

HOW MUCH DOES 1 DEGREE CELSIUS WORTH? - THE ECONOMIC VALUE OF PADDY FIELD HEAT SINK EFFECT EVALUATE BY THE CONTINGENT VALUATION METHOD

COMBIEN VAUT 1 DEGRES CELSIUS? LA VALEUR ECONOMIQUE DERIZIERE DISSIPATEUR EFFETE VALUER PAR LE PROCÉDÉ CONTINGENT D'ÉVALUATION

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ABSTRACT

Facing the global warming problem, the existence of paddy fields may be one of the natural solutions to the regional temperature mitigation. The paddy cultivation, compared with other vegetation, may have more functions such as production, ecology and social lives. This study evaluate the economic valuation of paddy field heat sink effect by contingent valuation method. Through the paddy field heat sink effect and in the face of worsening extreme global climate, the WTP of the general public in Taiwan for the decrease of 1°C with regard to the regional microclimate was evaluated. It was found that the public's total economic value for the temperature decrease of 1°C in the regional microclimate amounted to approximately NTD284 billion, thus indicating the general public's great concern for the issue of rising temperatures. In this regard, the economic value of 1°C must not be underestimated. In conclusion, it need to be more cautious while making decisions in changing paddy fields to other land uses.

Keywords: Paddy Fields, Heat Sink Effect, Contingent Valuation Method

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1. Introduction

The crisis of global warming has received growing world attention. According to scientific research, the global temperature only increased by 0.6 degrees Celsius (°C) over the last one hundred years. However, the rate of global average temperature increase is expected to exceed 3 degrees Celsius (°C) before the end of the 21st century, which is bound to lead to severe draughts, floods, and famine. Researchers have found that Taiwan's sea level rises annually by 0.32 centimeter, which is higher than the global average sea level rise of 0.1 to 0.2 centimeter every year. It is speculated that Taiwan's sea level rise will exceed 3 centimeters after 10 years, which will eventually aggravate environmental problems in coastal areas. Under the impact of global warming, the sea level rises year by year. In a decade, this problem will pose greater threats on people's living environment or natural ecology.

The main cause of this abnormal temperature rise is that there is increased artificial exhaust heat, such as hot air discharged from air conditioning equipment installed in the many high-rise buildings in the city, air exhaust of moving vehicles, artificial land cover, reduced evaporation due to diminished green spaces, water surfaces, and agricultural land, urban pattern changes, such as reduced cooling points of urban land area (large green spaces or water surfaces), weak weathering due to urban pattern changes, etc. Complemented by low-temperature suburbs, a high-temperature city is like a heated island, and this phenomenon is known as the "urban heat island effect" in meteorology.

Past studies show (Chiueh, 2012. Chiueh, et. al. ,2011.,Chen-Yi Sun, 2008; Tzu-Ying Chang et al., 2005; Fan-Tzu Kuo, 2005; Kuan-Ting Chen, 2000; Shao-Chen Liu et al., 2003; Tan et. al., 2006; Cheng et al., 2008) agricultural lands, green spaces, or water surfaces have relatively lower temperatures compared to peripheral areas and have a cooling effect. Compared to various plants that moderate or lower temperatures, the cultivation of paddy fields not only has the function of moderating temperatures, but also possesses production, ecology, and life-related functions. Because of their long-term ponded or moist growth environment, paddy fields have the functions of manmade wetlands. In the process of evaporation, a large amount of heat from the surrounding environment is absorbed to form the heat sink effect. If located in the metropolitan area, contrary to the heat island effect, paddy fields can functionally form the cooling effect. Tan and Hsu (2009) observed large areas of metropolitan areas and paddy fields in Taiwan through satellite telemetry and found that if 11% of the paddy field area in one rice cultivation area developed into the metropolitan area, the temperature in the area would increase by 1°C.

Concerning the current global warming issue, the existence of paddy fields is one of the ways to mitigate regional temperatures and achieve a balance in nature. With their effect put to proper use and through proper adjustment of the regional microclimate, the issue of global warming in a regional or even a global scale can be alleviated. Hence, the contingent valuation method (CVM) was adopted in this study to evaluate the benefits of the heat sink effect in central and southern Taiwan. Additionally, through the heat sink effect of rice fields, the price the Taiwanese people are willing to pay for every 1°C temperature decrease in the regional microclimate in the face of worsening extreme weather around the world.

2. Heat Sink Effect in Paddy Fields

The "heat island effect" is a phenomenon that emerged in the 1960s, the phenomenon of a regional climate in major cities around the world. Specifically, it refers to unusually higher temperatures from morning to after sunset in some parts of the city than surrounding areas. The discovery of this phenomenon is attributed to the emergence of satellites that enable infrared aerial shots of Earth. The original purpose of taking shots was for taking meteorological measurements needed to analyze the composition of rain clouds. Later on, from the infrared images, people discovered significant differences in temperatures in urban areas, making the city appear like a floating island amidst the surrounding areas.

In one region, variances in the heat sink effect are seen due to differences in land cover and location, thus the resulting heat sink effect. Due to interactions between the thermodynamic cycle and the heat flux of the land cover, regional temperature differences are produced. If this effect can be put to good use and the regional microclimate can be adjusted, the global warming problem will be alleviated.

Crop paddy rice planting patterns require massive irrigation. Paddy rice, during seedling, tilling, differentiation, and other vegetative growth stages, requires infiltration to maintain the normal growth of crops. During evaporation, paddy fields will absorb air and thermal energy on the ground surface to reduce the temperature of paddy fields and the air in the surrounding, which leads to a cooling effect known as "paddy sink effect". This effect is centered on paddy fields. The temperature of surroundings increases with increases in distance. Drawn in a temperature line chart, paddy fields appear to be a "cool island" erected on the hotter "ocean" of artificially paved surrounding ground surface, thus the name "cool island effect." Tan and Hsu used satellite telemetry to carry out observation of large areas of urban and paddy field areas in Taiwan. It was found that if 11% of the paddy field in one rice cultivation area is developed into an urban area, the temperature in the region will increase by 1°C.

3. Contingent Valuation Method (CVM)

The main purpose of the Contingent Valuation Method (CVM) is to express people's preference for wealth and goods in monetary amounts. The evaluation method is to establish a hypothetical market. Through the questionnaire survey method, people's Willingness to Pay (WTP) or their Willingness to Accept (WTA) standard changes or environmental resource quality changes were surveyed. The data obtained from the questionnaire was used to estimate the benefits or costs of specific environmental quality changes (Kai-Li Chen, Pei-Ying, Wu, 2003; Ming-Sheng Wang, Tung-Wei Hung, 2000).

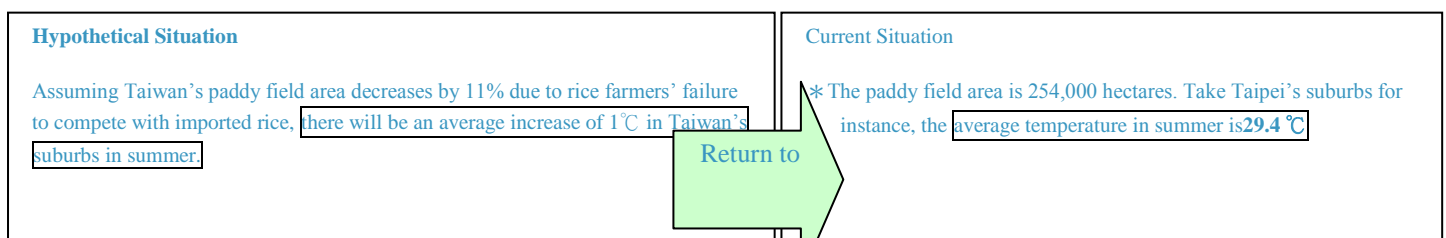
Paddy fields with the temperature regulation function are not general wealth and goods in the sense that there are no real markets or transactions. Therefore, their economic value cannot be determined through direct observations of market prices or number of transactions. In this study, a hypothetical direct market evaluation method, the CVM, was used to evaluate the economic value of heat sink effectiveness.

3.1 Questionnaire and Sampling Design

The CVM was used in this plan to evaluate experts' evaluation of the benefits of the paddy heat sink. The CVM respondents must first have certain knowledge of items evaluated. Therefore, experts specialized in paddy field environment and production fields were selected for interviews. In the first page of the questionnaire, information pertaining to the benefits of the paddy heat sink is provided. The first part of the questionnaire examines the respondents' knowledge and their degree of emphasis for the benefits of the paddy heat sink. The second part of the questionnaire covers descriptions of the hypothetical market through the CVM and the price inquiry questions. First, the descriptions are as follows:

In 2009, more than 254,000 hectares of paddy fields in Taiwan were used for planting rice, an average of 5,866kg per hectare. The infiltration planting pattern in the fields attracted air and thermal energy on ground surfaces and reduced the temperatures in the paddy field areas and the surrounding air, thereby achieving a cooling effect. The phenomenon of regional temperature drops, known as the paddy sink heat effect, was also produced. With this effect put to proper use and the regional microclimate adjusted, the problem of regional or even global warming can be mitigated. However, after joining the WTO, because of the lower foreign agricultural production costs compared to Taiwan's, the price of imported rice is lower than locally produced rice. Since Taiwan's rice has no price advantage over imported rice, arable land area is bound to decrease as a result. According to research of the Council of Agriculture, Executive Yuan, if 11% of the paddy field in one rice cultivation area is developed into an urban area, the temperature in the region will increase by 1°C.

A hypothetical situation was further proposed:



The respondents were then asked: "If Taiwan's paddy field area decreases by 11% due to rice farmers' failure to compete with imported rice, which results in an average increase of 1°C in Taiwan's suburbs in summer, if every kilogram of Taiwan rice is \$_____ more expensive than imported rice that has the same quality as Taiwan rice, will you be willing to continue buying local rice so that the regional temperature can be decreased by 1°C to return to the current standard? (The current average price is provided to respondents for reference).

For price inquiry in amounts, 15 amounts (\$_____) were set. In the last part of the questionnaire, the socioeconomic variables of the respondents were inquired to facilitate data analysis.

3.2 Empirical Results

The LIMDP software was used in this study to estimate the bid estimate equation through the logit model. The approximation approach of Newton's method was also adopted to estimate the various bid estimation equations using the Maximum-Likelihood Estimation (MLE) and substitute the mean values of the variables to calculate the mean WTP. Empirical results, as shown in Table 4, show that price inquiry in amounts and WTP had a negative correlation, which is in line with the expectations in the economic theory. Moreover, the greater the respondents' access to information, the more willing they are to pay to maintain the benefits of the paddy heat sink, especially the female respondents who were relatively more willing to do so. In terms of the significance of variables, the price inquiry in amounts reached the significant standard of 97.5%, information reached the significant standard of 95%, and the logit model reached the correct prediction rate of over 87%, indicating the empirical model's excellent correct prediction rate as a whole.

Table 4 The empirical results of the LOGIT model

The Empirical Results of the LOGIT Model		Coefficient	Standard Deviation	T Value	P Value
Intercept	ONE	0.331107	0.994749	0.332854	0.739244
Price inquiry in amounts	PRICE_DI	-0.00927	0.002712	-3.41849	0.00063
Information	KNOW	0.116233	0.04921	2.36197	0.018178
Gender	GENDER	-0.55573	0.60415	-0.91986	0.357649
No. of people in household	HOME_NUM	0.153417	0.143974	1.06559	0.286609
Area of residence	RESIDENC	0.191724	0.166258	1.15317	0.24884
Correct prediction = actual 1s and 0s correctly predicted		87.407%			
WTPTEM = 249 NTD/kg rice					

Based on the estimate results using the CVM model, in order to maintain the benefits of the paddy heat sink without having the 11% decrease, the expert respondents are willing to pay NTD249 every year for every kilogram of rice. In other words, in order to keep the temperature from increasing by 1°C, the expert respondents are willing to pay NTD249 per kilogram of rice every year.

The calculation model is as shown in the following equation:

$$\text{Valuation} = \text{WTP} * \text{H} * \text{R} * \text{E}$$

Whereas,

V: Benefits of the regional paddy heat sink; unit: NTD

WTP: The price respondents are willing to pay in order to prevent the temperature increase of 1°C. According to the empirical results in this survey study, the respondents are willing to pay NTD249 per kilogram of rice every year.

H: The number of households in the region affected.

R: The average kilograms of rice consumed by every household every year.

4. CONCLUSION

Facing the global warming problem, the existence of paddy fields may be one of the natural solutions to the regional temperature mitigation. The paddy cultivation, compared with other vegetation, may have more functions such as production, ecology and social lives. This study evaluate the economic valuation of paddy field heat sink effect by contingent valuation method. Through the paddy field heat sink effect and in the face of worsening extreme global climate, the WTP of the general public in Taiwan for the decrease of 1°C with regard to the regional microclimate was evaluated. It was found that the public's total economic value for the temperature decrease of 1°C in the regional microclimate amounted to approximately NTD284 billion, thus indicating the general public's great concern for the issue of rising temperatures. In this regard, the economic value of 1°C must not be underestimated. Besides the temperature mitigation function, the paddy fields also have other functions such as ground water recharge, and flood prevention, and their external benefits. The 0.75°C reduction while converting 5% paddy fields to the water ponds. If the paddy fields near urban area were converted to build-up areas continuously, the urban heat island effect may become more significant and other harmful results such as concentrated rainfall, floods, drought, short of harvest, and so on. In conclusion, it need to be more cautious while making decisions in changing paddy fields to other land uses.

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