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APPLYING THE RESIDUAL VALUE MODEL TO DEVELOP ENVIRONMENTAL FISCAL TRANSFER POLICY: ASSESSING THE ECONOMIC VALUE OF AGRICULTURAL WATER IN THE ULU MUDA PERMANENT FOREST RESERVE (UMPFR), MALAYSIA

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This article evaluates the potential of Ecological Fiscal Transfer (EFT) as a policy tool for biodiversity conservation by estimating the economic value of ecosystem services in the Ulu Muda Permanent Forest Reserve (UMPFR). The selection of UMPFR is significant, as it supplies agricultural water to the Muda Agricultural Development Authority (MADA), Malaysia's largest paddy granary. A total of 405 respondents from four different regions in the MADA area were interviewed face-to-face. Results from the Residual Value Model (RVM) indicate that the economic value of agricultural water services provided by the UMPFR is RM422.05 million per year. These estimates offer valuable insights for policymakers, highlighting the importance of EFT allocations from the Malaysian Government to preserve and conserve UMPFR. With proper adjustments and considerations, these estimates may also serve as a proxy for compensating other forests that provide similar ecosystem services for paddy cultivation.

Keywords: Ecological Fiscal Transfer, Residual Value Model, Ulu Muda Permanent Forest Reserve, agricultural water, Muda Agricultural Development Authority

INTRODUCTION

Research on biodiversity conservation has been conducted by many researchers (Alexandre et al. 2024, Norderhaug et al. 2023) for many purposes. One of the key research topics is on the economic instruments for financing biodiversity conservation (Izquierdo-Tort et al. 2024, Nyanghura et al. 2024). Various economic instruments have been used which include Payment of Environmental Services (PES) (Izquierdo-Tort et al. 2024), Environmental Reserve Quotas (Roque et al. 2024), Forest Concessions (Sist et al. 2021) and Tourism Concessions (Valentina 2018). Among these instruments, PES was the very popular for environmental policies (Salzman 2018, Jennifer & Hendrik 2014, Gómez-Baggethunet et al. 2010), and the instrument was used for valuing biodiversity-related services, such as agroforestry systems (Montagnini & Del Fierro 2024, Jennifer & Hendrik 2014), biodiversity and carbon sequestration (Kangas & Ollikainen 2022), and landscape features (Lū et al. 2020). The instrument, however, has some challenges (Jennifer & Hendrik 2014), limitations (Wunder 2015, Daniels et al. 2010) and only suits private resource user (De Paulo & Sombral Camões 2019).

The additional requirement for PES programs related to result in environmental benefits especially involving payments causes significant problem. Furthermore, PES systems typically reward larger landowners or holders of well-defined property rights. They may marginalise smaller or communal landholders which also support conservation initiatives, leading to problems with equity and accessibility

(Muradian et al. 2013). Transaction costs are another significant obstacle; especially in developing nations where property rights may be ambiguous. The costs of setting up and running PES programs, including contract negotiations and compliance monitoring can be unaffordable (Wertz-Kanounnikoff 2006). In addition, risk may arise in which conservation efforts in one area may unintentionally lead to increasing deterioration of another, undermining the overall goals of PES projects (Dennis et al. 2011, Engel et al. 2008). These limitations have motivated academics and policymakers to investigate alternative instruments, such as Ecological Fiscal Transfers (EFT), to fill some of the gaps in PES for larger biodiversity conservation goals (Busch et al. 2021).

Ecological Fiscal Transfer (EFT) is an alternative to compensate for biodiversity conservation and promote the creation of new municipal protected areas and programs related to solid waste management conservation, watershed protection, and landfills (De Paulo & Sombral Camões 2019). EFT is also an intergovernmental fiscal policy whereby the federal government transfers public money to the state based on the latter's ecological indicators. It is a compensation mechanism in which the federal government covers conservation costs to states that actively work to conserve biodiversity for the nation's benefit. The policy currently seems to be the most promising approach to combat issues related to biodiversity reduction and degradation. Since its inception, it has been used for financing biodiversity conservation in countries like Brazil, India, and China (Yang et al. 2023, De Paulo & Sombral Camões 2019). What was being disputed by researchers (Rodríguez-Labajos & Martínez-Alier 2013) is to determine and transfer these economic values onto good use.

Economic values can be determined *via* inductive and deductive methods. For inductive methods, economists (Isacs et al. 2024, Xepapadeas 2024) have proposed two techniques to estimate the values—a revealed and a stated technique. The advantages and drawbacks of both techniques have been discussed by many researchers such as Xepapadeas (2024) and Spash (2013). However, this article does not intend to discuss further details of these inductive methods. For deductive methods, the Residual Valuation Model (RVM) is the technique commonly used by researchers (Upadhyaya et al. 2023, Rodrigues et al. 2020). However, little is known about the RVM in valuing ecosystem services in Malaysia. When the economic values are available, policymakers could use such estimates to implement EFT in the country. Thus, the objective of the study is to estimate the economic value of ecosystem of a agricultural water service using the RVM technique. The current research selects Ulu Muda Forest Reserve (UMPFR) as the study site due to its role as a water catchment area, supplying water for paddy cultivation. The selection of UMPFR is crucial because it supplies agricultural water to the Mada Agricultural Development Authority (MADA), the largest paddy granary area in Malaysia. The RVM results show that the economic value of the ecosystem water service in UMPFR is RM422.05 million in a year.

Biodiversity Finance-Ecological Fiscal Transfer

Many researchers have studied the importance of ecosystem services to benefit humankind. These studies include but are not limited to the benefits of human health (Landrigan et al. 2024, Eichholtzer et al. 2024, Leddin 2023), climate change (Gillingham et al. 2023, Leddin 2023) and renewable energy (Gilad et al. 2024). Conserving biodiversity has become an important global agenda and many organisations have been established to support the conservation of biodiversity through concerted efforts.

One of the pressing issues in biodiversity conversation is in the area of finance. The emergence of the EFT economic instrument as an alternative to methods such as PES and has shed light on the future of biodiversity existence for the benefit of future generations. Countries like Brazil, India and China have extensively applied the EFT in financing their biodiversity conservation programs. However, implementing EFT is challenging, particularly in determining its economic values. This valuation topic has been discussed for many years and continues to be a significant focus.

Ecosystem services, such as the benefits provided by forests are unique. Unlike normal goods, they are not traded in the market and thus have no price tag. Nevertheless, excluding them from the decision-making framework can lead to market failure issues (Young & Loomis, 2014). Therefore, efforts made to determine their market value are upmost important. These value can be assessed based on the ecosystem services provided to people and the environment. For instance, forests offer numerous benefits; including preventing soil erosion prevention, natural water filtration and CO_2 absorption. However, the current article focuses on the role of forests in supplying agricultural water for paddy cultivation.

Environmental economists (Salzman et al. 2018, Jennifer & Hendrik 2014) have advocated for PES to determine the economic values of ecosystems. In brief, the method requires the receivers of ecosystem benefits to pay a certain amount of money to the providers of these benefits. PES has been applied in valuing ecosystem services including air quality (Jennifer & Hendrik 2014), water quality (Aguilar et al. 2018) and marine protected areas (Castaḫo-Isaza et al. 2015). The method is particularly applicable when the provider owns the environmental goods. However, PES is not a fool proof solution. De Paulo & Sobral Camões (2019) pointed out that the method is suitable only if the transactions involve private resource users. However, there is concern on the suitable applicable solution especially on forests owned by the government.

In the 1990s, countries such as Brazil and Portugal adopted EFT, believing that this transfer payment technique could address the limitations of PES. The EFT business model includes various forms of financial aid, such as transferring funds from federal to local governments and/or providing special budgets for biodiversity conservation. These budgets could be annual or one-off. More details on the instrument can be found in Busch et al. (2021). However, EFT is not free from criticism, particularly regarding the determination of economic transfer values. Typically, these values are derived from ecological indicators (Busch et al. 2021). To the best of our knowledge, no published article comprehensively explains the process of linking economic values and ecological indicators. Due to this limitation, this article seeks an alternative way to estimate the economic transfer value for EFT purposes.

Young and Loomis (2014) asserted that the economic values of water services and benefits can be estimated using two broad methods—inductive and deductive. Popular inductive methods include the Travel Cost Method (TCM), Contingent Valuation (CVM), and Choice Experiments (CE) (Isacs et al. 2024, Xepapadeas 2024, Samdin et al. 2019). For deductive methods, researchers can choose from options such as Computable General Equilibrium, Input-Output, and Mathematical Programming (Bagheri et al. 2024, Pfunzo et al. 2024, Mu et al. 2024).

The Residual Valuation Model (RVM) is an economic valuation method under the deductive methods category. Using an input-output framework, the model calculates the value of ecosystem services as the remainder of net income after all other relevant costs are accounted for (Young & Loomis 2014). In other words, RVM estimates the value of water, for instance, after considering all costs and yields of agricultural products. The early study using RVM to value water resources for agricultural purposes was conducted by Gray and Young (1974). Since then, the method has been used by many researchers (Upadhyaya et al. 2023, Rodrigues et al. 2020, Berbel et al. 2011).

RESEARCH METHODOLOGY

Study Area

The MUDA area is Malaysia's important agricultural landscape, especially for paddy production. It accounts for 40% of Malaysia's net paddy production. The total area of MUDA is 100,685 hectares, with 80,612 hectares in Kedah and the remaining 20,073 hectares in Perlis. The management of MUDA has divided the area into four regions: Region I (Perlis), Region II (Jitra), Region III (Pendang), and Region IV (Kota Sarang Semut). These division helps to manage the agricultural water supply efficiently, which is crucial for paddy cultivation especially during the dry season. Each region has its own network of canals and water control systems to ensure sufficient irrigation of the paddy fields. MADA is essential for supporting the country's food security and agricultural economy. MADA regions and water dams are shown in Figure 1.

The agricultural practices in the MUDA

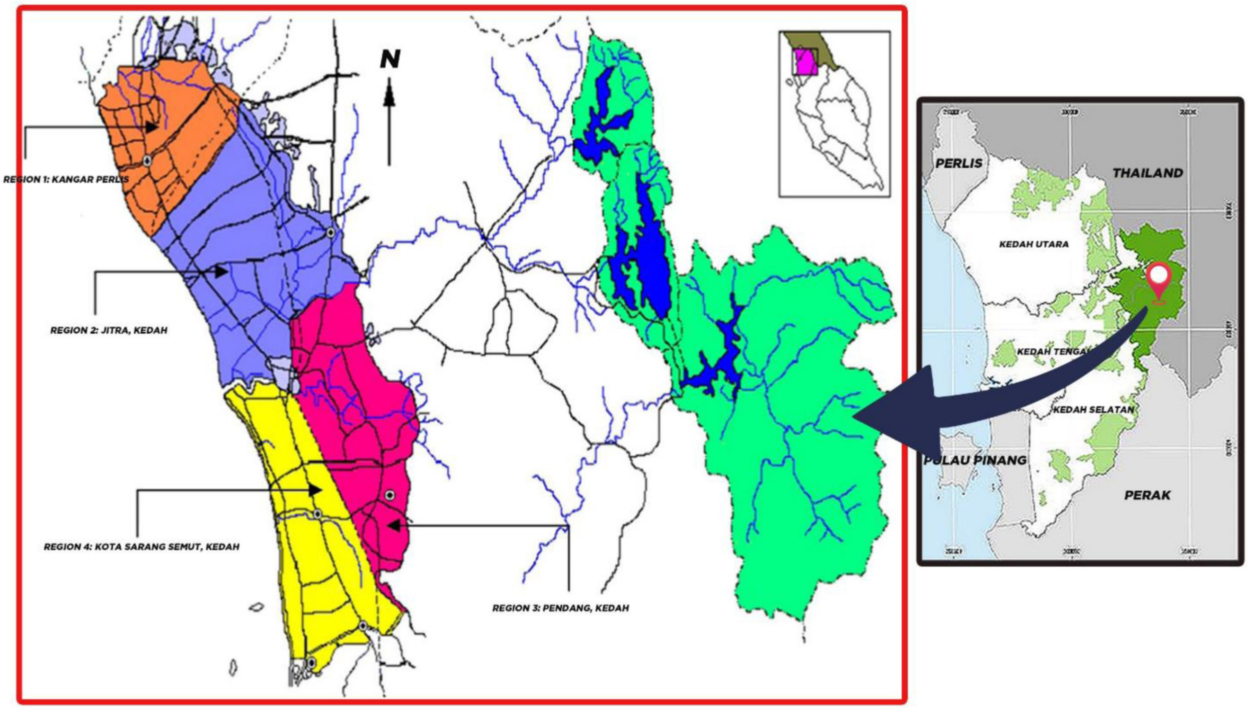

Figure 1 MUDA's regions and Ulu Muda Permanent Forest reserve (UMPFR) (Sources: Irrigation and Agriculture Division System, Ministry of Agriculture, Malaysia and Forest Research Institute of Malaysia)

area are well-adapted to the local climate and water availability. The two distinct planting seasons, Season 2 (S2) and Season 1 (S1), align with the rainy and dry seasons respectively, allowing farmers to utilise the most abundant water sources during each period. During the S2 season, rainfall serves as the primary water source, which is highly beneficial for paddy cultivation as it reduces the need for irrigation. In contrast, during the S1 season, the area relies heavily on water supplied by UMPFR, which is essential during the drier months. This strategic use of different water sources throughout the year helps ensure stable paddy production, which is crucial for Malaysia's food security.

Data Collection

Questionnaire were used to gather information from the respondents. Data collected were on paddy cultivation, socio-demographics, and the costs associated with cultivating paddy such as pesticides, seeds, and labour. The process of developing the questionnaire began with desktop research, during which all relevant published articles and reports were reviewed. This review focused mainly on the inputs and expenses involved in paddy cultivation.

Meetings with MADA officers were held to gather their opinions and thoughts on the suitability of the prepared questionnaire. One of their main concerns and recommendations was to separate the costs and expenses components into three periods: preparing the land, cultivating paddy, and harvesting paddy. Three focus group meetings were conducted with farmers and MADA officers before collecting the data. A total of 25 participants from Regions 1, 3, and 4 attended these meetings. With the aid of the volunteers, 405 were interviewed face-to-face in December 2021.

According to the study from Krejcie and Morgan (1970), the sample size is sufficient to represent the 57,635 registered farmers in MADA (MADA 2021). The calculation from Krejcie and Morgan (1971) in determining the sample size is shown in Equation 1. The total sample was then stratified for each region based on the region's area. For instance, the area of Region 1 is 20,073 hectares, encompassing 20%

Table 1 Respondents of the survey

Region	Paddy Area (hectare)	Area Percentage (%)	Target Respondents	Surveyed Respondents
Region 1 (Perlis)	20,073	20	81	75
Region 2 (Jitra)	32,595	32	131	135
Region 3 (Pendang)	22,682	23	91	90
Region 4 (Kota Sarang Semut)	25,335	25	102	105
Total	100,685	100	405	405

of the MADA planting area. Thus, based on 405 total respondents, the number of targeted respondents for Region 1 is determined by multiplying 20% with 405 respondents, resulting in a target of 81 respondents. However, in the actual survey, we interviewed 75 respondents. Meanwhile, the area for Region 2 is 32,959 hectares, which is equivalent to 32% of the MADA area. This required us to interview 131 respondents, but we managed to get 135 responses. The breakdown of these interviewed respondents is shown in Table 1.

$$s = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2 P(1-P)} \qquad \text{Equation 1}$$

where s = sample size, X^2 = Chi-square value for 1 degree of freedom at the desired confidence level, N = population size, P = population proportion and d = recision expressed as a proportion

The Residual Valuation Model (RVM)

Young and Loomis (2014) asserted that the application of the Residual Valuation Model (RVM) contain two assumptions. First assumption mentioned the water for agriculture is the main input in production. Second assumption suggested that the value of agricultural products can be divided among each input used in production. For example, if capital, labour, and water are used in paddy cultivation, then the value of the paddy yield is the sum of the inputs: capital, labour, and water. The mathematical function of RVM, as shown in Equation 2, is derived from these two assumptions (Young & Loomis 2014).

$$TVP_Y = (VMP_K * Q_K) + (VMP_L * Q_L) + (VMP_W * Q_W) \qquad \text{Equation 2}$$

where TVP_Y = the total value of agricultural output paddy; VMP = the marginal value of respective input; Q = the input quantity; and subscripts K, L and W = capital, labour, and water inputs, respectively. In this study, all input prices were collected from the survey, except for agricultural water. By rearranging Equation 2, the contribution of water input to agricultural production can be estimated as shown in Equation 3.

$$(VMP_W * Q_W) = TVP_Y - [(VMP_K * Q_K) + (VMP_L * Q_L)] \qquad \text{Equation 3}$$

As demonstrated in many microeconomics textbooks the marginal value of a good equals the input price of the good at its optimal level of production. Thus, the VMP is equal to the price of that respective input such as (P_K) for capital and (P_L) for labour at this optimal level. By substituting the VMP with their respective input price, we can calculate the price of water input for agricultural products (P_W) can be calculated by solving Equation 4.

$$P_W = \frac{TVP_Y - [(P_K * Q_K) + P_L * Q_L)]}{Q_W} \qquad \text{Equation 4}$$

RESULTS AND DISCUSSION

Respondents' socioeconomic

In order to generate the surveyed respondents profile, various socioeconomic characteristics were collected including farmer age, gender, education level, and paddy plantation size. Although these characteristics may not have influenced the economic value of agricultural water, it is important for readers to understand

Table 2 Respondents' socioeconomic

Attributes	n = 405 respondents	
Ethnic Group	Malays	400 (99%)
Gender	Male	393 (97%)
Age	Average	52.71
	Min	22
	Max	83
Education	No Formal Education	0
	Primary School	40 (10%)
	Lower Secondary School	73 (18%)
	High Secondary School	231 (57%)
	College/ Diploma/STPM or Vocational Institute	56 (14%)
	University Degree	5 (1%)
Duration of Planting Paddy (in years)	Average	24.7
	Min	1
	Max	60
Paddy Field Size (in *Relong*)	Average	13.4
	Min	0.5
	Max	150

the background of the community. The majority of surveyed farmers are Malay male, with an average age of 53 years. From the total number of respondents surveyed, 50% attained a high secondary level education, followed by the lower secondary school. For College/Diploma and Vocational Education, the percentages were 18% and 14%, respectively. The respondents have extensive experience in paddy cultivation, with an average of 24.7 years and the maximum number at 60 years' experience. The farmers' socioeconomic status details are shown in Table 2.

Economic value of agricultural water

Table 3 illustrates the calculation of water usage for paddy cultivation. MADA (2021) reported in their annual paddy report that the total quantity of water used for this purpose in S2/2020 and S1/2021 was 1,482,197,647 m^3 and 1,323,556,110.48 m^3, respectively. The water was distributed to the paddy fields across three growth phases—vegetative, reproductive, and mature/harvest—over 95 days (Han et al. 2022). It is worth noting that several factors, such as evapotranspiration (ET), seepage, and percolation (Mohamed Azwan et al. 2010), contributed to water loss in paddy fields. However, this study only considers the ET factor. Due to the unavailability of specific data, the ET for both S1 and S2 are assumed to be the same. In the MUDA area, the ET rate is 6 mm per day, equivalent to 573,904,500 m^3 per season. After accounting for the ET rate and other water sources, the amount of water from UMPFR was 145,326,907.84 m^3 in S2/2020 and 244,386,424.86 m^3 in S1/2021.

In the MADA region, a relong is a rice cultivation area that is equivalent to 30,976 square feet or approximately 0.7111 acres. Considering the size of MADA in relong, our calculations showed that the irrigation water use for per relong was 415.84 m^3 in S2/2020 and 699.29 m^3 in S1/2021. In the calculation for the monetary costs of paddy cultivation, the calculated costs are not only limited to expenses for paddy fertiliser, pesticides, and labour. All these costs were measured per relong. The calculations show that the average cost of planting paddy in S1/2021 was RM1,336.50 per relong, which is higher than the cost in S2/2020 at RM779.92 per relong. The average gross paddy yields per relong for S1/2021 and S2/2020 are 1.91 and 1.88 tonnes, respectively. Meanwhile, the gross paddy price remained constant at RM1,200.00 per tonne. By inserting all the information into Equation 4, the results show

Table 3 Water usage for paddy cultivation

Season	WATER USAGE			EVAPOTRANSPIRATION (ET)				NETT WATER USAGE (m^3)	WATER FROM MUDA DAM (in %)[#]	NETT WATER USAGE FROM ULU MUDA DAM (m^3)	PADDY AREA (in/*relong*)	AVERAGE WATER USAGE FROM MUDA DAM (m^3/*relong*)
	Acre-foot	Conversion factor	m^3	m^3	hectare	days	m^3					
	(a)	(b)	(c) = (a) × (b)	(d)	(e)	(f)	g = (e) × (f) × (g)	h = (c)−(g)	(i)	j = (h) × (i)	(k)	l = (j) / (k)
S2/2020	1,201,639.00	1,233.48	1,482,197,673.72	60.00	100,685	95.00	573,904,500.00	908,293,174.00	0.16	145,326,907.84	349,478	415.84
S1/2021	1,073,026.00	1,233.48	1,323,556,110.48	60.00	100,685	95.00	573,904,500.00	749,651,610.00	0.33	244,386,424.86	349,478	699.29

Source: MADA Annual Report (2021)

that the mean estimated value of agricultural water was RM3.54 m^{-3} during S1 and RM1.35 m^{-3} during S2. These estimates are consistent with findings from previous studies. For instance, a study by Kohzad et al. (2020) in Iran found that the economic value of agricultural water for rice depends on the production function used. The transcendental function estimated the value at RM2.06 m^{-3}, while the generalised Leontief function estimated it at RM2.36 m^{-3}. However, a study by Permana and Kusumawardani (2021) in East Java found the value to be RM1.25 m^{-3}.

Based on the fact that the water consumption per relong in S2/2020 and S1/2021 is 415.80 m^3 and 699.20 m^3, respectively, and the total paddy area is 349,377 relong, the total economic value of irrigation water in S1 and S2 is RM513.3 million and RM329.8 million, respectively. Thus, the average annual economic value for paddy water is at the amount of RM422.05 million.

CONCLUSION

In the current study, Residual Value Model was used to value the forest ecosystem services of the Ulu Muda Permanent Reserve Forest in Malaysia. It focuses solely on the economic value of agricultural water used for paddy cultivation in the MUDA granary area. The main objective of this economic valuation is to investigate the feasibility of implementing the Ecological Fiscal Transfer economic instrument. By definition, residual value refers to the remaining value after all inputs have been paid. It represents an average value, typically estimated over the long term (Berbel et al. 2011). Following this definition, respondents in this study were asked to report all expenses incurred in cultivating their paddy. The obtained information was then processed to estimate the economic value of agricultural water.

Preserving forests such as the Ulu Muda Permanent Reserve Forest (UMFR) entails opportunity costs, primarily the inability to develop the area for other purposes that produce monetary return. In order to offset these opportunity costs, environmental economists proposed the Ecological Fiscal Transfer (EFT) policy. This policy requires authorities to provide monetary compensation for biodiversity conservation efforts. In this study, the Residual Value Model (RVM) is used to estimate the economic value, enabling the calculation of appropriate compensation under the EFT policy. A total of 405 respondents were interviewed and were asked to report their monetary expenses related to paddy cultivation at market prices. These expenses were then used to estimate the value of water for paddy cultivation purposes.

The analysis of collected expense information using RVM shows that the annual average economic value of paddy water is RM422.05 million. This economic value reflects the market price for the paddy water services provided at UMPFR. In other words, it represents the economic value of ecosystem services for agricultural water used in paddy cultivation. These findings have policy implications for EFT, particularly for developing countries like Malaysia.

These estimated values provide valuable insights for policymakers, emphasising the need for EFT allocations from the Malaysian Government to preserve and conserve UMPFR. With appropriate adjustments and considerations, these values will serve as a proxy to compensate other forests that provide similar ecosystem services for paddy cultivation. Based on the respondents' responses to the questionnaire, the current study confidently show that the application of RVM is feasible in the study area. Therefore, the possibility of applying this RVM in other areas of Malaysia is considered high and feasible.

However, the findings must be interpreted cautiously due to the RVM valuation method applied in the study. Firstly, the method relies heavily on precise cost estimates for paddy inputs. Generally, keeping monetary expense records is not a common practice among farmers. During the interview sessions, many respondents had difficulty accurately recalling their input expenses and had to approximate the amounts, as they did not keep records. Therefore, in order to apply this RVM in the future, researchers are advised to cooperate with farmers to record their monetary expenses prior to the research. Secondly, the RVM is significantly sensitive to market prices and climate conditions. For instance, an increase in weeds, pests, or diseases is expected during severe climate conditions. Such scenarios lead to higher pesticide costs, thereby increasing the overall cost of paddy production. This in turn, reduces the economic value of paddy water. Therefore, the economic value of agricultural water may become irrelevant and debatable unless adjustments for market conditions are made.

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REFERENCES

Aguilar FX, Obeng EA & Cai Z. 2018. Water quality improvements elicit consistent willingness-to-pay for the enhancement of forested watershed ecosystem services. *Ecosystem Services* 30: 158–171. https://doi.org/10.1016/j.ecoser.2018.02.012

Alexandre G, Arthur R, Zacharias S & Alexander FW. 2024. Do investors care about biodiversity? *Review of Finance* 28: 1151–1186 https://doi.org/10.1093/rof/rfae010

Bagheri S, Saeed Y, Baky-Haskuee M & Babollah H. 2024. A Water-Embedded CGE Approach to Economic and Welfare Effects of Agricultural Water Transfer. *Journal of Irrigation and Drainage Engineering*. 150: 5. doi:10.1061/JIDEDH.IRENG-10218

Berbel J, Mesa-Jurado MA & Pistón JM 2011. Value of Irrigation Water in Guadalquivir Basin (Spain) by Residual Value Method. *Water Resource Management* 25:1565–1579. https://doi.org/10.1007/s11269-010-9761-2

Busch J, Ring I, Akullo M et al. 2021. A global review of ecological fiscal transfers. *Nature Sustainability* 4: 756—765. https://doi.org/10.1038/s41893-021-00728-0

Castaño-Isaza J, Newball R, Roach B & Lau WW. 2015. Valuing beaches to develop payment for ecosystem services schemes in Colombia's Seaflower marine protected area. *Ecosystem Services* 11: 22—31. https://doi.org/10.1016/j.ecoser.2014.10.003

Daniels AE, Bagstad K, Esposito V, Moulaert A & Rodriguez CM. 2010. Understanding the impacts of Costa Rica's PES: Are we asking the right questions? *Ecological Economics* 69: 2116–2126. https://doi.org/10.1016/j.ecolecon.2010.06.011

Dennis K, Van Riper CJ & Wood MA. 2011. Payments for ecosystem services as a potential conservation tool to mitigate deforestation in the Brazilian Amazon. *Applied Biodiversity Perspective Series* 1: 1–15.

De Paulo FLL & Sobral Camões PJ. 2019. The adoption of ecological fiscal transfers: An empirical analysis. *Land Use Policy* 88: 104202. https://doi.org/10.1016/j.landusepol.2019.104202

Dinica V. 2018. The environmental sustainability of protected area tourism: towards a concession-related theory of regulation, *Journal of Sustainable Tourism* 26: 146–164. DOI: 10.1080/09669582.2017.1322599

Eichholtzer A, Driscoll DA, Patrick R, Galletta L & Lawson J. 2024. The co-benefits of biodiversity citizen science for well-being and nature relatedness. *Applied Psychology: Health and Well-Being* 16: 515–536. https://doi.org/10.1111/aphw.12502

Engel S, Pagiola S & Wunder S. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological economics* 65: 663–674. https://doi.org/10.1016/j.ecolecon.2008.03.011

Gilad D, Borgelt J, May R, Dorber M & Verones F. 2024. Biodiversity impacts of Norway's renewable electricity grid. *Journal of Cleaner Production* 469: 143096. https://doi.org/10.1016/j.jclepro.2024.143096

Gillingham PK, Britton JR, Jones G et al. 2023. Climate change adaptation for biodiversity in protected areas: An overview of actions. *Biological Conservation* 289: 110375. https://doi.org/10.1016/j.biocon.2023.110375

Gómez-Baggethun E, De Groot R, Lomas PL & Montes C. 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics* 69: 1209–1218. https://doi.org/10.1016/j.ecolecon.2009.11.007

Gray SL & Young RA. 1974. The economic value of water for waste dilution: Regional forecasts to 1980. *Journal (Water Pollution Control Federation)* 46: 1653–1662.

Han PC, Zainura Zainon N, Nurfarhain MR & Che Hafizan. 2022. Water Footprint Assessment of Paddy Cultivation: Quantifying Direct and Indirect Water Consumption. *Journal of Sustainability Science and Management* 17: 110–128

Isacs L, Håkansson C, Lindahl T, Gunnarsson-Östling U & Andersson P. 2024. 'I didn't count "willingness to pay" as part of the value': Monetary valuation through respondents' perspectives. *Environmental Values* 33: 163–188. https://doi.org/10.1177/09632719241231509

Izquierdo-Tort S, Alatorre A, Arroyo-Gerala P, Shapiro-Garza E, Naime J & Dupras J. 2024. Exploring local perceptions and drivers of engagement in biodiversity monitoring among participants in payments for ecosystem services schemes in southeastern Mexico. *Conservation Biology*. e14282. https://doi.org/10.1111/cobi.14282

Jennifer Ag & Hendrik AW. 2014. Payment for Ecosystem Services from Forests. *Annual Review of Resource Economics* 6: 361—380

Kangas J & Ollikainen M. 2022. A PES scheme promoting forest biodiversity and carbon sequestration. *Forest Policy and Economics* 136: 102692. https://doi.org/10.1016/j.forpol.2022.102692

Kohzad S, Seyed Nm & Seyed Mohammad HMH. 2020. Estimation The Economic Value of Irrigation Water for Rice Farms in Iran. *Montenegrin Journal of Economics* 16: 109–122

Krejcie Rv & Morgan DW 1970. Determining Sample Size for Research Activities. *Educational and Psychological Measurement.* 30: 607—610

Landrigan PJ, Britt M, Fisher S et al. 2024. Assessing the Human Health Benefits of Climate Mitigation, Pollution Prevention, and Biodiversity Preservation. *Annals of Global Health* 90. https://doi.org/10.5334/aogh.4161

Leddin D. 2023. The Impact of Climate Change, Pollution, and Biodiversity Loss on Digestive Health and Disease. *Gastro Hep Advances* 3: 519–534. https://doi.org/10.1016/j.gastha.2024.01.018

Lü Y, Li T, Whitham C et al. 2020. Scale and landscape features matter for understanding the performance of large payments for ecosystem services. *Landscape and Urban Planning* 197: 103764. https://doi.org/10.1016/j.landurbplan.2020.103764

MADA 2021. Laporan Tahunan MADA. Kuala Lumpur

Mohamed Azwan MZ, Sa'ari M & Zuzana P. 2010. Determination of Water Requirement in Paddy Field at Seberang Perak Rice Cultivation Area. *The Institution of Engineers, Malaysia* 71: 32–41.

Montagnini F & Del Fierro S. 2024. Agroforestry Systems as Biodiversity Islands in Productive Landscapes. Pp 551–165 in Montagnini F. (ed) *Integrating Landscapes: Agroforestry for Biodiversity Conservation and Food Sovereignty. Advances in Agroforestry 14.* Springer, Cham. https://doi.org/10.1007/978-3-031-54270-1_19

Mu L, Wang Y & Xue B. 2024. The Impacts of Agricultural Water Pricing on Sustainable Agricultural Production. *Water Resource Management* 38: 1061–1078. https://doi.org/10.1007/s11269-023-03709-4

Muradian R, Corbera E, Pascual U, Kosoy N & May PH. 2010. Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. *Ecological Economics* 69: 1202–1208. https://doi.org/10.1016/j.ecolecon.2009.11.006

Norderhaug A, Clemmensen Ke, Kardol P, Thorhallsdottir Ag & Aslaksen J. 2023. Carbon sequestration potential and the multiple functions of Nordic grasslands. *Climatic Change* 176: 55 https://doi.org/10.1007/s10584-023-03537-w

Nyanghura QM, Biber-Freudenberger L & Börner J. 2024. Incentives for biodiversity conservation under asymmetric land ownership. *Ecological Economics* 219: 108152. https://doi.org/10.1016/j.ecolecon.2024.108152

Permana AW & Kusumawardani D. 2021. Estimation of Water Requirements and Value of Water in Agricultural Sector in East Java: The Case of Rice Plant. *Jurnal Ilmu Ekonomi Terapan* 6: 215–234.

Pfunzo R, Bahta YT & Jordaan H. 2024. Insights into the Impact of Irrigation Agriculture on the Economy of the Limpopo Province, South Africa: A Social Accounting Matrix Multiplier Analysis. *Agriculture* 14: 1086 https://doi.org/10.3390/agriculture14071086

Rodrigues GC, Da Silva FG & Coelho JC. 2020. Determining Farmers' Willingness to Pay for Irrigation Water in the Alentejo Region (Southern Portugal) by the Residual Value Method. *Agronomy* 11: 142 https://doi.org/10.3390/agronomy11010142

Rodríguez-Labajos B & Martínez-Alier J. 2013. The Economics of Ecosystems and Biodiversity: Recent Instances for Debate. *Conservation and Society* 11: 326–342. http://www.jstor.org/stable/26393130

Roque AM, Madi RR, Coelho AS et al. 2024. Conservation units and sustainable development goals: the private natural heritage reserves of Brazil. *Environ Dev Sustain* 26: 2183–2202. https://doi.org/10.1007/s10668-022-02809-2

Salzman J, Bennett G, Carroll N, Goldstein A & Jenkins M. 2018. The global status and trends of Payments for Ecosystem Services. *Nature Sustainability* 1: 136–144. https://doi.org/10.1038/s41893-018-0033-0

Samdin Z, Huda-Farhana MM & Hasan-Basri B. 2019. Conservation of Mangroves in Kuala Perlis, Malaysia—A Case Study of Socio-Economic Attributes of Fishermen Driving Valuation in Sustaining Livelihoods Through Forest Management. *Journal of Tropical Forest Science* 31: 433–442

Sist P, Piponiot C, Kanashiro M et al. 2021. Sustainability of Brazilian forest concessions. *Forest Ecology and Management* 496: 119440 https://doi.org/10.1016/j.foreco.2021.119440

Spash CL. 2013. The shallow or the deep ecological economics movement? *Ecological Economics* 93: 351–362. https://doi.org/10.1016/j.ecolecon.2013.05.016

Upadhyaya A, Jeet P, Singh AK & Sundaram PK. 2023. Estimation of the economic value of irrigation water in canal and tube well command areas. *H2 Open Journal* 6: 131–139. doi: https://doi.org/10.2166/h2oj.2023.011

Wertz-Kanounnikoff S. 2006. Payments for environmental services–a solution for biodiversity conservation. *Idées pour le débat* 12.

Wunder S. 2015. Revisiting the concept of payments for environmental services. *Ecological Economics* 117: 234–243. https://doi.org/10.1016/j.ecolecon.2014.08.016

Xepapadeas A. 2024. *Lectures in Applied Environmental Economics and Policy* 19: World Scientific Publishing, UK.

Yang S, Bai H & Li A. 2023. A futile help: do vertical transfer payments promote haze control? *Economic Change Restructuring* 56: 3411–3436. https://doi.org/10.1007/s10644-023-09537-1

Young RA & Loomis JB. 2014. *Determining the Economic Value of Water: Concepts and Methods.* 2nd Edition. Routledge, London.https://doi.org/10.4324/9780203784112