Assessment of the multifunctional role of wetlands in Indonesia: a case study in West Java Province

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Abstract. Agricultural activities in paddy fields (wetlands) producing products and sell that product, and also generate desirable or positive externalities as environmental services. Environmental services and the products that sell to the market are called multifunctional agriculture (MFA). This study aims to evaluate and economically assess the multifunctional role of wetland areas in Indonesia by taking the case of the West Java region. This study uses secondary data and data collected from various institutions and publications. This study uses the replacement cost method (RCM) to investigate the economic value of the role of MFA in wetland farming systems. The results show that the total value of environmental products and services marketed in wetland areas in West Java Province is around USD 36.59 billion per year or USD 39.41 million per hectare per year. The policy implications of this research are (1) attracting the maximum capacity of the stakeholders and community to participate in all the programs planned to protect, preserve and conserve the environment; (2) parting, endorsing, and strengthening the government and communities in the downstream area to invest in rehabilitating the upstream and middle watersheds; and (3) in per hectare a year, excluding the price of the land itself, the cost of building paddy fields, and the value of other infrastructure and facilities, USD 39.41 million is the replacement cost value if the rice fields are to be converted to non-agricultural use and replaced by the construction of rice fields new in other areas that are still possible.

1. Introduction
In Indonesia, the agricultural sector is one of the dominant activities in rural areas. The public's view of the function of agriculture, in general, is still limited to the function of producing goods that can be sole. The agriculture function on environmental services production is not widely known and tends to be often unnoted. Beyond the primary function of food production and supplying agroindustry inputs, agriculture generates several positive externalities that must include in the public policy decision-making. An economic assessment of the multifunctional role of agriculture can explain to society and the policy-making process that agriculture and ecosystem services are scarce and that their depreciation or degradation has costs associated with the community. Policies in land use and management will be more efficient, effective, and sustainable if the value of the land in monetary units is known, both the value of the production of goods and services and the value of the resulting environment.

The concept of multifunctional agriculture (MFA) emerged in the last decades of the twentieth century in many countries due to the function of agriculture function to produce environmental services stranded. Society was increasingly concerned with the quality of the food consumed and the surrounding environment. Agricultural systems play many significant roles. Producing food and other products that can be sell in the market is one role of agriculture systems. There are also many agriculture systems...
roles such as (a) retaining water flows and reduce flood intensity; (b) minimizing soil loss and landslides; (c) maintaining the values of rural socio-cultural; (d) job creation and reduce unemployment, (e) contribute to the country's economy; and (f) reduce rural poverty [1,2]. All agricultural activities and related land use lead directly to other non-agricultural functions ranging from social, environmental, economic, and cultural goods and services, generates significant benefits or costs. Agriculture systems have intrinsic multi-functionality. Higher benefits can be lead directly from a better and more systematic understanding of this multifunctional agriculture [3]. Generally, only in the short-term economic benefits for agricultural producers, communities, and governments consider due to the misunderstanding of MFA. Besides the food security and input of agroindustry, rural development, energy, and environmental sustainability at the local, national, regional, and global levels achievement significantly contributed by the MFA.

So far, the calculation of farming in paddy fields has not included aspects of the multifunctional values of the land, and an economic valuation approach is needed. If the environmental benefits are inseparable in calculating the values, the price of products of the paddy field should be higher than the current market price of the product. The community should also pay for these environmental benefits [14].

This study aimed to evaluate and study economically the multi-function of one of the agricultural land resources, namely rice fields in Indonesia, by taking the case of the West Java region. The results of this study intended to provide policymakers with specific insights, tools, and information applicable to measure the various roles of agriculture systems at the wetlands areas and society, and also from other views of point which to make informed policy decisions for sustainable agriculture and rural development in Indonesia.

2. Materials and methods

Replacement Cost Method (RCM) was carried out to measure MFA in this study. In the RCM, the goods and services traded in the market replace the function to be valued. The assumptions are that differences in the infrastructures and facilities values at the residential areas are reflected in the land prices and wages. The function is to be calculated based on the market price of the goods and services. This method has two advantages [4], first, can be evaluate each function separately, and second, the measurement is easy to understand due to the products and services are utilized instead of functions.

In the last two decades ago, several researchers in Indonesia have conducted MFA research using the RCM method, including the case of the Citarum watershed in West Java [5], the case of the Brantas watershed in East Java, and the case of the Sepuht-Sekampung watershed in Lampung [6], and with a slightly different scope from the MFA aspect but also in the case of the Citarum watershed in West Java [7]. After these studies in the last decade, there has been no research using the RCM method, and a comprehensive MFA measurement has not been yet.

This study uses secondary data collected from various institutions and publications, including (1) the value of public investments such as the construction of dams and systems for controlling landslides, erosion, flooding, and irrigation facilities constructions; (2) the number of agricultural tourism (eco-tourism, agro-tourism, rural indigenous society, and cultural tourism), wetland irrigated area, commodities production and prices (paddy/rice, secondary crops, and horticulture), damage due to natural disasters (landslides and floods), waste (solid and liquid, organic and non-organic), and any others; and (3) technical parameters of research results such water retention capacity, the rate of erosion and landslides, soil erosion and sedimentation, greenhouse gas absorption (SO\textsubscript{2} and NO\textsubscript{2}) by crops land and other related information.

Secondary data were collected from many institutions such as Perum Jasa Tirta II and other West Java DAM Authority offices, Provincial Development Planning Agency (BAPPEDA), Provincial Agriculture Service, Public Works and Human Settlements Service (MOPWHS), Ministry of Agrarian and Spatial Planning (MOASP), BPS-Statistics Indonesia National and Provincial, Social Service, Public Works and Human Settlements Office, Tourism Office, Regional Environmental Impact Management Agency (BAPEDALDA), Agro Soil and Climate Research Institute, and other relevant
agencies. This study examines the current situation of the economic value of MPAs throughout the West Java region which has around 41 watersheds with a special analysis on wetland areas. Following the approach taken by Irawan et al. [6] and Adnyana and Setiyanto [7] the analysis is divided into three categories, namely the upstream region, the middle region and the downstream region. The area of paddy fields in each region refers to the watershed map from the BAPPEDA of West Java Province [8], agricultural land statistics from the Ministry of Agriculture [9], and the land area according to its designation, from the Central Statistics Agency (BPS), national and West Java in 2020 [10]. Dams, check dams, and other infrastructure classified into upstream, middle and downstream areas are based on maps from the BAPPEDA of West Java Province [8] and the Ministry of Public Works and Public Housing of West Java Province and National (MOPWHS) statistical information [11].

Data analysis, in this case, the application of the RCM method predicts replacement costs through the contribution of agricultural land to the expected environmental services. All values converted into United States Dollar (USD), which is USD 1 equivalent to Indonesian Rupiah ( IDR) 14,400 according to the exchange rate assumption used in the 2019 State Budget by the Ministry of Finance (MOF) [12]. If the investment data such as (1) the construction of prevention and control dams and their network systems for soil erosion, landslides, and floods control budgets, and (2) the construction of paddy fields, land terraces, and other public investments budgets are not available will be excluded in the calculation. The analysis includes the value of marketed products and nine environmental values:

1. Value of marketed product (USD/year) or $VMP = \sum_{i=1}^{n} (P_i x Q_i) x HA$, where $i = 1, 2, 3 \ldots \ldots n$ is types of crops grown; $P$ is the price of each product (USD/ton); $Q$ is productivity of each crop (tons/ha); and HA is harvested area of each crop (ha).

2. Value of flood prevention function (USD) or $VFP =WR_1 x (DD+DM) + WR_2 x (DD + CM)$; where $WR_1$ is effective water retention capacity of non-rice field land ($m^3$); $WR_2$ is effective paddy field water retention capacity ($m^3$); DD is dam depreciation cost for water retention volume (USD/m$^3$); and CM is reservoir maintenance cost water retention volume (USD/m$^3$).

3. Value of water retention function (USD/year) or $VWR = WD x (DD+DM) + [GW x (CPF + RCF) x DG]$, where WD is water discharge for paddy fields ($m^3/s$); DD is depreciation cost of irrigation dam (USD/m$^3$/year); DM is maintenance cost of irrigation dam (USD/m$^3$/year); GW is volume of external ground water used ($m^3$); CPF is capacity of rice field irrigation water ($m^3$); RCF is rainwater capacity of rice fields ($m^3$); and DG is price difference between groundwater and surface water (USD/m$^3$).

4. Value of soil erosion prevention function (USD/year) or $VSEP = (ENP–EPF) x SDR x (DDS+DCM) x PFA$; where ENP is estimated erosion rate of non-rice land ($m^3$/ha/year); EPF is estimated erosion rate of paddy field ($m^3$/ha/year); SDR is sediment delivery rate of paddy field; DDS is dam depreciation cost per sediment volume (USD/m$^3$/year); DCM is dam maintenance cost per sediment volume (USD/m$^3$/year); and PFA paddy field area (ha).

5. Value of landslide prevention function (USD/year) or $VLP = (LSN – LSN) x AL$; where LSN is number of landslides in non-rice fields; LSP = Number of events landslides in paddy fields; and AL is average loss per landslide event (USD/year).

6. Value of garbage or waste disposal function (USD/year) or $VGD = (OFxPOFxPFA) + (PFAGxCGD)$; where OF is volume of organic fertilizer used in paddy fields (tons/ha) area; POF is price of organic fertilizer, estimated based on processing costs (USD/ton); PFA is paddy field area (ha) and it is assumed that lowland rice does not produce products that pollute the environment, or does not produce waste; G is volume of waste generated by non-paddy field land (tons/ha); and CGD is cost of processing non-rice land use (USD/ton).

7. Value of air pollution reduction (USD/year) due to absorbed GV or gas volume is equal to paddy field wasted economical volume (tons) and total GV is equal to (9.67+13.64) kg/ha/year x PFA or $VAPR = (GV/0.10xPAC)/PFA$; where PAC is activated carbon price (USD/ton) it is assumed that volume of GV is 0.1 of active carbon [6] and PFA is area of paddy fields (ha).

8. Value of rural facilities for recreation and relaxation or rural amenities (USD/year) or $VRA = (TNx PTRxCxCE) + (PNRxCPxPRVxCR)$; where TN is number of tourists who need recreation (person/year); PTR is proportion of tourists who come to rural areas (%); CT is correction coefficient
for the proportion of tourists who use agriculture as their recreational object (%); CE is visitor expenditure (USD/person/year); PNR number of people going to rural areas (persons/year); CP is proportion of people returning to rural villages (%); PRV is proportion of people returning to rural villages for agricultural reasons (%); and CR is cost of returning to rural villages (USD/person/year).

9. Value of urbanization reduction function (USD/year) or VUR = (PFA x VAL); where PFA is paddy field area (ha); VAL is value of agricultural labor absorption (USD/ha/year).

10. Value of heat mitigation function (S/year) or VHM = [NF x (FM+FD) + NAC (ACM+ ACD)] where NF is number of fans in the study area (unit); FM is fan maintenance cost (USD/unit/year); FD is fan depreciation cost (USD/unit/year); NAC is number of air conditioners in the study area (unit); ACM is air conditioner maintenance cost (USD/unit/year); and ACD is air conditioner depreciation expense (USD/unit/year)

3. Results and discussion

West Java Province with an area of 3,537,776 hectares, has a land use that is dominated by agricultural land (45.07%). In 2019, the area of rice fields was 928,218 hectares (25.03%) and non-rice fields (plantation, dry land, dry land and dry land) were 743,422 hectares (20.04%) [8,9,10]. The identification results show that in West Java there are rice fields that are not only planted with rice, but also planted with other crops such as corn, soybeans, peanuts, sweet potatoes, sugarcane, mangoes, bananas, onions, chilies, and many other crops, especially vegetables and fruits that can be harvested in one season.

West Java Province has 4 reservoirs namely Saguling, Cirata, Jatiluhur, and Jatigede; 32 dams including Cipancuh, Walahar, Rentang, Cipanas, Ciawi, Katulampa, and Cimahi; as well as 12 weirs and check dams such as Cibereum, Cibayat, Cicamas, Cigadog, Cinangka, Leuwitunggak, and Patat. [11]. Data on total investment costs, water storage capacity, the developed water flow, the depreciation and annual maintenance costs, and external groundwater use from those reservoirs and dams by upstream USD 1,239,194,962, middle USD 2,247,844,443, and downstream USD 2,684,539,437 with a total investment cost incurred are USD 6,171,578,843 which are presented in Table 1.

Table 1. Investment costs and use of external groundwater in 4 reservoirs, 32 dams, 12 weirs and check dams in West Java Province, 2019 [8,11,13].

| No. | Item                                      | Upstream          | Central         | Downstream      | West Java       |
|-----|-------------------------------------------|-------------------|-----------------|-----------------|-----------------|
| 1.  | Total investment cost (USD)               | 1,239,194,962     | 2,247,844,443   | 2,684,539,437   | 6,171,578,843   |
| 2.  | Average life time (year)                  | 75                | 100             | 125             | 100             |
| 3.  | Construction cost depreciation (USD/year) | 16,522,599        | 22,478,444      | 21,476,315      | 60,477,359      |
| 4.  | Total life saving capacity (water/sediment) (M3/year) | 78,250,000        | 103,523,952     | 152,902,298     | 334,676,250     |
| 5.  | Annual maintenance cost (USD/year)        | 94,090,909        | 116,218,964     | 136,172,996     | 347,102,869     |
| 6.  | Rice developed water flow (m³/s)          | 4,581             | 4,751           | 4,995           | 14,327          |
| 7.  | Average cost depreciation of water from water flow irrigation per dike develop (USD/m³/s) | 3,607             | 4,731           | 4,300           | 12,638          |
| 8.  | Annual maintenance costs per stream developed (USD/m³/s) | 292,467           | 222,120         | 270,828         | 785,415         |
| 9.  | External groundwater utilized volume (m³)  | 3,199             | 2,177           | 2,303           | 7,679           |

Note: USD 1 = IDR 14,400.00
The total economic value of the marketed product and the value of nine environmental services of wetland areas in West Java Province is about 36.59 billion per year (Table 2). In the upstream, the value is USD 10.86 billion per year, in the middle USD 14.52 billion per year, and in the downstream is USD 13.37 billion per year.

The economic value of the marketed product upstream is USD 1.78 billion per year, the middle is USD 2.35 billion per year, and the downstream is USD 1.74 billion per year. Meanwhile, the economic value of environmental services upstream has amounted to USD 9.09 billion per year, the middle is USD 12.17 billion per year, and the downstream area is USD 11.64 billion per year. The marketed products contributed about 16.02\% (USD 5.86 billion/year). These are the total of the products provided by marketed products like various commodities grown by farmers at the wetland of West Java Province. About 83.98\% or USD 30.73 billion annually is the contribution of environmental services to the total economic value of the wetland area of the West Java Province. Without wetland preservation and conservation, West Java Province will experience an economic value loss of no less than USD 30.73 billion yearly.

Table 2. Economic value of the total area of agricultural wetlands in West Java Province in 2019 (USD million/year).

| Item                                    | Upstream | Middle | Downstream | West Java |
|-----------------------------------------|----------|--------|------------|-----------|
| A. Value of marketed product           | 1,767.55 | 2,353.91 | 1,740.55 | 5,862.01 |
| B. Value of environment                |          |        |            |           |
| 1. Flood control and prevention         | 838.19   | 1,462.73 | 861.13    | 2,072.78 |
| 2. Water retention                      | 1,356.32 | 1,077.77 | 1,374.26  | 3,811.24 |
| 3. Soil erosion control                 | 482.37   | 692.04  | 360.68    | 1,364.98 |
| 4. Landslide’s control                  | 1,848.44 | 3,169.96 | 2,499.05  | 6,661.86 |
| 5. Waste disposal                       | 2,321.33 | 2,722.10 | 3,676.84  | 8,720.12 |
| 6. Air purification                     | 269.73   | 474.91  | 424.58    | 1,177.88 |
| 7. Rural amenity                        | 905.57   | 879.65  | 843.04    | 2,567.24 |
| 8. Urbanization control                 | 375.68   | 684.44  | 496.51    | 1,557.96 |
| 9. Heat mitigation                      | 691.14   | 1,005.75 | 1,089.02  | 2,785.91 |
| Subtotal                                | 9,088.77 | 12,169.35 | 11,625.12 | 30,719.96 |
| C. Total (A+B)                          | 10,856.32 | 14,523.26 | 13,365.66 | 36,581.97 |
| D. Percentage of marketed product (%)   | 16.28    | 16.21   | 13.02      | 16.02     |
| E. Percentage of environmental services (%) | 83.72     | 83.79   | 86.98      | 83.98     |
| F. Per hectare value (USD/ha/year)      | 79,238.60 | 36,568.33 | 33,918.19 | 39,410.96 |
| 1. Value of marketed product           | 12,901.08 | 5,926.95  | 4,417.00  | 6,315.34 |
| 2. Value of environmental              | 66,337.52 | 30,641.38 | 29,501.18 | 33,095.63 |

Note: USD 1 = IDR 14,400.00

The results of the calculation of the economic value per hectare show that the economic value of the upstream area is higher than the middle and downstream areas. The high economic value of products marketed in the upstream areas is due to the fact that many types of horticultural crops are grown in monocultures and intercropping, while the middle and downstream areas are generally monocultures of rice and secondary crops, or sugarcane, only a small portion of which is planted with shallots, chilies and even mangoes, banana. Meanwhile, the high economic value of environmental services per hectare in the upstream area is because the upstream watershed contributes significantly to conservation and preservation compared to the middle and downstream areas.

Conversion of one hectare of paddy fields will cause the Province of West Java to lose the value of the marketed product of USD 6.32 billion per ha year, the environmental economic value of USD 33.10 million per ha per year, or the total economic value of 39.41 million per ha per year. This value does not include the price of the land itself, the cost of building rice fields, the value of infrastructure, and other
facilities. These values are the value that must be paid if a hectare land conversion is carried out in West Java Province for non-agricultural use. In other words, these values represent the replacement costs that must be paid if the rice fields in West Java Province have to be converted for other uses and replaced with other land elsewhere.

4. Conclusions
The total value of commodities produced from rice fields in West Java Province is amounted to USD 1.78 billion per year in the upstream area, USD 2.35 billion per year in the middle area, and USD 1.74 billion per year in the downstream area of the West Java watershed. The total economic value of marketed products or commodities from this area is about USD 5.86 billion per year. This value is around 16.02% of the total economic value of rice fields or wetland areas in West Java Province. Around 83.98% was contributed by the economic value of paddy fields or lowland rice in preserving the environment. The upstream watershed makes a more significant contribution to conservation and reservation than the middle and downstream areas. Conversion of one hectare of paddy fields will cause West Java Province to lose the market value of USD 6.32 million per year, the environmental economic value of USD 33.10 million per year, or the total economic value of 39.41 million per year.

Based on the results of this study, the government recommended taking some policies, first, attracting the maximum capacity of the stakeholders and community to participate in all the programs planned to protect, preserve and conserve the environment. Second, parting, endorsing, and strengthening the government and communities in the downstream area to invest in rehabilitating the upstream and middle watersheds. Third, apart from the price of the land itself, the cost of building rice fields, the value of infrastructure and other facilities, the Province of West Java loses economic value of USD 39.41 million per year if one hectare of rice fields in West Java is converted into non-agricultural uses. The government and the community must take this value as a replacement cost if the rice fields are converted to other uses other than agriculture and replaced with the construction of new rice fields in other areas that are still possible.

References
[1] Organization for Economic Cooperation and Development 2001 Multifunction: Towards an Analytical Framework (Paris: Organization for Economic Cooperation and Development)
[2] Yoshida K 2001 Economic Evaluation of the Role of Multifunctional Agriculture and Rural Areas in Japan Technical Bulletin 154 (Taipei: Center for Food and Fertilizer Technology)
[3] Food and Agriculture Organization 1999 Multifunction Character of Agriculture and Land (Rome: Food and Agriculture Organization)
[4] Nishizawa E, Yoshida T and Kato T 1991 The hedonic price approach to estimating the benefits convenience brought by agricultural land and forests Nosokkenkiho 11 1–8
[5] Agus F, Watung R L, Suganda H, Tal'a'ouh S H, Wahyunto, Sutono S, Setiyanto A, Mayrowani H, Nurmanaf A R and Kundarto 2003 Multifunctional Study of Rice Farming Environment in Citarum Watershed, West Java, Indonesia Multifunction and Agricultural Land Conversion (Bogor: Center for Soil and Agroclimate Research and Development) pp 1–28
[6] Irawan B, Askin A, Setiyanto A, Rahmanto B and Agustin N K 2002 Analysis of the Economic Value of Agricultural Land Resources (Bogor: Center for Agricultural Socio-Economic Research and Development, Ministry of Agriculture).
[7] Adnyana M O and Setiyanto A 2006 Economic evaluation of the multifunctional role of agricultural development in Indonesia: a case study in Citarum watershed, West Java SOCA 6 1–33
[8] Regional Development Planning Agency 2019 The Regional Medium Term Development Plan RPJMD) of West Java Province for 2018–2023 (Bandung: Regional Development Planning Agency)
[9] Ministry of Agriculture 2020 Agricultural Land Statistics 2015–2019 (Jakarta: Center for Agricultural Data and Information Systems, Ministry of Agriculture)
[10] BPS-Statistics Indonesia 2020 West Java in Figures 2020 (Bandung: BPS-Statistics Indonesia)
[11] Ministry of Public Works and Human Settlements 2020 PUPR Infrastructure Statistics 2019 Information (Jakarta: Center for Data and Information Technology)
[12] Ministry of Finance 2019 State Revenue and Expenditure Budget 2019 (Jakarta: Directorate General of Finance)
[13] Perum Jasa Tirta II 2019 Annual Report 2019 (Purwakarta: Perum Jasa Tirta II)
[14] Patiung M 2014 Multifunctional economic valuation of rice fields (environmental service approaches that do not have market prices) in Sidoarjo Regency, East Java Province Doctoral dissertation (Malang: Universitas Brawijaya)