a core part of the project. Joint staff training workshops and/or PhD summer schools will be planned in Germany and Taiwan.

It is worth noting that the project results will be kept for at least 10 years after the project conclusion by two research teams. The report will be accessible on the websites of the IEE-NSYSU as well as PuR-TUM. The relevant IPR policies of NSYSU and TUM will be applied as is common practice in international collaborative research projects.

7. Annex

7.1 Curriculum Vitae of all participants of the project (German and Taiwanese side)

7.2 List of the most important publications of the working group

(Please enclose the application form and the abovementioned two annexes in order into a PDF file and submit it online.)

8. References

CalEPA. (1999). *Air toxics hot spots program risk assessment guidelines: Part 1. The determination of acute reference exposure levels for airborne toxicants*. Retrieved from

CalEPA. (2015). *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*. California

Environmental Protection Agency (CalEPA), Office of Environmental Health Hazard Assessment BUND-Friends of the Earth Germany (2018). Gewässerreport 2018

Bundesinformationszentrum Landwirtschaft (2020). Nitrat im Grundwasser – Was hat die Landwirtschaft damit zu tun? https://www.landwirtschaft.de/diskussion-und-dialog/umwelt/nitrat-im-grundwasser-was-hat-die-landwirtschaft-damit-zu-tun (accessed: 01.02.2021)

Chen, W. H., Chen, G. F., & Lin, Y. C. (2019). Influence of emulsified biodiesel on the emission and health risk of polycyclic aromatic hydrocarbons in the vapor and particulate phases during engine combustion. *Environmental Science and Pollution Research, 26*(13), 13510-13521. doi:10.1007/s11356-019-04805-y

Chen, W. H., Huang, T. H., & Wang, C. Y. (2018). Impact of pre-oxidation on nitrosamine formation from a source to drinking water: A perspective on cancer risk assessment. *Process Safety and Environmental Protection, 113,* 424-434. doi:10.1016/j.psep.2017.11.016

Evans, A.EV., Mateo-Sagasta, J., Qadir, M., Boelee, E., Ippolito, A. (2019). Agricultural water pollution: key knowledge gaps and research needs. Current Opinion in Environmental Sustainability, 36(20-27)

FAO (2018) More people, more food, worse water? A global review of water pollution from agriculture. Edited by Javier Mateo-Sagasta (IWMI), Sara Marjani Zadeh (FAO) and Hugh Turral.

German Environment Agency (2017): Waters in Germany: Status and assessment. Dessau-Roßlau.

Kirschke, S., Häger, A., Kirschke, D. and Völker, J. (2019). Agricultural nitrogen pollution of freshwater in Germany. The governance of sustaining a complex problem. Water, 11(2450)

Mackay, D., & Paterson, S. (1991). EVALUATING THE MULTIMEDIA FATE OF ORGANIC-CHEMICALS - A LEVEL-III FUGACITY MODEL. *Environmental Science & Technology, 25*(3), 427-436. doi:10.1021/es00015a008

OECD (2012) Water quality and agriculture-meeting the policy challenge. OECD studies on Water. Paris

OECD (2017) Diffuse pollution, degraded waters: emerging policy solutions. Paris

Szöcs, E., Brinke, M., Karaoglan, B. and Schäfer R.B. (2017). Large Scale Risks from Agricultural Pesticides in Small Streams. Environmental Science and Technology, 51(13)

.