Increasing of fish productivity by finding suitable FADs placement locations based on Landsat 8 Imagery’s analysis

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Abstract. The main fishing ground of Pacitan Regency are Pacitan Bay and Indian Ocean. In addition to traditional methods, Pacitan fishermen also use Fish Aggregating Devices (FADs) to catch fish. The use of FADs in areas that have suitable water quality can further improve their production. The purpose of this study was to determine the effective of fish production at FADs locations, which are located in areas with appropriate oceanic conditions. This applies for both fishermen who use fishing rods and those who use FADs. The data collection method in this study used Landsat 8 Imagery, with parameters used in this study including temperature, current velocity, turbidity, salinity, depth and abundance of chlorophyll-a. The method used in this research was Spatial analysis with GIS technique. As for obtaining production data, an interview was conducted with fishermen. The results showed that fish production from fishermen using FADs was 400% larger than that of fishermen by traditional fishing methods. Areas that are oceanographically very suitable for FAD placement produce fish with better quality than those that are satisfactorily suitable -with more than 75% of its production is large pelagic fish.

1. Introduction
The beach of Pacitan Regency in East Java consists of gulfs and the open sea. Pacitan Regency is located in the coordinates of 7°55’00” - 8°17’00” South Latitude and 110°55’00” – 111°25’00” East Longitude. The regency is directly adjacent to the Indian sea which is rich in fishery products. Therefore, Pacitan Regency is one of the fisheries centers in Southern Java [1].

As a center for fisheries, along the coast of Pacitan Regency there are 17 Fish Landing Places, for fishermen who are looking for fish in the Indian Ocean. Of the 17 places, only 6 locations were equipped with fish auction/fish sales markets. The six locations are Tamperan Port, Teleng, Watukarung, Tawang and Sumberejo. Tamperan and Teleng ports are in Pacitan Bay, while other fish ports are located on the coast directly adjacent to the Indian Ocean [2].

Since 2007, Tamperan has been designated as a Coastal Fisheries Port. The other five ports are still considered as small fishing ports. However, their locations are still easier to visit for fish traders to those fish landing sites without market/fish auction sites. The Tamperan Fishery Port is located in Pacitan City which is highlu accessible from various cities in Java. This port is also designated as the catchment fishing base and the core zone of the Minapolitan Region [5].

The open seas in front of Pacitan Regency are waters that rich of large pelagic fish resources, such as skipjack and tuna. The level of utilization of pelagic fish resources in these waters is still below its maximum sustainable potential. The maximum sustainable potential of pelagic fish in the southern
region of East Java for the period of 2009 to 2013 was 219,189.45 tons/year. As for the level of utilization of fish, the new average is 49.48%. The maximum sustainable potential value for tuna species (yellow fin tuna and bigeye tuna) in the waters south of East Java is estimated to be around 2,568 tons/year with utilization of around 78.81% [1]. Thus, efforts in effective fishing still need to be improved.

Most Pacitan fishermen are still exploiting fish resources only from around the coast and still using traditional fishing tools. Majority of the boats that used are boats with added motor, only few fishermen use motorboats. Some even use motorless boats. The fishing gear used consists of groups of gill nets, fishing rods, traps, and trawl nets which are operated with simple technology [2]. The catch generally consists of demersal fish and small pelagic fish, with relatively smaller production. Due to this, more fishing aids and methods begin to be developed to obtain more fish with FADs.

FADs began to be used officially at Pacitan Sea in 2005. This was a form of government intervention, through the Ministry of Fisheries and Marine Affairs, to increase fisheries production in Pacitan Regency. The results of using FADs showed that the production has increased [1]. Since then, FADs has grown rapidly in Pacitan. In 2013 a fishing boat based in Tamperan Fishery Port used 250 FAD units which were installed at a depth of 100 to about 500 meters [4].

FADs increase biomass in the waters, causing many small fish to gather. Larger fish use FADs to get food. That causes around the FADs many fish of various sizes gather [3]. Availability of biomass is inseparable from oceanographic conditions and water fertility. Preferably, FADs are located in areas that are in accordance with oceanographic requirements, so that increased production can be achieved. This research has two objectives: looking for an area that is suitable for FADs placement and knowing fisheries production using traditional methods and using FADs, in areas suitable for FAD placement

2. Methodology
This research was carried out at the coast of Pacitan and the sea in front of Pacitan Regency within 77.5 km with an area of 3,859.5 km². Research in the front sea of Pacitan Regency was conducted to find out which areas were suitable for FADs placement. Meanwhile, to find out capture fisheries production, interviews with fishermen were conducted in two locations. The first location was in Tamperan Fishery Port. Tamperan Fishery Port, is a modern port, a landing place for fish using deep sea FADs. Fleet fishing gear uses ships/trawler fleets and tonda fishing rods [2]. This port is also designated as the base of capture fisheries and the core zone of the Minapolitan Region [5]. The deep sea FADs are located above 50 km from the beach. The depth of FADs is around 500 meters or more. The second interview location was the small port of Tawang fisheries. FADs were installed at a distance of 30 km while some were above 50 km. The depth was from 100 m to more than 1,000 m. Interviews were conducted with 20 fishermen in the Tawang fishery port, and 10 fishermen who captured fish in Tamperan. For a detailed location of the study, see the following figure 1.
To find the suitable location for the placement of FADs, two methods were carried out with Landsat 8 OLI imagery. From the OLI Landsat 8 image, oceanographic variables are obtained. The water quality parameters that can be detected, which includes salinity, temperature, current velocity, water depth, and turbidity. Chlorophyll-a parameters were used to determine the variables of marine fertility. Oceanographic conditions in an area that has an abundance of nutrient supply results in a high concentration of chlorophyll-a. The other oceanographic parameters that cannot be detected from images, such as pH, were obtained by taking water samples around the location of the FADs. The sampling location was marked using GPS. The current velocity was digitised from the BMKG Open Forecast System. As for obtaining the FADs suitability area, the data was analysed using the overlay technique from the geographic information system. The detailed picture of research framework can be seen as shown in the following figure 2.
Pacitan Regency has traditional and modern types of fishing gear. Many modern fishermen use FADs. There are traditional fishermen who use and not use FADs. Traditional fishermen are dominated by local residents of Pacitan who do not use FADs, meanwhile those using FADs are dominated by fishermen who are not native to Pacitan. Traditional fishermen who do not use FADs have different productivity than those using FADs. Productivity tends to be smaller than those who do not use FADs. In order to acquire larger productivity, it is necessary to see areas suitable for the placement of FADs in order to increase capture fisheries production. There is a measurable difference between the production of fishermen who use fishing rods only and who use FADs. Between areas suitable for placement of FADs and those that are satisfactory suitable, there is also a significant difference in production. Comparing the difference in productivity, it is expected that fishermen will prefer to use FADs. To produce optimal production, fishermen require more information about areas which are suitable for FADs.

3. Results and Analysis

3.1. FADs suitable area by Landsat 8

From the results of processing Landsat 8 OLI images downloaded via https://www.usgs.gov/ and digitized from pH and current velocity, almost all of the FADs suitable areas show that the oceanographic factor that determines FADs suitability is depth parameter. This is in accordance with interviews conducted with fishermen. Areas that are less suitable for FADs are those that have a low depth around the Pacitan bay. The detailed picture can be seen as shown in the following figure 3.

![Figure 3. Suitable area of FADs.](image)

To answer the research objective, the approach was used by overlay analysis with parameters such as temperature, salinity, turbidity and current velocity. To get FADs locations that produce high fish production, an abundance of chlorophyll-a parameters is added. Thus table 1 shows that the suitable area for FADs is around 53.71% and the quite suitable area for FADs is around 21.8%, while 24.42% is an area that is less suitable area for FADs. There is a percentage area of FADs. The area of the study
is 3,859.5 km². The suitable area of FADs is 2,072.9 km², the quite suitable area for FADs is 841.37 km², and the area that is less suitable of FADs is 926.2 km².

Table 1. Parameters suitable for FAD locations.

| Parameter       | The area of suitable (km²) | The Percentage of Suitable area (%) | The area of quite suitable (km²) | The percentage of the quite suitable area (%) | The area of Less suitable (km²) | The percentage of less Suitable (%) |
|-----------------|----------------------------|-------------------------------------|--------------------------------|-----------------------------------------------|--------------------------------|-------------------------------------|
| Turbidity       | 2,162.3                    | 56                                  | 887.6                          | 23                                            | 810.4                          | 21                                  |
| Salinity        | 1,813.9                    | 47                                  | 926.2                          | 24                                            | 1,119.0                        | 29                                  |
| Depth           | 136.5                      | 66                                  | 540.3                          | 14                                            | 771.9                          | 20                                  |
| Chlorophyll-a   | 2,006.9                    | 52                                  | 1,196.4                        | 31                                            | 656.1                          | 17                                  |
| SST             | 1,813.9                    | 47                                  | 849.09                         | 22                                            | 1,196.0                        | 31                                  |
| Current Velocity| 2,431.4                    | 63                                  | 926.28                         | 24                                            | 501.7                          | 13                                  |
| Ph Meter        | 1,736.7                    | 45                                  | 578.92                         | 15                                            | 1,543.8                        | 40                                  |
| Total Rata-rata | 2,072.9                    | 53.71                               | 841.37                         | 21.8                                          | 926.2                          | 24.42                               |

Source: Modified from [6].

3.2. The role of Chlorophyll-a
The abundance of phytoplankton and primary production in a body of water can be seen in the presence of chlorophyll-a in area of field. [10]. Chlorophyll-a can be seen using Landsat TM green to reflectance [8] Chlorophyll-a can be used for indicators of aquatic fertility, aquatic fertility associated with food availability for fish. So that areas with high chlorophyll a, will be related to the high fish population. From the analysis of Landsat 8 imagery, the condition of the waters of Pacitan Bay based on its waters is as follows, can be seen as shown in the following figure 4.

Figure 4. Chlorophyll-a in Southern waters in Pacitan.
For the case of Pacitan waters, Chlorophyll-a, is not related to the installation of FADs. Chlorophyll-a is only high along the Pacitan coast, which is not an area for FADs. This is because large pelagic fishes in FADs do not eat plankton directly, but their food is small pelagic fishes. Whereas small pelagic fishes eat chlorophyll-a. So that chlorophyll-a increases when on the coast near the land because the dominating one is small pelagic fish which are abundant on the coast.

3.3 Fishery Productions of FAD in PPP Tamperan and TPI Tawang

PPP Tamperan and TPI Tawang have different capacity. Capacity in PPP Tamperan can collect a lot of fish with a relatively large amount. Whereas in TPI Tawang has a relatively small catchment capacity because it is dominated by traditional fishermen. From an interview with the ship captain and owners of FADs whose production on PPP Tamperan and in TPI Tawang there is a FADs coordinate point as in the following table 2.

**Table 2. Location of FADs placement.**

| Tamperan | Tawang |
|----------|--------|
| Latitude | Longitude | Latitude | Longitude |
| 8° 22' 57'' S | 111° 11' 44'' E | 8° 16' 34.76'' S | 111° 15' 54.73'' E |
| 8° 48' 15'' S | 111° 00' 41'' E | 8° 19' 48.23'' S | 111° 19' 0 8.59'' E |
| 8° 45' 50'' S | 110° 56' 20'' E | 8° 20' 52.81'' S | 111° 25' 13.92'' E |
| 8° 50' 50'' S | 110° 57' 20'' E | 8° 33' 38.10'' S | 111° 23' 52.83'' E |
| 8° 51' 20'' S | 111° 16' 20'' E | 8° 37' 29.99'' S | 111° 23' 55.28'' E |
| 8° 58' 20'' S | 111° 14' 40'' E | 8° 42' 8.69'' S | 111° 23' 55.14'' E |

Source: Field Data

From the table 2, it can be seen that the installation of FADs that are landed in Tamperan is about 100 km, especially those farther from 9° Latitude. From that location, the fish that caught are generally large pelagic fish, because the area is the path of sharing Tuna species. The FADs with production landed in Tawang in this study are limited to the farthest distance is at the coordinates 8° 42' 8.69'' S or about 50.8 km from TPI Tawang. Hence, on the location of the FADs there are still traditional fishermen who are looking for fish in the vicinity without using FADs.

The type of fishing gear used in FADs are different for the two landing sites. That is landed in PPP Tamperan the devices are tonda fishing rod, krendet, Gill Net, Payang and Purse Seine [9]. The purse seine fishing boat is in the middle of the south sea around 7 days to 15 days. With one go to the sea, fish production from 3 to 10 tons from interviews with fishermen while those landed in Tawang are stretched fishing in the sea for 2 to 3 days, with production of around 500 kg – 1,400 kg.

In addition to deep sea FADs, as described above, on the coast of Pacitan there is also a shallow sea clump that is installed at a depth below 100. This FAD is used by local fishermen. The amount is not much, because at that depth fish products without FADs are considered sufficient for fishermen who carry out one day fishing activities. Although fishermen admit that they use more FADs, many of them still do not use FADs. The reason are, among other things, the necessity of installation, and maintenance. The results of fish production using FADs compared to those that do not are as follows, as shown in table 3.

From the table 3, it can be seen that the fish landed in Tamperan, mostly from deep-sea FADs. Traditional fishermen who do not use FADs only look for fish around the coast with a simple motorboat with a size of < 5 GT. The landed in Tawang consists of deep sea FADs and shallow marine FADs. Deep sea FADs are around 30-40 km. The shallow marine FADs are less than 7 km from the coast. The result allows that the use of FADs can increase yield up to 4 times. Even sometimes it can be up to 7 times.
Table 3. Fish productivity with FADs and without FADs.

| Far from TPI (km) | Fish Production in Tamperan Port (kg/month) | Fish Production in Tawang Port (kg/month) |
|------------------|--------------------------------------------|------------------------------------------|
|                  | With FADs        | Without FADs                  | With FADs        | Without FADs                  |
| < 4              | 3,000           | 300 – 400                    | 2,000           | 50 - 100                      |
| 4 – 40           | 6,000           | -                           | 2,800           | 200 - 500                     |
| 40 – 100         | 9,000           | -                           | 4,800           | -                            |
| >100             | 15,000          | -                           | 6,000           | -                            |

Source: Interview Data.

3.4. The Quality of Fisheries in FADs in PPP Tamperan and TPI Tawang

When viewed from the quality of the catch, the fish originating from deep sea FADs, which are landed in Tamperan, are of average size. Catches are also dominated by large pelagic fish. Large Pelagic fish have high economic value. can be seen as shown in the following figure 5.

PPP Tamperan has the type of fish that dominates are skipjack tuna 4,382.84 kg/year, lemadang fish \((\text{Coryphaena hippurus})\) 156,091 kg/year, yellowfin tuna fish \((\text{Thunnus Albacares})\) 156,065 kg/year, Marlin fish \((\text{Tetrapturus Albidus})\) 43,252 kg/year and fish mackerel \((\text{Euthynnus affinis})\) 3,866 kg/year. So from the graph above, it can be concluded that the one that dominates the fish in Tamperan is a large pelagic fish.

These phenomena can explain that about 50% of landed fish in TPI Tawang are small pelagic fish (figure 6), such as Layur \((\text{Trichiurus savala})\), Banana Banana, Rengis and Teri (anchovy). Large pelagic fish such as Tuna, Lemadang and mackerel are not abundant in Tamperan. This is because in the Tawang Harbor the fish originates from a distance of less than 40 km. Besides that traditional fishermen also land their fishing results in the Tawang port.
4. Conclusion

Over the area of the sea south of Pacitan that studied, 53.71% is suitable for placing FADs, consisting of the eastern part of the study area encompassing 21.8% of satisfactorily suitable area and the western area encompassing 24.42% of unsuitable area.

The quantity of fish production of fishermen who use FADs differ between those in Tamperan and in Tawang. Fish production in Tamperan consists of more quantities of large Pelagic fish, as 100% come from deep sea FADs, which is located 100 km from the coast. The production in Tawang comes from capture fishery using FADs and in traditional methods. This explains that in addition to large Pelagic Fish, there are also quite a lot of small Pelagic fish.

The comparison of results between fish captured in traditional methods and using FADs is at least in the ratio 1:4. In certain conditions, this can increase up to seven folds.

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