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How to make the ally of inland fisheries and inland aquaculture: A review

I Ma'ruf[1,2,*], M M Kamal[3], A Satria[4], Sulistiono[3]

[1] Aquaculture Department, Faculty of Agriculture, Universitas Muhammadiyah Palembang, Jl. Jend. A. Yani 13 Ulu Plaju, Palembang, Indonesia
[2] The Study Program of Natural Resources and Environmental Management Science, Postgraduate School, IPB University (Bogor Agricultural University), Kampus IPB Baranangsiang Jl. Raya Padjajaran Bogor, Kota Bogor 16151, Indonesia.
[3] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia
[4] Department of Communication Science and Community Development, Faculty of Human Ecology, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia

*Corresponding author: irkhamiawan_p062180151@apps.ipb.ac.id

Abstract. Inland fisheries are a significant sector especially for those living in villages as a source of both nutritious yet affordable food and the community's income. The increasing pressure on inland fisheries causes a reduction in the amount and size of fish caught as well as the rarity of some species of fish. One measure taken to intensify inland fisheries is by implementing inland aquaculture. Unlike any other controlled condition aquaculture, inland aquaculture is done with adjustment to the water condition. This study aims to describe characteristics of several inland waters of Ogan Komering Ilir regency, South Sumatera Province, Indonesia in particular as well as to provide a guideline for inland aquaculture based on the characteristics of the waters. The description is done by reviewing a number of academic journals and publications which are verified by academics and expert judgment. The main points in describing inland fisheries are water typology, fish resource, water quality, and social community characteristics. After analyzing the inputs from inland fishery characteristics based on the 4 main points previously mentioned, a guideline is created for conducting fish farming in terms of farming methods, seed selection, seed stocking criteria, and institutional arrangement in fish ownership issue.

Keywords: culture-based fisheries; fisheries management; inland aquaculture; inland waters; OKI

1. Introduction

Inland fisheries are a vital sector that provides the community with food and income, especially for those living in villages. They can be a reliable solution to prevent and eradicate poverty in villages [1–4]. In villages where it has become a dominant ecosystem and developed relatively close to where people live, inland fisheries are the source of not only food and income but also some other necessities namely

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agriculture, raw materials for household needs, facilities for bathing, washing, and latrine, and many more.

Rapid economic and population growth creates pressure toward inland water resources. This pressure is caused at least by 5 leading factors: overfishing, water pollution, habitat degradation, invasive species, and river flow modification [5]. The degrading quality leads to several things: reduction in amount and size of fish caught as well as the rarity of some species of fish [6,7].

Some efforts need to be done in order to increase the community's fishery gains. In addition, intervention is also needed to find solutions to the cause of declining fish resources. One of the solutions is to apply aquaculture in inland waters [8–10]. Fish cultivation with the characteristics of rapid growth and options of fish species to choose from (being able to choose types of fish with high economic value with rapid growth) is potentially fulfilled the needs for food, community income, as well as the source of seeds to increase stock in the waters [11]. Nonetheless, in many cases, the contribution of inland fisheries is extremely hard to replace by aquaculture for factors such as production cost and lack of cultivation skills [1,12]. Therefore, the contribution of capture fisheries and aquaculture will be massive if implemented together. Inland aquaculture is considered a "close friend" with inland fishery management.

Inland waters used for aquaculture in Ogan Komering Ilir (OKI) regency in particular have huge potential. About 70% of its area is lowland, making it water niches that in some parts are permanently inundated while the other parts are temporarily inundated following the current season. Estimated production values based on primary productivity of several types of waters show that lakes have the potential of 111±50,1 kg/ha/year, while floodplains on average with 266±188 kg/ha/year, and small reservoirs on average have the potential to produce 2.835±623,6 kg/ha/year [13].

1.1. Stocking and enhancement strategy program

Stocking and enhancement programs can be conducted by spreading fish seeds to the waters. Seed spreading generally aims at enhancing fish stock in the waters so that in the end it will increase the fish catch or restore fish resource [14, 15]. However, whatever the choice is to be done, the fish seed spreading activities in public waters at least should consider the capacity of the water, and its purposes are solely to repair the habitat and enhance the fish stock (figure 1).

Inland aquaculture is a cheap and easy undertaking compared to other controlled closed containers. Nevertheless, this activity is considered high risk, not only because the hard-to-control environment factor exists but also not careful aquaculture can lead to environmental damage and existing water ecosystem disturbance in which the aquaculture is being conducted. Inland waters have various typologies and are prone to external changes. Water fluctuation which is difficult to forecast and the risks of flooding in rainy seasons and drying land in the dry seasons make inland fisheries, especially those of large-scale fisheries, closely examine land and water management with the location-based technology implementation [17]. Intervention towards inland fisheries should be done so that it does not exceed the capacity, can take advantage of the niche, as well as is scientific data-based.

2. Methodology

This academic paper aims to provide a description and guideline for those who are active in the fishery as well as the academics in this field; it is also considered as a proposed guideline to understanding inland fisheries better, resulting in better options in implementing inland aquaculture. This paper also is a part of efforts to promote and popularize environmentally friendly fish cultivation models.

The methodology used is the literature review, which surveys academic journals and publications related to the inland fisheries in general and inland fisheries in Ogan Komering Ilir regency, South Sumatera Province, Indonesia in particular. Due to the vast areas of discussion regarding this field, this paper limits the discussion only to floodplain rivers and wetlands (riparian vegetation and swamp forest) which both are most commonly found in OKI regency [18]. The result of the literature review later will be verified by a team of experts to earn scientific opinions and confirmations.

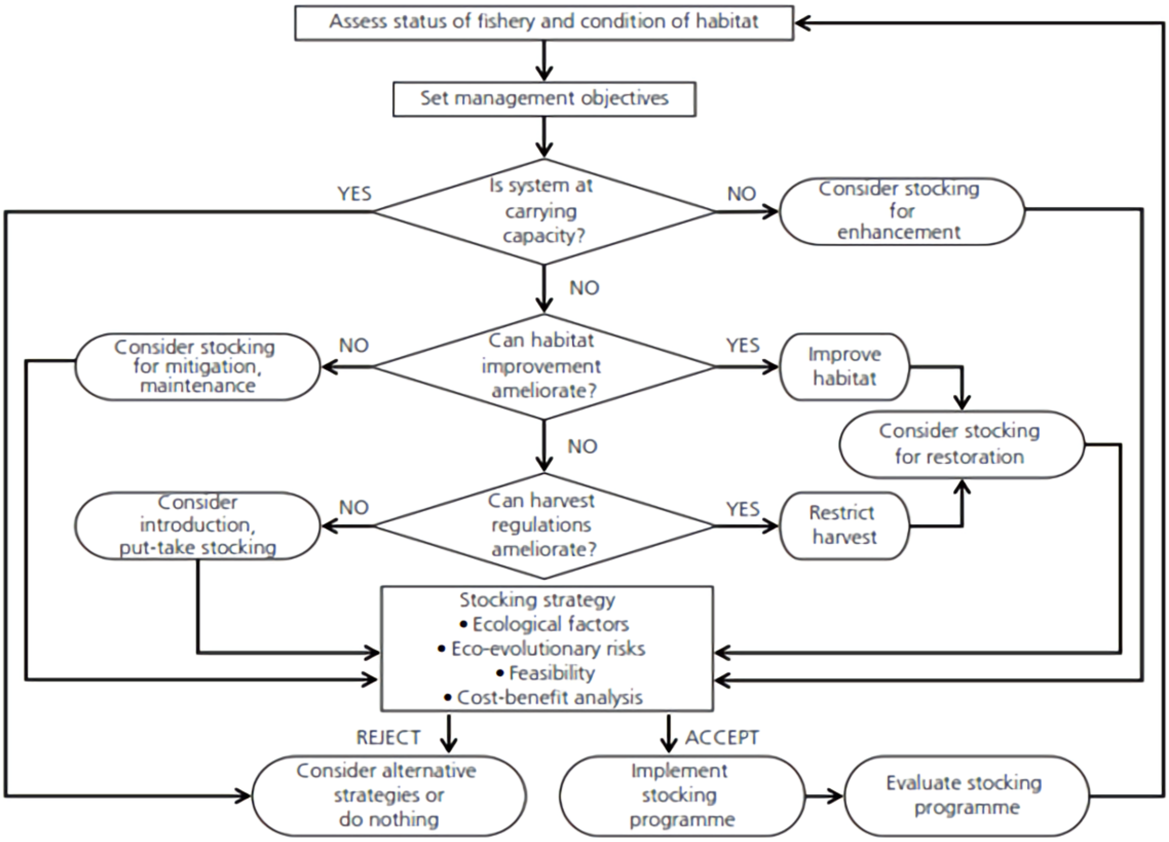

Figure 1. Flowchart to understand habitats and stocking strategy program [16].

3. Results and discussions

The results of the study identify at least four pressing issues of inland fisheries, which later can be used as inputs in the decision making process of implementing aquaculture in inland waters and as a guideline for its technical implementation. The issues are water typology, fish resource, water quality, and social community characteristics.

3.1. Water typology

A floodplain is a waterlogged area, which can be permanent or seasonal, connected to the rivers in rainy seasons (figure 2). Floodplains are highly affected by their inundation height, which can influence fish productivity. In the beginning of rainy season, river streams deposit nutrient materials and lead fish migration to floodplains [19]. Floodplain inundation heights in rainy seasons vary, while in extreme dry seasons the channels are completely dry. In general, the two biggest problems in floodplain and reservoir fisheries are pollution and extreme change in inundation height [20]. Typology-wise, there are 3 characteristics of floodplain. The further description can be seen in table 1.

Table 1. Floodplain typology.

Type	Flood Duration	Depth
Shallow floodplain	< 3 months	< 50 cm
Middle floodplain	3–6 months	50–100 cm
Deep floodplain	>6 months–permanent	>100 cm

Source: Widjaja-Adhi *et al.* [22]

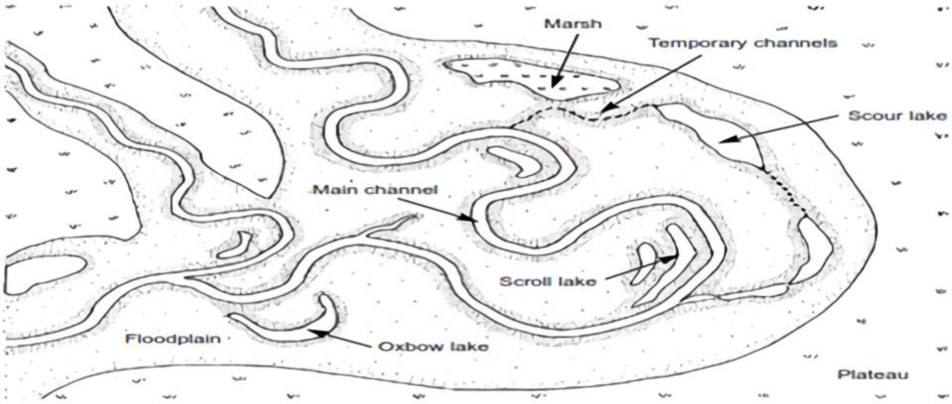

Figure 2. Diagram of the main channel and floodplain [21].

3.2. Fish resources

In Indonesia, the diversity of fish resources follows the Wallace and Webber Line. The area was divided into the Sunda shelf, the Wallace area, and the Sahul shelf. Cited from Mogabay[1] site, there are 1130 fish species in Indonesia, consisting of 19 introducing species, 88 endemic species, and 1008 native species, while the rests are still unknown.

Referring to some studies published in several academic journals, there are 14 species of 62 types of fish found, comprising both invasive and native types of fish (table 2). Some potentially invasive types of fish are *Clarias batrachus, Oreochromis niloticus* and kinds of *Tilapia* sp. [26]. Those species of fish that have been classified are expected to describe types of native species of the inland waters of OKI regency.

Table 2. Fish caught on a floodplain.

Location	Time	Type of species			Reference
Lebak Jungkal, Pampangan, OKI	Feb-Jul 2013	*Nandus nebulosus* *Anabas testudineus* *Helostoma temminckii* *Kryptopterus lais* *K. apogon* *K. macrocephalus* *Parachela oxygastroides* *Puntius lineatus*	*P. pentazona* *Trichogaster pectoralis* *T.tricopterus* *Belontia hasselti* *Pristolepis grootii* *Pseudeutropius brachypopteru* *Channa bankanensis*	*C .lucius* *C. striata* *C.pleurophtalmus* *Clarias batrachus* *C. teijsmanni* *Mystus micracanthus* *M.nemurus*	[23]
Lubuk Lampam, Pampangan, OKI	Feb-Oct 2012	*Paradoxodacna piratica* *Acrochordonichthys rugosus* *Anabas testudineus* *Bagrichthys macracanthus* *Mystus nemurus* *M. nigriceps* *Colossoma macropomum*	*Gyrinocheilus pustulosus* *Hampala ampalong* *H.macrolepidota* *Labiobarbus festivus* *L.leptocheila* *L.leptocheilus* *Leptobarbus* sp *Luciosoma trinema*	*Mastacembelus erythrotaenia* *Nandus nebulosus* *Pristolepis fasciata* *Notopterus notopterus* *Belontia hasselti* *Oreochromis niloticus*	[24]

[1] https://fish.mongabay.com/data/Indonesia.htm#hH8Ve2erorul50s3.99. The primary resources are from fishbase.org.

Location	Time	Type of species			Reference
		Channa lucius *C. melastoma* *C. pleuraptalmus* *C. striata* *Clarias batrachus* *Clupeoides borneensis* *Cynoglossus waandersi* *Albulichthys albuloides* *Barbichthys laevis* *Barbodes goneonotus* *B.schwanenfeldii* *Crossocheilus oblongus* *Cyclocheilichthys apogon* *C. apogon* *C. enoplus*	*Osteochilus hasseltii* *O.microcephalus* *O.schlegelli* *Parachela oxygastrodes* *Puntioplites bulu* *P.waandersi* *Puntius johorensis* *P.lineatus* *Rasbora caudamaculata* *Oxygaster anomalura* *Oxyeleotris marmorata* *Helostoma temminckii* *Hyposarcus pardalis* *Macrognathus acuelatus*	*Osphronemus goramy* *Tilapia mosambicus* *Trichogaster pectoralis* *T.trichopterus* *Luciosoma trinema* *Pseudeutropius brachypopterus* *Kryptopterus apogon* *Ompok eugeneiatus* *Phalacronotus micronemus* *Silurodes hypophthalmus* *Wallago leerii* *Tetraodon palembangensis*	
Lebak Deling, Pangkalan Lampam, OKI	Mar-Jul 2018	*Channa striata* *C.pleuraptalmus* *C. lucius* *C. melastoma* *Cryptopteru* sp. *Clarias* sp. *Trichogaster pectoralis*	*Pristolepis fasciata* *Belontia hasselti* *Pristolepis grootii* *Mystus nigriceps* *Mystus nemurus* *Anabas testudineus* *Helostoma temminckii* *Barbodes goneonotus*		[25]

3.3. Water quality

When a body of water is enough filled with materials of organic matter and nutrients, slight eutrophication occurs, and this process is beneficial for fish [27]. However, when the body of water is over enriched with those materials, it becomes hypertrophic that will cause algae and water vegetation blooming leading to lower dissolved oxygen levels which is deadly for fish, especially those without additional respiratory that allows them to breathe from open air. Several water quality parameters of floodplain in OKI regency can be seen in table 3.

Table 3. Water quality index of floodplain in OKI regency.

Source	Parameter value	
Lebak Jungkal, Pampangan, OKI (Feb-Jul 2013) [23]	pH 4.4–60 DO 5.5–6.9 mg/L	Temperature 34–39 ^{o}C Clarity 14.5–67 cm
Lebak Deling, Pangkalan Lampam, OKI (Mar-Jul 2018) [25]	pH 4.1–5 Temperature 28.1–32.2 ^{o}C DO 1.7–4.1 mg/L Depth 70–500 cm	Clarity 20–50 cm TDS 13–35 Phosphate <0.060–<0.090 mg/L N total 12.50–38.90 mg/L Ammonia 0.68–0.95 mg/L
Lubuk Lampam, Pampangan, OKI (Dec 2012-Nov 2013) [28]	Depth 2.49±0.40 m Flow velocity 0.16±0.05 m/s Clarity 0.48±0.17 m	COD 56.04±44.54 mg/L N total 47.82±10.30 mg/L Nitrate 0.18±0.39 mg/L

Source	Parameter value	
	Turbidity 22.74±9.04 NTU Temperature 29.67±0.88 °C pH 5.14±0.41 DO 2.84±1.54 mg/L DHL 43.13±11.50 mg/L BOD 1.78±1.71 mg/L	Nitrate 3.01±2.60 mg/L P total 3.56±1.49 mg/L Orthophosphate 0.10±0.08 mg/L Alkalinities 33.94±17.35 mg/L
Lubuk Lampam, Pampangan, OKI (Jan-Oct 2012) [19]	Temperature 29 °C Clarity 0.24–0.63 DHL 44–64.89 µS TDS 22.50–32.43 µg/L pH 4.5–5.6 DO 4.21–5.15	CO_2 11–16.57 mg/L N total 0.37–0.43 mg/L P total 0.05–0.07 mg/L Alkalinities 1.14–2.43 mg/L Hardness 3.3–5.22 mg/L

The differences in temperature are closely linked to the condition of vegetation both around and in a water body. Besides, the connectivity to the main rivers cause the temperature become lower [21]. The characteristic of pH of floodplains tends to be acidic or near normal. It is due to the high amount of organic materials which lead to decomposition and the potential acid sulfate soils [29]. The level of dissolved oxygen (DO) tends to be relatively low due to the decomposition process of organic materials as well as oxidation of both organic and inorganic matters. For most native fish, the adaptation process occurs with the appearance of additional breathing apparatus making them possible to breathe from air [30].

3.4. Social community characteristics

The common management regime especially in river and floodplain areas is the auction system. Within this system, a winner of the auction is granted the ultimate power of fish catch, while the rest of the community has no legitimate rights to catch fish or conduct aquaculture activities without the permission from the aforementioned winner. Some issues and conflicts have emerged due to the border obscurity between the objects of auction, and the utilization of damaging fish catching tools that is hard to be controlled by the authority [31].

3.5. Recommendations in inland aquaculture

From the analysis of the inputs of the characteristics of inland fisheries above, the following flow chart is drawn to be the consideration in implementing inland aquaculture. There are at least four things that should be examined when implementing inland fisheries:

1. Aquaculture method applied. In general, two methods are applicable, namely open water methods (e.g. culture-based fisheries (CBF)) and closed container methods (e.g. cage system and pen culture). CBF can be defined as an aquaculture method using waters as natural containers and maximizing natural source of food from the waters. CBF makes possible of aquaculture to be done cheaply and collectively, without giving extra food and involving community in the activity. CBF is an adaptive choice to be integrated with capture fishery. CBF allows fish stock enhancement by adding more seeds that have been grown from aquaculture activities [9, 10].

   Aquaculture using cage system can be implemented in waters with sufficient depth. Cage placement should consider waters depth, flows, and should not disrupt other users of bodies of waters namely transportation and household needs. Cage placement should also be far enough from conversation areas (both regulated areas and yet to be regulated areas but have functioned as one) [32]. The implementation of cage system should also really examine the location and placement. Aquaculture using cage system will increase sedimentation and material deposits such as Nitrogen and Phosphate which can accelerate the growth of benthic zone in the waters [33, 34]. Some studies conducted in

Africa and Cambodia reveal that cage system significantly contributes to the increase of fish catch and can be done sustainably with mutual support from conservation and capture measures [35].

2. Types of fish for aquaculture. The types of cultivated fish will be heavily depend on waters typology, aquaculture method, water quality, and inundation period. In closed waters with the use of cage system/pen culture, in which disturbance in ecosystem can be localized, it is highly recommended to cultivate non-invasive, plankton-eater type of fish. Plankton eater is a type of fish with rapid growth, making the harvest time shorter and crating less impairment to the native fish of the given ecosystem. The fish chosen to be cultivated should also be native, non-invasive kind of fish. Although using controlled containers (cage, for example), there is still high potential of fish escaping to the waters. The selection of invasive types of fish will potentially harm the ecosystem since they become competitor of native fish [36, 37].
3. The selection of fish seeds. Seeds used will be heavily independent to the quality of the waters. Inland waters, including swamps, either minerals or turf, are a fragile ecosystem, and their poor water quality will cause hindrance in fish growth or even death. However, if the aquaculture should be done in this circumstance, one way to do it is by using large seeds which have been previously conditioned with the water quality of the destined waters. The seeds preparation and adaptation will open doors for community to improve their economy. One way that can be done is by establishing community seeding unit (UPR). Seed adaptation can be undertaken by developing both land-based and water-based UPR. Seed adaptation at land-based UPR can be done using water resource from waters in which seeds will be scattered. Addition to that can be done gradually by monitoring the growth of fish seeds. In deep enough floodplain, seeds nursery can be done using cage system [25].
4. Fish ownership. The issues on fish ownership will emerge in public waters with open access and CBF method. This method allows fish to be taken care of by nature [38]. Therefore, in open access waters, the ownership of the spread fish becomes crucial. A lesson learned from various CBF implementations is that the ownership of fish spread in inland waters is highly doable. Regarding the waters which can the object of auction, the local or fishing authorities can act as the owners of the objects and can grant limited fishing rights to certain groups from the community with quota based fishing that should be agreed by all parties. The source of the fish seeds can be imposed to the auction winner with the obligation to support restock enhancement program by allocating 5% of the auction value to buy spread fish seeds [39]. The fund deposited by the winner can be managed by CBF groups, and those groups can use the money to prepare seeds that are about to spread.

4. Conclusion

Based on the elaboration of all four points above, a framework flow chart can be designed, and this flow chart is expected to assist in decision making process of inland aquaculture program in open waters. The flow chart is in figure 3.

Water availability is a crucial factor in aquaculture. Almost no aquaculture activities can be done without sufficient water availability. Based on floodplain characteristics, it is safe to say that the floodplain aquaculture should be implemented in floodplains with at least 6 months of inundation or in deep floodplains. For floodplains with a duration less than 6 months, stocking the seeds can be done to increase fish stock and resource restoration (non-aquaculture).

The cage system can be a choice for closed waters or individual-owned waters. For public waters and open-access waters, however, culture-based fisheries can be applied, or with a strictly regulated cage system. The choice of seeds should be done using non-invasive, native fish species with large size. Seeds with the size of >8 cm are ideal since they have better endurance toward the change of water quality as well as the predators.

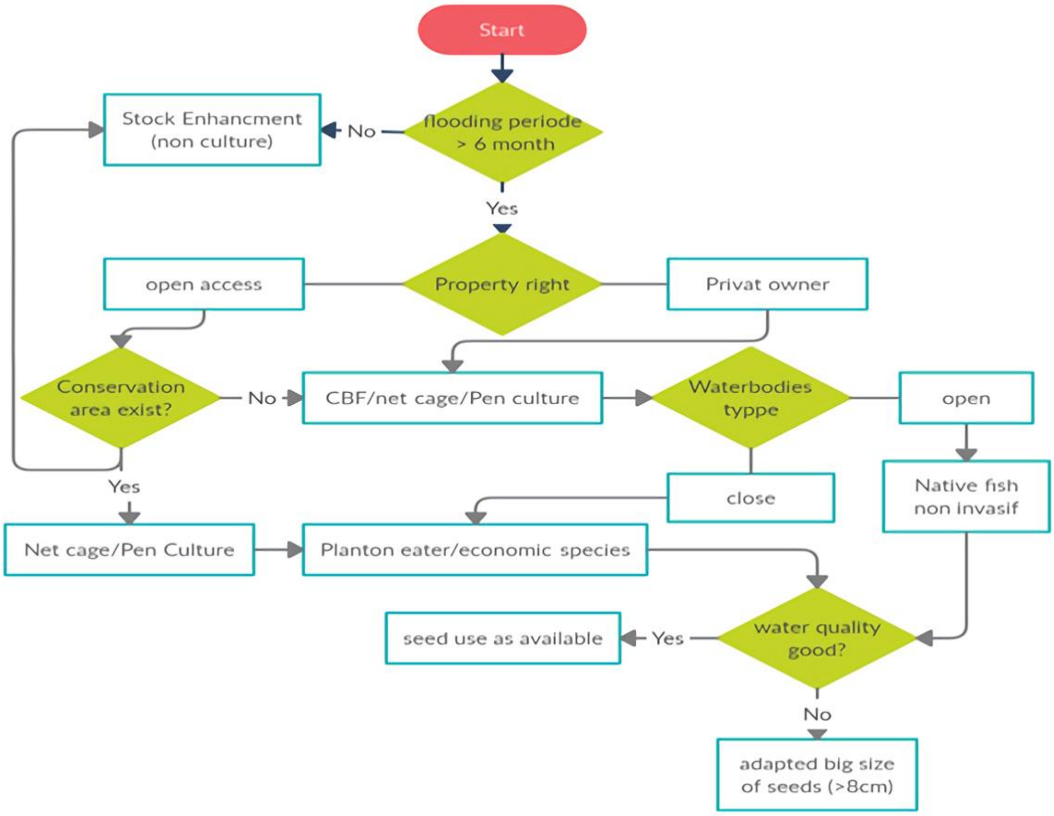

Figure 3. Inland aquaculture decision framework.

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