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Environmental Problems in Developing Aquaculture in the Jatigede Reservoir, West Java, Indonesia

Iskandar[1*], Heti Herawati[1], M. Candra Wirawan Arief[1], Sulastri Prihandini[2], Zahidah Hasan[1]

[1]Fisheries Department, Faculty of Fisheries and Marine Science, Universitas Padjadjaran
[2]Fisheries Study Program, Faculty of Fisheries and Marine Science, Universitas Padjadjaran
[*]**Corresponding Author: iskandar@unpad.ac.id**

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ABSTRACT

The inundation of Jatigede Reservoir significantly impacted the local environment and communities. While aquaculture could alleviate economic hardship, floating net cages (FNC) were banned to protect water quality. However, this still led to unintended environmental issues, particularly waste from the Cimanuk River during rainy seasons. This study analyzed waste composition at the reservoir's inflow and investigated water surface dynamics, aiming to inform future floating net cage aquaculture development in Jatigede. The study was conducted in Jatigede reservoir, Sumedang, West Java. Field investigation on waste distribution was conducted between February 15th and April 30th, 2023. Waste samples were collected by transect 2 × 2 meters on 5 spots at the Jatigede inlet from the Cimanuk River. Water samples of combined sources were collected from 4 sampling points representing the reservoir's inlet, middle, and outlet to evaluate water quality parameters, viz. temperature, pH, transparency, dissolved oxygen, and ammonia, assessing their suitability for aquaculture production. The temporal water surface dynamics were determined using Sentinel remote sensing data (2022 – 2023), with a spatial resolution of 10 meters, applying Normalized Difference Water Index (NDWI) in ArcMap 10.8. The large size of organic waste dominates Jatigede Reservoir's composition, increasing during rainy seasons due to higher Cimanuk River flow. Remarkably, water quality remains suitable for aquaculture. However, the reservoir surface area fluctuated between 2,600-4,100 ha from April 2022 to December 2023, peaking in June and reaching the lowest in December. According to the FNC estimation calculation, about 3,279 floating net cages operate in the reservoir's center, where the water volume is least stable. Environmental problems found in Jatigede Reservoir for aquaculture development include waste pollution and fluctuating water volume. To mitigate this issue, it is recommended to install the waste trap in the inlet of the aquaculture system, and estimate the carrying capacity of the reservoir for floating net cage installation.

INTRODUCTION

A reservoir is an artificial body of water that serves multiple purposes to meet human requirements. The primary functions of reservoirs are to generate hydropower, store freshwater, and support the agricultural sector. Subsequently, water facilities evolve into fisheries, aquaculture, and tourism. A recent advancement in the field of water technology is the floating solar panel. Floating solar panels offer several advantages, including a natural cooling effect that enhances energy yield and efficiency. Additionally, they can help reduce water evaporation by providing shading to the water beneath them. Installing solar PV above the water's surface can reduce water evaporation by up to 28%, as observed **(Nisar *et al.*, 2022)**. Installing FPV systems on water bodies may greatly increase solar energy capacity without significantly increasing land consumption, in addition to improving performance and reducing evaporation. Currently, China and the United Kingdom are leading the structural analysis of FPV systems to endure extreme ocean conditions **(Silalahi & Blakers, 2023)**. Another promising location for installing FPV is hydropower dams. **Almeida *et al.* (2022)** reported that, the installation of FPV in 10% area of the world's hydropower reservoirs is equivalent to the installed electricity generation capacity of fossil fuel power plants. Moreover, it may provide nearby residential areas with green energy, promoting local sustainability and lowering dependency on non-renewable energy sources **(Gadzanku *et al.*, 2022)**.

The initiation of hydroelectric reservoir development in Indonesia was in 1957 with the construction of the Jatiluhur reservoir in Purwakarta, West Java, situated along the Citarum River. In the early 1980s, the Saguling and Cirata reservoirs were constructed on the same river, establishing them as serial reservoirs along the Citarum cascade. The Saguling and Cirata developments displaced almost 10,000 households, predominantly farmers, who were compelled to relocate their means of subsistence or adapt to alternative livelihoods. Aquaculture on the reservoir has been promoted as a viable alternative means of livelihood for individuals impacted by the project. The floating net cage was initially implemented to cultivate the common carp (*Cyprinus carpio*), and subsequently, it was employed for the cultivation of the Nile tilapia (*Oreochromis niloticus*). Unfortunately, the floating net cages have increased along the reservoir, declining its water quality, as mentioned earlier—eutrophication results in the occurrence of anoxic conditions, leading to mass fish mortality. Since late 2019, the government authority of the West Java province has been responsible for facing this challenge and has issued a Governor's Decree to decrease the quantity of floating net cages on each reservoir.

The history of hydroelectric reservoir development in Indonesia, particularly along the Citarum River, underscores both the benefits and challenges associated with such projects. The construction of reservoirs like Jatiluhur, Saguling, and Cirata has undoubtedly contributed to energy production and water resource management. The promotion of aquaculture as an alternative means of livelihood for those impacted by the reservoir projects demonstrates a proactive approach to mitigating social disruption. However, the proliferation of floating net cages for fish cultivation has led to unintended consequences, such as declining water quality and eutrophication of the reservoir. Eutrophication, characterized by excessive nutrient levels in the water, can lead to algal blooms and oxygen depletion, ultimately resulting in fish deaths and ecological imbalances.

According to the survey results from 2003-2018, the average increases every year amounted to 13,401 floating net cage unit/year **(PJB-BPWC, 2019)**. The number of floating net cages initially operating in 2003 was 31,392 units, increasing to 98,397 units in 2018, while those permitted to operate were 12,000 units **(PJB-BPWC, 2019)**. The floating net cages exhibited a wide scope of activities covering 6.45% of the reservoir area. Notwithstanding, the maximum limit allowed to be covered is 0.3% of the water area of the reservoir **(Nastiti *et al.*, 2018; Pratiwi, 2020)**. This significant increase might have happened because of the decrease in the number of fish caught by fisherman **(Apriliani *et al.*, 2025)**. The government's response, as outlined in the Governor's Decree issued by the West Java province, reflects recognition of the need to address these environmental concerns. Efforts to decrease the quantity of floating net cages on each reservoir demonstrate a commitment to balancing economic development with environmental sustainability.

The commencement of the inundation of the Jatigede reservoir in Sumedang Regency, located in West Java, on the Cimanuk River occurred in 2015, with its peak level being attained in 2017. To mitigate the occurrence of comparable issues in Saguling, Cirata, and Jatiluhur, the local government of Sumedang Regency has officially prohibited the implementation of floating net cage operations along the reservoir. It is worthnoting that, floating net cages have been prohibited since 2019. Unexpectedly, an increase in environmental issues emerged. The waste from the Cimanuk, the main river, periodically covered the waters during the rainy season, and the Jatigede reservoir water surface was shrinking during the dry season.

The inundation of Jatigede Reservoir was a significant event, impacting both the local environment and communities. However, despite efforts to prevent similar issues encountered in other reservoirs like Saguling, Cirata, and Jatiluhur, the prohibition of floating net cage operations since 2019 has resulted in unforeseen environmental challenges. The decision to prohibit floating net cages was likely aimed at preventing the degradation of water quality and ecosystem health within the reservoir. However, the unintended consequences of this prohibition have become apparent, as evidenced by the increase in environmental issues. The waste from the Cimanuk River, the main water source for the reservoir, now poses a significant problem, especially during the rainy season. Periodic covering of the reservoir's waters with waste indicates potential pollution issues in the upstream, highlighting the interconnectedness of water systems and the importance of upstream management practices.

This study aimed to analyze the waste composition at the inflow of the Jatigede reservoir source from the Cimanuk River and to investigate the dynamics of the water surface, under the existing issues. The findings of this study can be utilized as a valuable resource for the advancement of floating net cage aquaculture in the Jatigede reservoir.

MATERIALS AND METHODS

1. Description of the sampling sites

The study was conducted in Jatigede reservoir, Sumedang, West Java, field investigation on waste distribution spanned between February 15th and April 30th of 2023, within the Wado area as the inlet from the Cimanuk River in Sumedang, West Java (Fig. 1). The Cimanuk watershed is close to residential areas, with numerous markets. The water in the Cimanuk watershed is used as a water source for agricultural activities. Throughout the dry season, residents often plant this area with various secondary crops, such as corn, cassava, and sweet potatoes. In research observations, the color of the water in the Cimanuk watershed tends to be yellowish brown. On the other hand, during the rainy season, the reservoir water has a highwater flow rate, causing the water to become cloudy. The area on the edge of the Cimanuk watershed holds the largest volume of waste. It is estimated that this rubbish comes from residential activities, shipments from the Garut area, and market activities around the area.

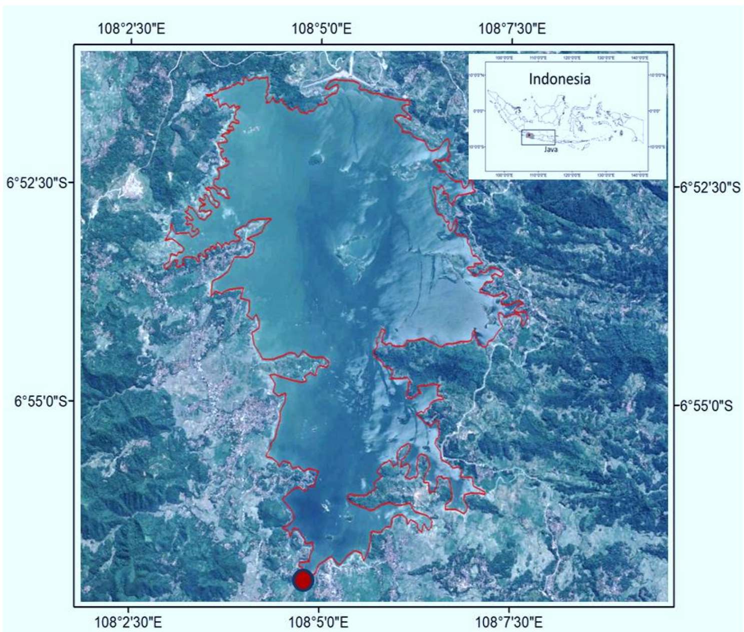

Fig. 1. The Study site on Jatigede reservoir (red polygon), inlet Cimanuk (red circle) in West Java, Indonesia

2. Waste collection and analysis

Waste samples were collected by transect 2 × 2 meters on 5 spots at the Jatigede inlet from the Cimanuk River. The waste is subsequently separated by type, documented based on its attributes, and measured and categorized into macro-sized and meso-sized waste to determine its weight for the waste classification. The classification system used in this study, according to **Eyerer (2010)**, is displayed in Table (1).

Table 1. Waste categories and classification by **Eyerer (2010)**

No.	Category	Waste Type
1	PETE (*Polyethylene Terephthalate*)	Most drink bottles are clear or transparent plastic.
2	HDPE (*High-Density Polyethylene*)	Gallons, soap bottles, detergent bottles, lubricant jerry cans, shampoo bottles, medicine bottles, cosmetic bottles, and Tupperware.
3	PVC (*Polyvinyl Chloride*)	This type is usually found in plastic wrapping, water hose pipes, building pipes, and plastic tablecloths.
4	LDPE (*Low-Density Polyethylene*)	This type is usually used for food containers and various other types of thin plastic.
5	PP (*Polypropylene*)	Plastic cups, sanitizer bottles, bottle caps, and plastic cutlery.
6	PS (*Polystyrene*)	Styrofoam.
7	Organic	Animals or plant substances
8	Others (0)	Other types of plastic besides numbers 1 – 6. Household items contain other categories.

3. Water quality and water surface analysis

The water quality sample was collected from the Jatigede Reservoir at the 4 sampling points representing the reservoir's inlet, middlet, and outlet (Table 2). The water quality parameters measured in the study area were temperature, pH, transparency, dissolved oxygen, and ammonia addressed for the suitability of the aquaculture production. The temporal dynamics of water surface were assessed using Sentinel 2A remote sensing data (2022 – 2023) with a spatial resolution of 10 meters, applying the Normalized Difference Water Index (NDWI) in ArcMap 10.8 at the Center of Environment and Sustainability Science Universitas Padjadjaran.

Table 2. Sampling points of water quality

Sampling Point	Coordinate	Location
1	S 06^0 56. 776’ E 108^0 05. 296’	Inlet
2	S 06^0 56. 739’ E 108^0 05. 383’	Midllet
3	S 06^0 56. 710’ E 108^0 05. 408’	Midllet
4	S 06^0 56. 649’ E 108^0 05. 533’	Outlet

4. Aquaculture development

The aquaculture activities information was attained via collecting the number of floating net cages (FNC) through visually interpreting the 2022 Google Earth high-resolution image (Fig 2). The 7 x 7-meter block was counted at the line of the FNC.

Fig. 2. Floating net cages along the Jatigede reservoir

RESULTS AND DISCUSSION

1. Waste abundance and composition

The waste abundance and composition in the study location can be seen in Fig. (3). The result revealed that the composition of waste found in the study location consisted of 8 categories of waste according to **Eyerer (2010)**. The organic type dominated the waste composition in the study location, with an abundance of about 19.432 Kg. The following categories in sequence were: LDPE (15.29 kg), other types (10.94 kg), PS (9.279 kg), PETE (2.458 kg), PP (2.206 kg), PVC (1.755 kg), and HDPE (0.88 kg). The inlet of the Jatigede Reservoir, located in the Wado subdistrict, initially supplied the waste discovered in the study area. According to the study conducted by **Wulan *et al.* (2024),** 42.6 hectares of waste are expected to be distributed throughout the Cimanuk River, 2,17 hectares in the Cibudah River, and 23,3 hectares in the Cialing River. Those rivers are the water sources of Jatigede Reservoir. This result represented the current issue of Jatigede Reservoir.

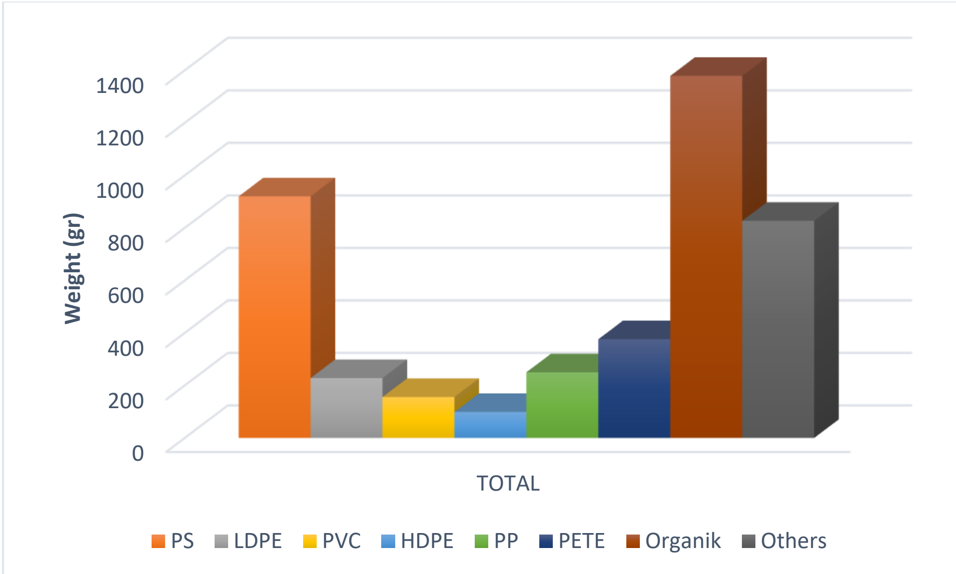

Fig. 3. Total waste abundance and composition in Jatigede Reservoir

The waste composition was separated into small, medium, and large waste categories based on size, as shown in Fig. (4). The Jatigede Reservoir's waste distribution was dominated by the large size category, with organic waste serving as the primary source. The Cimanuk watershed, which flows through several West Java cities and regencies, including Garut and Sumedang, is the source of a substantial amount of waste. According to **Kodoatie (2020)**, the Cimanuk River tends to discharge more floodwater during the rainy season and less during the dry season. Since the river's flow rate increases during the rainy season, waste production also increases.

The organic and inorganic waste, including plastic and microplastic, discharged to the reservoir can bring several negative impacts. According to **Siddiqua *et al.* (2022)**, waste disposal, particularly from landfills, may cause leachate to seep into surface waters. This pollution has the potential to lower reservoir water quality to the point where it is unfit for human consumption and other uses, such as fishery activities. Inappropriate land-based waste disposal can also change the hydrological cycles surrounding reservoirs. For instance, excessive organic waste disposal along the riverbank may cause pollutants to build up and eventually leak into the reservoirs during periods of high precipitation **(Kusari, 2019)**. The accumulation of plastic in reservoirs can harm aquatic and terrestrial life directly, deteriorate ships and other hydraulic infrastructure, and raise the risk of urban flooding as a result of clogging. Furthermore, aquatic organisms may consume microplastics, which could harm them and possibly make their way up the food chain.

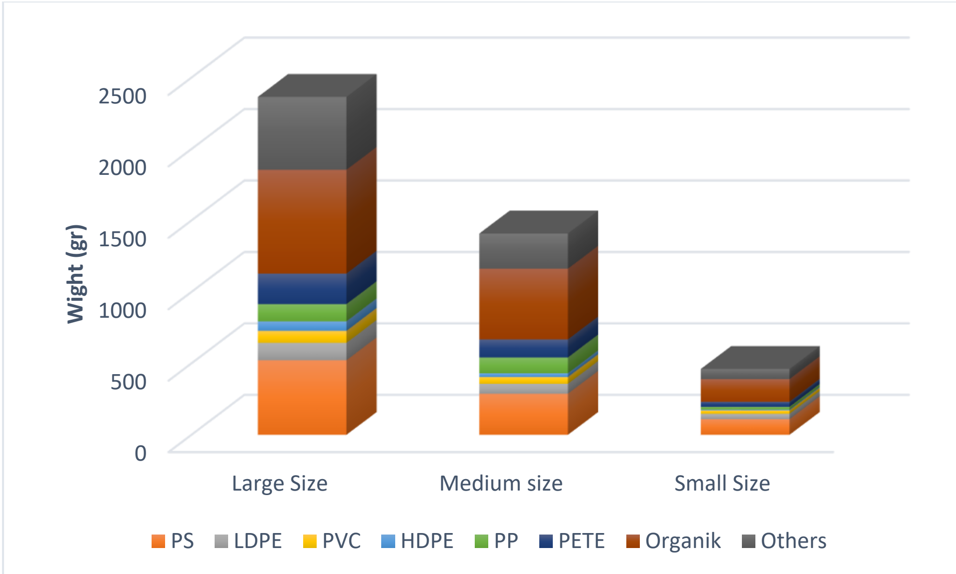

Fig. 4. Waste abundance and composition according to size

2. Water quality and surface temporal dynamics

An optimal aquatic environment for fish is characterized by suitable physicochemical conditions, which is essential for facilitating the growth and development of fish throughout all phases of their life cycle. Furthermore, these aquatic environments must possess the capacity to facilitate the decomposition of organic debris, preventing its accumulation to levels that could be harmful to fish. The sustainability of aquaculture is influenced by water quality, which is considered to be a limiting factor **(Schmittou & Rosati, 1991)**. Important water quality factors to be considered in aquaculture activities encompass dissolved oxygen (DO), pH, carbon dioxide (CO_2), ammonia, nitrates, nitrites, hydrogen sulfide, and water turbidity levels **(Siagian, 2009)**. The water quality test data reveal the physical and chemical parameters of the Jatigede Reservoir, as presented in Table (3). Generally, the water quality of the Jatigede Reservoir is still relatively suitable, as indicated by the collected data. Additionally, **Herawati *et al.*, (2025)** stated that Jatigede Reservoir is suitable for aquaculture development due to its high chlorophyll-a concentrations and optimal surface temperatures.

Table 3. Water quality analysis

Parameter	Unit	Observation Stations			
		1	2	3	4
Temperature	℃	27.2 – 29.2	26.7 – 29.6	28.1 – 29.3	27.8 – 29.2
DO	mg/l	4.5 – 5.9	4.4 – 5.6	4.3 – 5.4	4.6 – 6.2
Ammonia	mg/l	0.001 – 0.0043	0.0013 – 0.0044	0.0012 – 0.0033	0.001 – 0.0032
Transparency	m	0.445 – 1.08	0.38 – 0.94	0.615 – 1.50	0.67 – 1.20
pH	-	6.86 – 7.3	6.94 – 7.53	6.96 – 7.59	6.93 – 7.15

As a poikilothermic organism, the surrounding temperature influences the fish's metabolic rate and behavior **(Fujaya, 2004)**. The thermal characteristics of reservoir water can impact the efficacy of aquaculture. Typically, the temperature at the sampling site remains constant within a narrow range, with limited fluctuations. The water surface temperature of Jatigede Reservoir varies between 26.2 and 29.3°C. The range remains within the optimal threshold for fish survival and reproduction. Notably, the ideal temperature range for promoting fish growth in tropical situations is between 28 and 32°C **(Harmilia & Ma'ruf, 2022)**. The recommended temperature range for commercial fish farming, such as carp, is 28 – 30°C **(Laila, 2018)**, and for the tilapia fish is 25 – 32°C **(Wijaya & Riyadi, 2021)**.

Dissolved oxygen (DO) significantly restricts aquaculture activities. DO is involved in the metabolic activities and respiration of aquatic organisms. The solubility of oxygen in water is affected by the pressure and temperature of the water **(Wetzel, 2001)**. The required level of the DO varies among different fish species and is determined by parameters including age, size, activity, and metabolic rate of fish **(Fujaya, 2004)**. The lowest acceptable level of the DO for fishery activities is 3ppm, whereas the ideal range is between 5 – 7ppm **(Riadhi & Rivai, 2017)**.

The levels of the DO at these sampling stations exhibit stability within the range of 4.5 – 6.8ppm. The Jatigede Reservoir has sufficient quantities of dissolved oxygen on its water surface to facilitate the growth and development of fish, particularly to cultivate tilapia and carp, which are highly demanded at the market. According to **Laila (2018)**, carp requires dissolved oxygen levels within the range of 3.40 & 5.19ppm, whereas tilapia requires levels over 5ppm **(Pratama *et al.*, 2021)**. According to Indonesia's Government Regulation No. 22 of 2021 concerning the implementation of environmental protection and management, the dissolved oxygen levels on the water's surface at the Jatigede Reservoir are within the bounds of class 1 and 2 for water quality criteria. Based on its dissolved oxygen content, the measurement's findings indicate that the Jatigede Reservoir is appropriate for aquaculture operations.

The pH level of water might harm the growth of fish. The expansion of aquaculture fish will be hindered in an environment with a pH range of 6 – 6.5. Fish mortality can occur when the pH levels are excessively acidic (<4) or highly alkaline (>11) **(Siagian, 2009).** According to test results, the pH at the Jatigede Reservoir's water surface is between 6.8 and 7.5. Government Regulation No. 22 of 2021 states that the pH range of 6 to 9 is appropriate for fisheries, with 6.5 to 9.0 being the most advantageous range. Therefore, based on their pH level, the Jatigede Reservoir is suitable for aquaculture activity.

Ammonia is a crucial ingredient that influences the fertility rate of water. Ammonia is the product of protein metabolism at a chemical level. Ammonia in water exists in two forms: ammonium ions (NH_4^+), which are harmless to fish, and ammonia (NH_3), which is extremely harmful to fish **(Wetzel, 2001)**. The presence of ammonia in water arises from the decomposition of organic matter originating from feed residues, fish waste, and the remains of aquatic plants and plankton. According to **Wurts (2003)**, ammonia toxicity is influenced by several variables, including temperature, dissolved oxygen concentration, and pH level. Under typical pH conditions, the concentration of poisonous ammonia is less than 1%. However, if the pH level rises, the toxicity of ammonia will also increase.

According to **Mustapha and Akinshola (2016)**, for pond fish, the toxic levels of unionized ammonia for brief exposure typically range from 0.6 to 2.0ppm, with sub-lethal effects possible at 0.1 to 0.3ppm. Overdosing of ammonia can cause decreased growth rate, gill damage, decreased appetite, decreased respiration rate, and ultimately death **(Harlina, 2021).** According to Indonesian Government Regulation No. 82 of 2001 about Water Quality Management and Water Pollution Control, the permissible amount of free ammonia in water of class 2 and class 3 requirements is equal to or less than 0.02ppm. The study resulted in ammonia measurements between 0.001 and 0.004ppm. This result validates the safety of using the Jatigede Reservoir for aquaculture since it shows that the ammonia levels in the surface water is within the low range.

In aquaculture, physical attributes are just as important as chemical parameters. The physical parameters that place restrictions on aquaculture operations include current velocity, water depth, and brightness. The brightness of the waters indicates the extent to which sunlight is able to penetrate into aquatic environments. The brightness of the water is directly proportional to its depth and turbidity. In general, as the depth and turbidity of the water increase, water brightness level drops. The brightness of the water is also contingent upon the quantity of particles and colloids that are suspended in the aquatic environment. The optimal brightness level for freshwater aquaculture runs from 25 – 40 cm. This range allows for effective absorption of sunlight by phytoplankton, facilitating efficient photosynthesis **(Harlina, 2021)**. Phytoplankton and photosynthesis serve as a vital source of nourishment for fish, thus the productivity of phytoplankton and the rates of photosynthesis can contribute to the prosperity of aquaculture, as long as they remain within the acceptable range.

The results showed that the Jatigede Reservoir's brightness level varied from 0.38 to 1.50 m. Additionally, the reservoir's brightness level distribution was consistent at every station. The Jatigede Reservoir's low nutrient and vegetation levels permit excellent light penetration. In addition to brightness, the depth of the aquaculture site needs to be considered. According to **Siagian (2009)**, a reservoir's minimum water level needed for aquaculture operations is four to five meters. **Ondara *et al.* (2017)**, however, postulated that 10 meters is the ideal depth for aquaculture. The fluctuations and dispersion of organic materials are related to the depth of the reservoir. The probability of a turnover-related mass fish mortality event is higher in shallower water. Each station's depth at the study site showed a propensity to vary between 7.1 meters in the inlet area and 49.3 meters in the outlet area. These results suggest that the depth of the Jatigede Reservoir makes it a good location for aquaculture.

The current's velocity and trajectory are vital to the aquaculture activities carried out in the reservoir. Currents are essential to the movement of water and the dispersal of nutrients **(Purba & Pranowo, 2015)**. A decrease in the regularity of the spacing between aquaculture structures can result from an excessive current speed altering their layout. Additionally, the movement of plankton, organic materials, and nutrients can be facilitated by the current, which will homogenize the water. Moreover, this mixing can improve the dispersal of pollutants **(Putra & Buchari, 2015)**. The water surface area at the research site exhibited current speeds ranging from 0.08 to 0.2m/ second. The current speed of the water on the surface of the Jatigede Reservoir is low due to its sluggish nature. **Siagian (2009)** stated that the minimum current speed required at the aquaculture site is 5 - 10 m/second to ensure the proper circulation of nutrients, plankton, and organic waste. Therefore, the Jatigede Reservoir's current speed at this time is inappropriate for aquaculture operations.

Along with the water quality condition, the surface water temporal dynamic is also an important factor in aquaculture development **(Siagian, 2009)**. According to the remote sensing analysis, the surface water's temporal dynamics in Jatigede Reservoir during the study (2022 – 2023) is displayed in Fig. (4). According to the result, the water areas of Jatigede Reservoir fluctuated from 2,600 ha to 4,100 ha surface area. The surface water areas found in 2022 were slightly higher than in 2023. However, the temporal dynamics patterns between these two different times were similar. The surface water area in April, June, and August was higher than that recorded in October and December. The highest surface water area was found in June at both periods. According to **Zhang and Xu (2024)**, the water surface areas of the reservoir are strongly related to the climate elements or meteorological factors in that location, including the precipitation. Usually, when the amount of precipitation in the reservoir location is high, the surface water area is also high. When the amount of precipitation is low, the surface water area is also low. Thus, observing the climate elements around the study location is critical.

According to the data published by the BMKG Sumedang Regency, the amount of precipitation at the Jatinunggal Station in 2022 is between 12 and 633mm (Table 4). During study time, the highest amount of precipitation was detected in April, which was about 633mm, with 17 days of rain within a month. This result shows that the amount of precipitation influences the surface water area in Jatigede Reservoir, which shows the high-water levels in the same month (3,800 ha). However, in the following period, June 2022, the precipitation was slightly lower than the previous month, yet the water surface area was higher, up to 4,100 ha. A similar result was shown in December 2022, the level of precipitation in that period was high (560mm), but the surface water area was the lowest within the year. It shows that the meteorological factor is not the main factor in the dynamics of water surface areas in Jatigede Reservoir. Instead, the reservoir discharge level also should be considered, because based on the study of **Vieira Valadão *et al.* (2023)**, the most linked factors to the unstable or decreasing of surface water areas in the reservoirs are change in the use of and use (including deforestation) and reservoir discharge level, not the precipitation level.

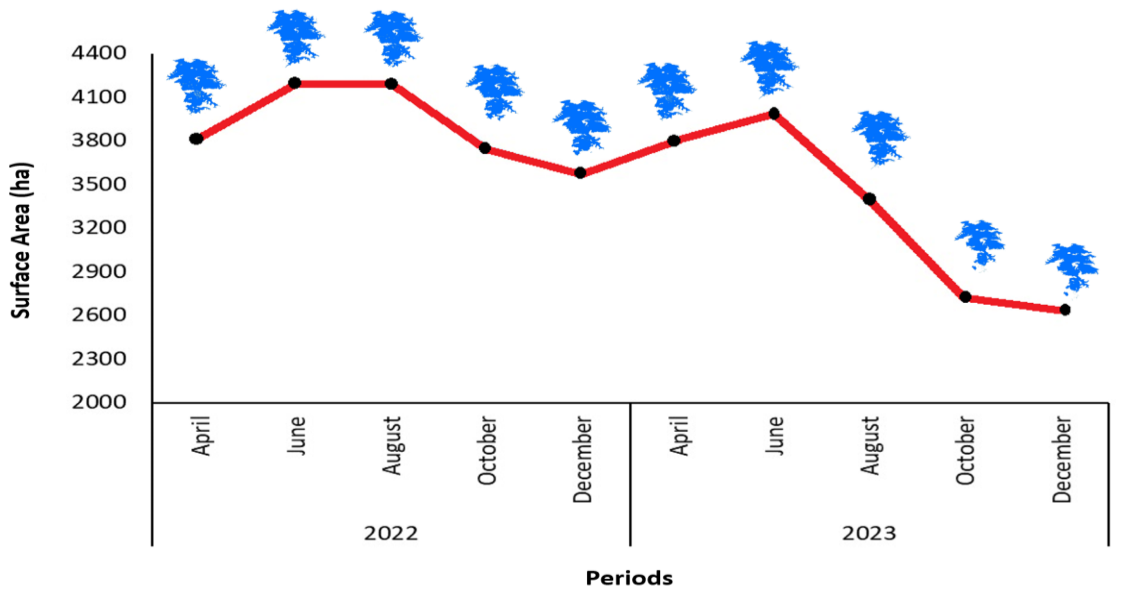

Fig. 5. Surface water temporal dynamics of Jatigede Reservoir

Table 4. Observation of climate elements by month

Month	Number of Precipitation (mm)	Number of Rainy Days (day)
January	996	21
February	1194	24
March	1119	25
April	633	17
May	429	15
June	496	14
July	195	6
August	12	3
September	113	8
October	140	17
November	703	24
December	560	23

Sources: Technical Implementation Unit of the Jatinunggal Subdistrict Agriculture Service, 2022.

3. Aquaculture development and challenges

Aquaculture development in the reservoir is a promising option to mitigate the economic devastation of the local community affected by the Jatigede Reservoir construction. The aquaculture industry also plays a significant role in providing food security, reducing the pressure on wild fish stock in the reservoir, optimizing the utilization of the reservoir, and enhancing the reservoir's productivity. However, irresponsible aquaculture practices in the reservoir will negatively impact the environment, including water quality degradation and toxicity bioaccumulation. Thus, sustainable aquaculture practices should be developed to avoid the negative impact on the reservoir. Sustainable aquaculture refers to the long-term economic, social, and environmentally responsible methods of fish cultivation, crustaceans, and other aquatic organisms in water **(Frankic & Hershner, 2003)**. This method seeks to create healthful seafood, assist reservoir communities, and preserve productive ecosystems for future generations by balancing environmental health, economic viability, and social responsibility.

Developing a sustainable aquaculture in the reservoir requires taking several factors into account. To prevent toxic bioaccumulation, it is first important to implement proper waste management, emphasizing the efficient management of fish waste, excess nutrients, and chemicals. Second, aquaculture practices should be ensured to protect the reservoir's ecosystem by preventing habitat destruction and preserving biodiversity. This involves controlling the environment's temperature, precipitation, insolation, and other features. Third, fish health can be preserved by upholding strict animal welfare guidelines and putting biosecurity protocols in place to stop disease outbreaks and preserve the well-being of farmed species. To ensure that aquaculture operations are environmentally sustainable, the final step is to regularly conduct environmental impact assessments to identify and mitigate any negative effects on the ecosystem.

The research addressed the temporal dynamics in surface water, water quality, waste composition, and distribution. The development of sustainable aquaculture at Jatigede Reservoir faces several challenges. One of the concerns is the Jatigede Reservoir's fluctuating water surface. The study's findings indicated that the Jatigede Reservoir's most unstable water surface area was represented by the red and black areas outlined in Fig. (6). During the study period from April 2022 to December 2023, there was a noticeable decrease in the surface water area at that particular location.

The calculation to estimate the number of floating net cages installed in the Jatigede Reservoir is revealed in Table (5). The total number of floating net cages is about 3,729 blocks within the 202 FNC complexes. This amount is relatively high, according to **Siagian (2010)**, who stated that the appropriate number of FNCs installed in the reservoir should cover only 1% of its total water area. These NFCs are mostly located in the central area of the reservoir, whereas the fluctuation rates of its water surface were the highest. **Larsson (1984)** asserts that the fluctuating water volume in aquaculture development can result in issues with inadequate water quality, which can raise fish mortality rates and can cause serious environmental problems. The reservoir's water fluctuations have the potential to increase turbidity, organic matter accumulation, and nutrient levels **(Boyd & Pillai, 1984)**. Given the decline in water levels, it may also result in increased concentrations of phosphorus, ammonia, and nitrite **(Nur *et al.*, 2021)**. According to **Nisa (2023)**, fish that are stressed out by volume fluctuations are also more prone to illness and parasites due to unstable water quality.

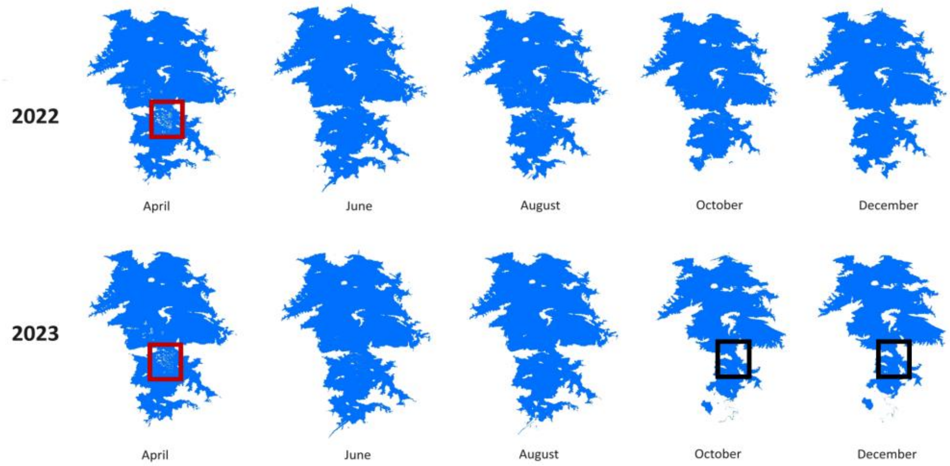

Fig. 4. Unstable water surface areas in Jatigede Reservoir and the FNCs distribution (red and black box)

Table 6. NFC blocks and complex in Jatigede Reservoir

NFC Block (7 x 7 m)	Numbers NFC Complex
≤10	59
10 - 20	73
20 - 30	41
30 - 40	19
> 40	10
Total NFC Block 3729	**202**

CONCLUSION

According to the study on waste abundance and composition, Jatigede Reservoir water was polluted by waste that consists of eight waste categories, with organic waste as the highest amount at an abundance of about 19.432kg. The following categories in sequence were: LDPE (15.29 kg), other types (10.94 kg), PS (9.279 kg), PETE (2.458 kg), PP (2.206 kg), PVC (1.755 kg), and HDPE (0.88 kg). The large waste categories dominated the waste composition in Jatigede Reservoir, followed by the medium and small. To prevent this issue, the recommended action is to install the waste trap in the inlet area of Jatigede Reservoir to avoid waste input from the Cimanuk watershed, especially during the rainy season. According to the study of water quality, NFC estimating calculation, and surface water temporal dynamics of Jatigede Reservoir, in conclusion, aquaculture development can be conducted in this location, however, the unstable water volume and the floating net cages total number should be considered. So, it is crucial to carry out zoning and environmental suitability analysis when developing aquaculture in the Jatigede. In addition, estimating the maximum number (carrying capacity) of aquaculture operation units is significant in maintaining the sustainability of the reservoir for aquaculture development. However, further research of microplastic distribution by FT-IR and Raman analysis in order to mitigate the impact of aquaculture production is recommended.

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