A review on the floating net cage waste management for the sustainability of Cirata Reservoir service life

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Abstract The number of Floating Net Cages (FNC) in Cirata reservoir has exploded four times more than allowed. It makes water quality problem severe because 22,260 tons/month of stools and excessive feeding threaten the benefits, functions, and service life of the reservoir. This is a review paper to explore FNC waste management methods, the potential of integrated FNC management, and the implementation strategies. Twenty-eight articles published between 2015 and 2019 about aquaculture technology have been discussed to improve understanding of FNC waste management. Several solutions have been recommended based on an integrated management approach. Technical ideas are proposed for water control and in situ treatment management. Management of water control reduces the concentration of pollutants by increasing water destratification. The IFCAS (Integrated Floating Cage Aquageoponics System) - PFF (Precision Fish Farming) - IMTA (Integrated Multi-Trophic Aquaculture) concept is an effort to manage FNC using both approaches. The IFCAS-IMTA concept can reduce the main concept of waste by creating the nitrification and assimilation of phosphate. The concept of PFF can improve the capacity of farmers in water quality detection and monitoring. The manager needs to modify aquaculture techniques in water and nutrition, feeding formulations, technological innovations, and the inclusiveness of scientific-based management. Management must involve FNC farmers, research and development institutions, Cirata authorities, Fisheries and Marine Service of West Java Province, and investors.

1. Introduction
Reservoirs are the economic foundation of sustainable development especially for fisheries sector [1], domestic water needs [2], [3], power plant [3], [4], and as an effort to mitigate climate change through flood control [5]. The reservoir service life is threatened by sedimentation, pollution, and unwise management [6], [7]. Suspended sediment loads fill the dead storage areas, thereby reducing water volume capacity, disrupting water flow control and speed, and ultimately, decreasing reservoir productivity [8]. Cirata Reservoir is one of the reservoirs of Java-Bali power plants, agricultural irrigation, aquaculture, but the service life has been reduced for 20 years due to sedimentation [7].

In addition to electricity, the aquaculture in Cirata Reservoir can produce 113,231.53 tons/year of fish (96.07% of the needs of freshwater fish in West Java with a turnover of IDR 450.59 trillion) [9]. The number of aquacultures (Floating Net Cage/FNC) has reached four times (49,995 units) compared to the number of FNC allowed by the West Java Fisheries Service, causing sediment generation of 9,000 tons/month from feces and fish feed residues in 2010 [10]. The sediment load
increased to 22,260 tons/month in 2013 due to intensification [4]. This happens because fish demand continues to grow 13% every year [11] so that although integrated aquaculture has been carried out to reduce the sedimentation load, the implementation is not as expected [12].

Ignoring reservoir carrying capacity is a significant problem of reservoir management because the incoming sediment load is too high compared to the nitrification and N (nitrogen), P (phosphorus) and organic decomposition capabilities carried out by decomposer [13]. This condition causes eutrophication which triggers the harmful algal bloom and decreases dissolved oxygen levels [14], increases fish ectoparasites population [15], increase the death mass frequency of fish, and decreases the productivity of freshwater aquaculture [4], [16]. Corrosivity due to H₂S content increases the cost of maintaining electricity-generating components. This decrease in water quality has caused agricultural output in Cianjur district to decrease [17].

The study of Multidimensional Scaling (MDS) and Monte Carlo analysis showed that the ecological and spatial dimensions have a low sustainability index, and the technology has the highest index [18] Even though technology has only quite a sufficient index, management has the opportunity to develop FNC to be more environmentally friendly, and is able to control contamination and upwelling phenomena. The MDS study is an essential basis, and the urgency of the discussion about innovative technologies in aquaculture needs to be done.

2. Review Method

This study used the type of Scoping Study or Systematic Mapping Study method. The fundamental question used in this study is "How should FNC be developed to optimize space and all dimensions of sustainability in Cirata Reservoir?". Literature was collected then identified, screened, evaluated, and analyzed related to the consistency of the relationships of the research questions [19]. The new concept of FNC was obtained from the last 5 years article analysis. There are four steps to obtain a new concept of FNC.

The first step is to discuss the principles and environment required by the FNC. The second step is to explore each system or new technological concepts in aquaculture. The third step is to understand the characteristics of the Cirata reservoir and analyze its opportunities. The principle of the new concept of FNC is to improve the health of aquatic ecosystems, and also the productivity and the capacity of farmers in order to increase productivity by reducing FNC waste and increasing the quality of feed nutrition and detecting its effects. The fourth step is to analyze strategies for implementing the new concept of FNC.

3. Result

3.1. The Fundamental of Floating Net Cage

Aquaculture is an effort to meet the needs of the fish without depending on natural stocks, through fish farming in a controlled location. This effort requires an understanding of technical and non-technical factors that influence direct and indirect success. One of the aquaculture practices conducted in reservoir waters is to apply FNC (Floating Net Cage) [20]. To achieve good productivity, FNC requires habitat with certain criteria (table 1) [21].

| Parameter         | Variables                                                                 |
|-------------------|---------------------------------------------------------------------------|
| Suitable location | DO > 3 cc/liter; water flows at the rate of 0.2 - 0.5 m/sec; pH 7.5 - 8.5; Temperature is 27°C to 32°C; Coliform bacteria 500 CFU/100 ml. |
| Design & size     | Rectangle or square; 4m long, 10 m wide, and 2 m deep.                     |
| Mesh size         | 0.65 cm for fish below 5 cm; 1.27 cm for fish between 15-20 cm; 2.5 -3.8 cm for fish above 21 cm. |
| Material          | Wood, bamboo, drum                                                        |
| Stocking density  | 60 fish/m³ (without artificial Hides) or 156 fish/m³ (with artificial Hides) |
| Feeding           | Formulated feed or trash fish at 6-7 am and 5-7 pm                        |
| Treatment         | Pre-stocking of 0.1% sulfamonemethoxine                                    |
| Grading           | Once each fortnight                                                       |
| Promoter          | Growth using Nitrovin                                                     |
Water quality parameters have an interrelated relationship where the essential parameters in aquaculture are:

1. **DO (Dissolved Oxygen)** show oxygen levels in the water, which are the main living conditions for organisms. A standard DO value for optimal fish farming is more than 5 ml/liter. However, DO values are highly determined by pollutant levels, temperature, and dissolved salts as indicated by the value of Total Dissolved Suspended, photosynthetic activity, and respiration of aquatic organisms [22].

2. **Water temperature** controls the life processes in the ecosystem because every living thing has an optimal temperature. Improper temperature can cause stress to organisms, inhibit growth, and even lead to death [22]. Water temperature affects biological and physical processes so that this parameter is classified as the most crucial parameter for ontogenesis ectotherms [23] because it affects the abundance and structure of phytoplankton populations [24] and zooplankton [25] which play a role in ecosystem balance.

3. The **pH value** has an impact on productivity, with the optimal pH range is 6.4 to 8.3. The acidity of allochthonous affects the process of decomposition and photosynthesis. In low pH waters, DO tends to decrease, whereas the BOD (Biological Oxygen Demand) is quite high [22].

4. **BOD (Biology Oxygen Demand)** shows pollution status because it is influenced by the number of organic materials and nutrients that are broken down by bacteria and assimilation. High BOD levels cause unpleasant odors and an unhealthy environment. Indirectly, the high value of BOD threatens aquaculture productivity [22].

5. **COD (Chemical Oxygen Demand)** is a reliable parameter for assessing the level of pollution in water. Its value increases with increasing concentrations of organic and inorganic materials [22]. High COD and BOD can cause a significant decrease in DO and even become anaerobic.

6. The **Nitrogen element** in water can be found in the form of nitrite (NO${}_2^-$), nitrate (NO$_3^-$), and ammonia (NH$_3$). These elements can be produced from fish farming waste, especially food waste. Higher protein requirements than carbohydrates in the cultured fish cause ammonia in feces to increase due to improved protein and amino acids [26]. This element is concentrated around FNC especially during low reservoir water flow rates [22]. The form of FNC needs to be addressed because it inhibits the flow rate of water to a depth of 3 meters, that makes the concentration of the element is getting higher [27].

7. **Phosphate** is an essential element for the growth and quality of minerals contained in fish. Adding P in fish feed can improve feed efficiency and increase productivity [28]. However, feeding which incompatible with the digestibility of fish causes the P elements to be released into the water, at least 5.58% of the total weight of the feed given.

8. **TDS (Total Dissolved Solids)** is a parameter that reflects the presence of salt-forming inorganic material in the waters. The maximum TDS concentration in freshwater is up to 1000 mg /liter because if it is more than the threshold, it will become brackish water or saltwater [29]. However, the maximum TDS is only 100 mg/liter for fish farming [22].

9. **TSS (Total Suspended Solids)** is a parameter that indicates the level of solids in the water. The ideal water conditions for fish farming based on TSS value is <25 mg/liter and a maximum of 80 mg/liter [29]. When TSS is high, the respiration process will be disrupted because the gill filter will be disrupted and it can inhibit growth [30].

Phytoplankton, zooplankton, bacteria, and nekton populations will form food webs and have an essential role in mixing stratification of the water layer. However, in general, physical-chemical-biological processes in the reservoir waters ecosystem are influenced by temperature dynamics, dissolved oxygen, total mineral load, nutrient entry, and residence time of water [31]. The mixing of water masses process can occur partially (meromictic) or wholly (holomictic). This process is very influential in food webs and the stress level of the biological community [32]. During the period of stratification, oxygen in the hypolimnion will thin out, and affect the condition of other solutes. As a
result, organisms must overcome the chemical conditions in this gradient zone, some can adjust, and some others experience pressure and move to suitable locations [33]. The conditions become a problem for aquaculture.

3.2. Floating Net Cage Development
Aquaculture has great potential to meet protein needs. This cultivation system is proliferating both in scale and technology. Several technologies and concepts that have developed include:

1. Integrated Floating Cage Aquageoponics System (IFCAS)
   This system requires control on various factors such as nitrate concentration temperature [34], and ammonia concentration [35]. Grow beds, commodity types, and water circulation rate should be developed according to the character of the location [36]. This system is capable of lowering the concentration of ammonia [37]. IFCAS is the development of aquaponics or the integration of fisheries and horticulture, which is proven to be able to increase productivity. The intensity of sunlight is an essential factor in influencing horticultural production (Fig. 1) [38]. This system can improve the investment efficiency and profit ratios [39], improve water quality due to an increase in DO and plant quality by up to 64.1% in the shoot to root ratio \( S : R \) parameter, and increase the average fish weight by 16% [35].

![Figure 1. Sketch of IFCAS systems components][38]

2. Precision Fish Farming (PFF)
   PFF is a development of the Precision Livestock Farming (PLF) approach. PFF encourages aquaculture system to collaborate with the experience of traditional farmers (experience base) and the science and technology that are developing (knowledge base) to get the most suitable aquaculture system for the location. Farmers are required to improve their ability to collect and document everything that happens during the fish production process and are trained to be able to interpret data, conclude data, and determine actions based on fish culture theory. This concept requires the help of scientists on methodologies that are appropriate to the conditions in the field [40]. The PLF concept itself requires interdisciplinary collaboration and technological advances, especially in sensor technology [41].

3. Feed Formulation (FF)
   The technology of nutrition has grown, but it cannot ensure the stability, sustainability, and reliability of aquaculture productivity and ensure the impacts that arise for public health and the environment [42]. How to improve farmers' knowledge to be able to recognize the effects of feed use on fish health, productivity, and environmental health requires multidisciplinary science assistance [43]. Feed management is not only on the right formulation but also on the method of storage, feed transportation, and control of the manufacturing process [44]. The use of phytase enzymes in feed can increase the Food Conversion Ratio (FCR) that increase the growth of fish absolute weight and survival rates [45].
4. Integrated Multi-Trophic Aquaculture (IMTA)
IMTA is implemented by increasing the population of farmed-fish feed organisms (extractive species) so that it can indirectly increase productivity and improve the ecosystem [46]. IMTA has the potential for environmental improvement, through the utilization of waste (by-product) by the extractive species such as algae (inorganic) and molluscs (organic) to create an ecosystem balance. This system can maintain the ecological health of the waters and increase fish productivity, although some studies show that improvement is less noticeable [47]. IMTA also improved its profit from result diversification, capital efficiency, and mitigating environmental damage [48]. This system can support FNC productivity in another trophic level sustainably [49].

5. Artificial Mixing and Oxygenation Hypolimnetic (AMOH)
This approach uses the bubble-plume epilimnetic mixing (EM) system and side-stream supersaturation (SSS) hypolimnetic oxygenation system that can increase Dissolved Oxygen (DO) levels in the hypolimnetic layer (figure 2) [50]. The quality of the aquatic ecosystem can be improved when the application of the system runs properly, and it is essential to note the bubble speed and exact location [5]. This approach effectively controls the dynamics of phytoplankton populations, removes some taxa of toxic algae (Cyanobacteria), and increases thermal destratification [51]. The system prevents the accumulation of Fe and Mn due to oxidation [52]. This method releases compressed air through a perforated diffuser, and then the air bubbles rise to the lake surface carrying oxygen in a turbulent clump upwards and spreading vertically. This has led to destratification [53].

![Figure 2. Illustration of Artificial Mixing and Oxygenation Hypolimnetic](image)

6. Ecosystem Dynamic for Assessment (EDA)
The success of FNC is strongly influenced by physical-chemical-biological water, so it requires continuous observation of water parameters to avoid the danger of contaminants to fish and a decrease in carrying capacity. Cyanobacteria populations need attention because they produce cyanotoxins that are harmful to fish farming and should be controlled through monitoring using sensitive indicators [54]. Microorganism parameters that influence the quality of aquaculture are total plate count, total coliform, and fecal coliform because they increase the risk of fish contamination and can cause various diseases [55]. Fecal coliform is the most relevant biological parameter as a sensitive indicator [56].

7. Non-technique (Carrying Capacity & Lice Cycle Assessment tool)
Developing FNC through multi-aspect standardization is needed to ensure the sustainability of benefits in all aspects. The economic aspect shows the level of efficiency in the use of financial resources, economic feasibility, durability, and capacity to absorb negative external costs and to generate funds for reinvestment. Environmental aspect reflects the use of natural resources, the efficiency in using resources, the minimization of the pollutants and byproducts that are not used, and the risk reduction for biodiversity. The social aspect reflects the capacity to generate benefits...
for local communities, including employment and food security, equitable distribution of income, equality of opportunity, and the involvement of socially vulnerable groups. The system can use certification organizations, investors, and policymakers [57]. Assessment can use the method of Life Cycle Assessment (LCA), as well as demonstrations as a basis for decision making in sustainable production efforts. In the case of Cirata, to support the preservation of cleaner production, based on an analysis of decreases in LCA in the number of FNCs is a priority [58]. A healthy environment can provide maximum ecosystem services through high primary production by plants, nitrification by bacteria, and decomposition by other bacteria. The reviews about these processes allow balanced ecosystems to Werner and aquaculture carrying capacity (ACC) as the ability of the ecosystems to accommodate aquaculture. It needs information about the maximum number of aquaculture that can occur in a particular body of water [11]. Certification has been widely applied in various sectors to improve product quality and the environment but requires adequate tools and assistance in the freshwater fisheries sector.

Some factors that cause low fish production are lack of farmers’ knowledge, poor fisheries extension services, feed fraud, low water quality, high construction cost, and insufficient water flow [43]. Interdisciplinary research in aquaculture innovation can provide significant insight to support the development of a resilient and sustainable aquaculture sector. Research results usually have a high success but are challenging to apply in sustainable cultivation practices. Therefore, the social, ecological, and institutional innovation of aquaculture should be considered in creating innovation. One tool that can optimize resources and improve strategy effectiveness is to use the SWOT-TOWS matrix [59]. Table 2 below is the result of the literature review. The development of FNC management system has been generally applied and is still a concept.

**Table 2. The Technology approach for optimal management of Floating Net Cage (FNC)**

| IFCAS | PFF | FF | IMTA | AMOH | EDA | Non-technique |
|-------|-----|----|------|------|-----|---------------|
| A food production system, development of a combination of aquaculture and hydroponic [34] | The application of collaboration concept with farmers’ experiences in order to increase the ability of farmers to monitor, control, document, and interpret data to take appropriate actions. [40] | The feed formulation is essential in fisheries productivity to determine profitability and environmental quality. Feed technology can ensure safe feed, increase aquaculture product, and maintain environmental sustainability [42] | develops complete ecosystem principle, using a multi-trophic approach that allows the flow of energy and material from one trophic level to another to minimize waste [47] | Intervenes the water layer to reduce the potential of algal blooms and hypoxia by circulating hypolim-netic air at the bottom of the thermocline and managing the phyto-plankton population [60] | A system for assessing carrying capacity quality based on ecological dynamics using bioindicator. The key species of toxic organisms (Cyanotoxins) and species that are sensitive to changes in water quality (specific plankton) as determinants [54]. | Management efforts through multi-sector standar-dization based on indicators of economic, environmental, and social. Ecolabel/ certifica-tion can be imple-mented [57]. |

3.3. Characteristic and Opportunity of Cirata

The characteristics of bathymetry, morphology, and water quality significantly affect the reservoir carrying capacity. Bathymetry and morphology influence sunlight intensity, sediment distribution, water purification, and stratification. Water quality will determine the feasibility of water utilization [61], [62]. All of them affect the ecosystem, especially on primary productivity produced by organisms such as phytoplankton [13].
Cirata has an area of 6,200 ha. Water resources come from 12 sub-watersheds with catchments area reaches 603,200 ha, which covers the areas of Cianjur, West Bandung, and Purwakarta [18]. The maximum average water flows reaches 0.16 m/sec and is classified low (<0.5 m/sec) [63], while the water residence time is 0.696 years [10]. Long water residence time will trigger the bacterial growth [64], the holomictic condition (perfect water masses mixing), low DO, and increase the anoxic zone, especially around the FNC [65].

The assimilation capacity of ecosystems in Cirata against Pb and Zn elements is only 13 and 9 tons/year [64]. It shows that the Phosphorus load has exceeded the capacity [67]. On the one hand, the P content in the feed is still high. The P load generated from a ton fish feed used by farmers reaches 106.8 kg [68]. This condition causes more intensive stratification. At depths of > 27 m, the DO value is only 0.5 to 0.9 mg/liter or 10% compared to the surface (the first 0-6 meters) [62]. SO2 reaching 12.54μg / m3 has caused corrosive steel tailrace [69]. In general, Cirata water quality does not meet the quality standards for fish and livestock (the parameters H2S, DO, COD, BOD, Cd, E. coli, and Coliform are higher than standard) [7].

Based on the biophysical conditions of the Cirata reservoir, managers are required to reduce the intensity of stratification and increase purification. One of the efforts for both is to increase the mixing of water and form a trophic chain through the selection of types that can absorb excess pollutant elements. The practice of aquaculture combined with agriculture has the potential to create a cycle of nitrogen and phosphor.

3.4. New Concept of Floating Net Cage for Cirata Reservoir

Several previous studies have provided direction for FNC management in Cirata, including reducing the number of FNCs [58], [63], regulating the presence of FNCs, tightening new FNC licenses [18], and also increasing feeding formulation and feeding systems [12], [70], collection of environmental improvement costs or incentives for FNC farmers to improve water quality [71], and internalization of environmental costs to increase carrying capacity [72]. Most of the previous studies have not focused on the development of FNC or pilot project and need a new concept that was initiated based on a comprehensive assessment.

FNC farmers and the Cirata Reservoir Management Agency (BPWC) need to build a water quality control system and a balance of carrying capacity and capacity to ensure the sustainability of reservoir service life. Water quality can be improved by lowering the concentration of pollutants through reducing sediment and waste loads, increasing assimilation and nitrification capacities, increasing water layer destratification, and developing a water quality monitoring system. The aquaponics concept needs to be developed through improving water quality that has been carried out in Cibalagung Watershed (Cirata Sub-watershed). The practice has improved water quality and fish productivity. The ammonia levels are also 91% lower than conventional systems because the recirculation system triggers decomposition and nitrification. However, when fish demand is high, the feeding system becomes uncontrolled and increases waste. This system can be improved by involving other systems that have been studied, one of which is implementing IFCAS-IMTA as an integrated aquaponics concept. The IFCAS principle has not been widely adopted by the FNC in Indonesia.

Based on seven approaches (table 2) on FNC management practices, the IFCAS-IMTA concept has the potential to support the success of cleaner production in the context of sustainable development. It is supported by a combination of the two principles. Resource efficiency, biodiversity conservation, and waste reduction of IFCAS-IMTA comply with the cleaner production principles launched by the United Nations [73]. IFCAS-IMTA approach allows managing waste that occurs at all stages of production, improving the efficient use of resources or raw materials, and ultimately reducing production costs and increasing social and environmental economic benefits. Considering the source of pollutants also comes from the water catchment area, a quality monitoring system should be developed with the concept of farmers’ independence. In the concept of PFF, farmers are the main subject in controlling water quality.
Increasing the capacity of farmers is the most crucial aspect in the concept of cleaner production because the actors of Indonesian aquaculture are dominated by small farmers. In addition to market needs that have turned into organic and eco-friendly as the demands for the sustainable development goal, the Government should communicate with farmers and the private sector to develop organic production standards and procedures for farmers in implementing organic farming [74].

The simultaneous implementation of IFCAS-IMTA-PFF conceptually can increase the potential for increasing the FNC sustainability index. The concept is similar to Rimmer Minapolitan initiative in 2013 [74]. The IFCAS-IMTA-PFF approach is the intensification of existing production systems and commodities to realize Indonesia as a World aquaculture producer. There are three strategies to achieve this vision, and the other two are the development of existing production systems and commodities strategy (extensification) and the increased diversity of production through the implementation of new commodities strategy.

3.5. Implementation Strategy in Cirata Reservoir

The system of integrated multi-trophic aquaculture (IMTA) developed in Cirata is illustrated in figure 3. IMTA practice was conducted with the aim of reducing a load of feed waste because artificial feed produced residues that could increase eutrophication. There are at least 11 types of fish pellets containing 1.27% - 1.66% phosphorus, whereas it only takes 0.5-0.9% for growth (table 3). However, IMTA practice in Cirata was not different from intensification. The every season pattern is 71.41 kg of goldfish in B, while 69.19 kg of tilapia C or 122.28 kg of pomfret in B and 60.51 kg of tilapia in C. every year, farmers harvest 5 times from pool B, whereas pool C only 2 times. Farmers’ empowerment in feed management includes the quality, storage, frequency of feeding, and the use of various types of fish that are urgently needed to be done [12]. There is a strong correlation between the sex of fish and feed efficiency, that single-sex female of patchouli fish (nilam fish) can be used as a controlling organism phytoplankton growth and as a bio-cleaning agent of periphyton in Cirata reservoir [70].

This discussion shows the importance of a comprehensive understanding of appropriate resolution approaches and the need to experiment with several approaches implemented simultaneously. In particular, the case of dangerous algae requires some approaches to reduce stratification (hypolimnetic to epilimnetic) with destratification and oxygenation, floating and deadly covers with H₂O₂ (Hydrogen Peroxide) [75].

![Figure 3: The practice of integrated multi-trophic aquaculture system in Cirata Reservoir [12]](image-url)
Table 3. Nutrient content in fish feed of IMTA system

| Type of Feed | Protein | Fat | Coarse fiber | Ash | Water Content | Phosphor |
|--------------|---------|-----|--------------|-----|---------------|----------|
| Px1          | 25      | 6   | 7            | 12  | 12            | 1,45     |
| Pxm          | 25      | 6   | 7            | 12  | 12            | 1,64     |
| Pxn          | 26      | 5   | 7            | 12  | 12            | 1,66     |
| Pxo          | 24-26   | 6-8 | 4-6          | 10-13| 11-13        | 1,59     |
| Pxp          | 24      | 5   | 7            | 12  | 12            | 1,44     |
| Pxq          | 25      | 5   | 7            | 12  | 12            | 1,59     |
| Pxr          | 26      | 5   | 7            | 12  | 12            | 1,50     |
| Pxs          | 29-30   | 5   | 7            | 12  | -             | 1,62     |
| Pxt          | 26      | 6   | 6            | 11  | 12            | 1,38     |
| Pxu          | 24-26   | 5-7 | 6-8          | 5-8 | 11-13        | 1,27     |
| Pxv          | 25      | 5   | 6            | 12  | 12            | 1,40     |
| Range        | 24-30   | 5-8 | 5-8          | 5-13| 11-13        | 1,27-1,66|
| Average      | 25,25   | 5,33| 6,78         | 11,89| 12,00        | 1,50     |

Implementation of IFCAS-IMTA-PFF can adopt the Minapolitan by designing integrated farming areas; upgrading human resources as farmer entrepreneurs through stimulus programs, motivational training in production, processing, and marketing; creating networks between government (Marine and Fisheries Department of West Java/MFDWJ), the private sector and farmers; developing appropriate technological support and innovation; making collaborative-inclusive management based on the results of research from institutions and information by farmers; empowering individuals and groups to increase ecosystem resilience, social security and welfare; and providing sufficient quantities of superior broodstock and high quality seed to support aquaculture production [74].

MFDWJ should ensuring the availability of fisheries production and continuous improvement in product quality and also as the working group coordinator [76]. Application of the measures demands the manager to increase the active role of all stakeholders related to the implementation inclusiveness of the program based on the results of scientific studies. Multi-stakeholder for FNC management should involve farmers as the main actors who need to be supported technically and financially to carry out the eco-friendly FNC management.

4. Conclusion

To maintain an optimal level of FNC productivity in Cirata reservoir, management needs several approaches to resolve it. The principles of pollution control, pembilan detection systems, and development of FNC must be based on the results of the research. This discussion provides recommendations for implementing the IFCAS-IMTA-PFF concept. The combination of these three approaches applies cleaner production principles that have the potential to realize sustainable development goals.

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