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Sustainability of the Boat Bagan Fishing Business Operating in the Waters of Kao Bay Halmahera, Indonesia

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ABSTRACT

Bagan fishing operations in the waters of Kao Bay, Halmahera, consist of one-boat bagan and two-boat bagan systems. The number of bagans continues to increase due to their perceived profitability. However, there is currently insufficient information regarding the sustainability of these fishing practices. This study aimed to analyze productivity and to assess the business sustainability of one-boat and two-boat bagan operations based on investment criteria and benefits for fishers. Data collection was conducted through observations and interviews. The analysis included productivity assessment, investment criteria evaluation, and business benefit analysis. The results showed that the revenue from a one-boat bagan was 25,392 USD, which was higher than that of a two-boat bagan, at 17,005 USD. The Net Present Value (NPV) of the one-boat bagan (12,056 USD) was also significantly greater than that of the two-boat bagan (4,554 USD). The Internal Rate of Return (IRR) for the one-boat bagan was 25.94%, compared to 16.42% for the two-boat bagan—both exceeding the prevailing bank interest rate of 12%. Both types of bagans had a Benefit-Cost (B/C) ratio greater than 1—1.09 for the one-boat bagan and 1.05 for the two-boat bagan—indicating that revenues consistently exceeded the costs incurred to support operations. The profit from the one-boat bagan (28,155 USD) was higher than that from the two-boat bagan (12,337 USD), although the payback period was slightly faster for the two-boat bagan (7 months) compared to the one-boat bagan (8 months). During the fishing season, the income of fishers operating one-boat and two-boat bagans (263 USD and 344 USD, respectively) exceeded the 2023 regional minimum wage of North Maluku Province (183 USD). However, during the normal season, their income (160 USD and 230 USD) fell below the minimum wage. These findings suggest that both one-boat and two-boat bagan fishing operations can be sustainable in terms of productivity and investment viability. However, there is a need for targeted support to address the lower incomes of fishers during the regular season to ensure equitable and sustainable livelihoods.

INTRODUCTION

The waters of Kao Bay have long served as a vital source of livelihood for the coastal communities surrounding the bay. The local economy is heavily dependent on the

exploitation of the bay's marine biological resources. These resources include anchovies, squid, jellyfish, small and large pelagic fish, demersal fish, sea cucumbers, and tiger prawns. To harvest these resources, fishers utilize various types of fishing gear, such as gill nets, hand lines, bottom longlines, bagan, beach seines, shrimp nets, giobs, and purse seines **(Muhammad *et al.*, 2022)**. Among these, the most commonly used are bottom longlines—primarily for demersal fish—and boat bagan, which target small pelagic species **(Taeran & Karman, 2019)**.

Bagan is a type of lift net that uses light as a fishing aid to attract phototactic fish species **(Sulaiman, 2015)**. The boat bagan operates by lowering the net into the water column and lifting it once a sufficient number of fishes have aggregated. The fishing operation involves relocating the boat to areas estimated to contain large fish schools. One way to increase income in the capture fisheries sector is to establish productive fishing units capable of achieving optimal catch volumes.

In Kao Bay, bagan fishing is widely practiced, with two primary types used: boat bagan and raft bagan. Among these, boat bagan is the most dominant and is further categorized into one-boat and two-boat bagan systems. The increasing number of boat bagan units indicates high community interest in this business. Although requiring substantial investment, the boat bagan business is perceived as profitable and thus continues to be pursued. These operations are often funded by investors with considerable capital, including entrepreneurs, civil servants, military personnel (TNI), police officers, and retirees.

The sustainability of the boat bagan business depends on several supporting factors, particularly the satisfaction of the stakeholders—both investors and fishers. Investors in this sector face various risks, including technical, seasonal, social, and economic challenges. Technical factors involve decisions regarding the optimal type and size of bagan units to maximize efficiency and productivity. **Takril (2008)** noted that the number of lamps, fuel usage, and vessel size significantly influence the productivity and profitability of boat bagan operations.

Seasonal changes also pose a challenge, affecting the quantity and species of catch. The primary targets of lift nets—anchovies and squid—are migratory pelagic species that follow current patterns influenced by seasonal winds. Strong winds can create large waves that destabilize the net bags under the bagan frame. Additionally, heavy rains can reduce light penetration, impairing the ability of the lamps to attract fish.

Social factors pertain to the extent to which the bagan boat business engages local fishers and contributes to community employment. Economically, profitability remains a central concern for investors. The bagan boat business can be considered beneficial to fishers if it provides a stable and adequate monthly income.

The objective of this study was to analyze the productivity and to assess the sustainability of one-boat and two-boat bagan operations based on investment criteria and the associated benefits to fishers.

Previous studies on bagan fisheries in Kao Bay have addressed various technical and sustainability aspects. For instance, **Ahmad *et al.* (2013)** examined the effect of enhanced lighting on squid catch rates. **Muhammad *et al.* (2022)** investigated the productivity of boat nets in relation to moon phases. **Kadir *et al.* (2022)** explored technical factors affecting two-boat net production, while **Karman *et al.* (2023)** assessed the sustainability of boat net fisheries based on squid production. **Gaus *et al.* (2023)** provided a comprehensive analysis of the sustainability status of boat net fisheries, considering ecological, technological, economic, social, and policy dimensions.

While these studies have predominantly focused on technical improvements and broader sustainability concerns, the present study evaluates both one-boat and two-boat bagan systems with a specific emphasis on monthly productivity, investment performance using established criteria, and the financial benefits to fishers. These earlier works will be used as references to contextualize and support the findings of this study.

MATERIALS AND METHODS

Research location and time

The research was conducted at Kao Bay, Halmahera Island, North Maluku Province, in May 2023. This location was chosen because it has a relatively large number of bagans operating in the bay (Fig. 1).

Method of data collection

The data collection method used in this study was a survey method with interview, observation, and direct measurement techniques. Interviews were conducted by distributing questionnaires to respondents, namely selected fishers and bagan owners. Respondents were determined by purpose sampling. The number of respondents taken was 30 fishers/bagan owners, 15 respondents each for one-boat bagan and 15 respondents for two-boat bagan. Interviews were conducted using a list of questions that had been provided. The types of interview data consisted of investment cost data, operational cost data, monthly production data for the year 2022, catch data for the last month during the research, fishing trip data, fish price data, and profit-sharing data. Observations were made on the objects of fishing units, fishing areas, and fishing operations. Direct measurements were carried out to obtain data and information related to the technical aspects of the bagan fishery unit. The data collected consists of: investment cost data, operational cost data, monthly production data during 2022, catch data for the last month during the research, fishing trip data, fish price data, profit sharing data, and technical data including: net length, net width, electric lamp capacity, number of fishers (crew), number of settings per night. Meanwhile, secondary data consists of: business credit interest data from government banks, North Maluku regional minimum wage (UMR) data in 2023. Types of observation and direct measurement data included net length, net width, electric lamp capacity, number of fishermen (crew members), and number of

settings per night. The secondary data consist of credit interest rate data from a government bank, which is 12% per year, and the North Maluku Province's 2023 provincial minimum wage (UMP) of IDR 2,976,720, referring to Decree of the Governor of North Maluku, 2022.

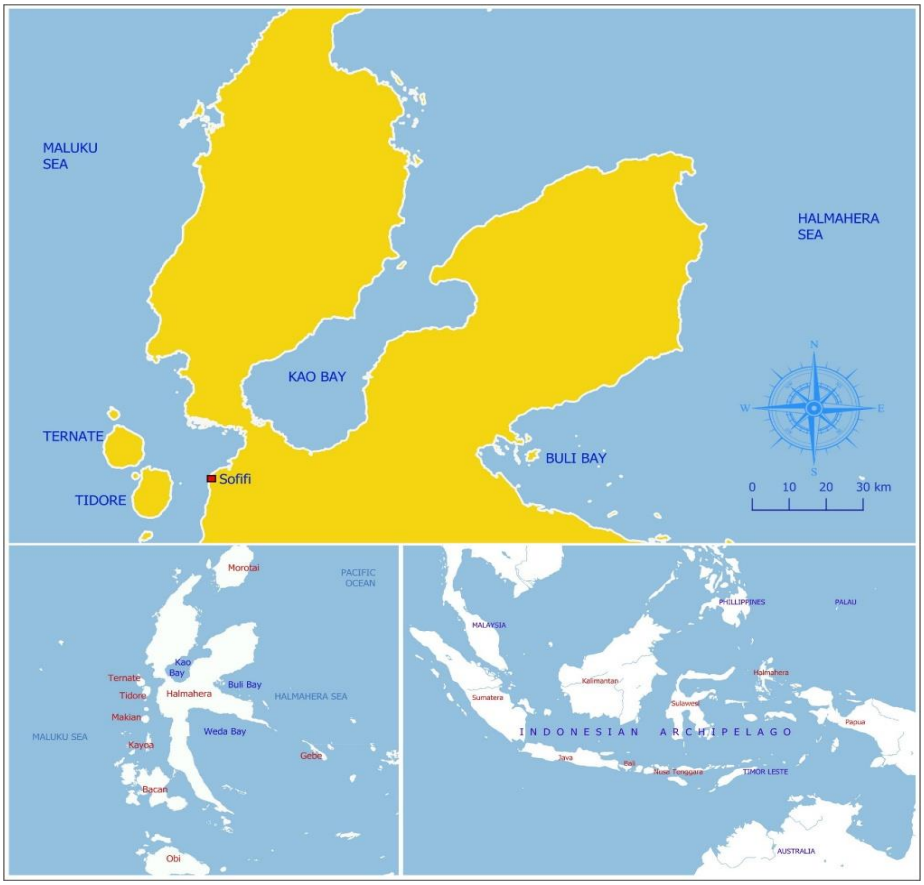

Fig. 1. Map of researh area at Kao Bay, Halmahera Island of North Maluku Province

Data analysis

The data analysis used consists of productivity analysis, business feasibility analysis, and business benefit analysis for fishers. The details of the analysis were as follows:

Productivity analysis

The productivity analysis of bagan fishing involved comparing the total catch (in kilograms) with the number of fishing efforts (trips) conducted over the course of one month. This analysis was conducted using the equation described by **Prayitno *et al.* (2017)** and **Taeran *et al.* (2022)**:

$$\text{Productivity} = \frac{\sum \text{production}}{\sum \text{fishingefforts}} \text{x}100\%$$

Investment criteria analysis

Investment criteria analysis was carried out to test the possibility of profit or loss obtained from the one-boat bagan and the two-boat bagan. The analysis used was financial analysis developed by **Harley and Splash (1993)**, **Neliyana *et al*. (2014)** and **Taeran *et al*. (2023)** as follows:

Net present value (NPV)

Net present value is the present value of the net profit that will be obtained in the future. Mathematically, NPV was expressed by the formula:

$$\text{NPV} = \sum_{t-1}^{n} \frac{\text{Bt} - \text{Ct}}{(1 + \text{i})}$$

Where:
Bt = profit from a project in year t
ct = cost of the project in year t
i = prevailing interest rate
t = technical life of the project

Criteria interpretations were as follows:
If NPV>0: The business is assumed feasible,
If NPV<0: The business is assumed not feasible, and
If NPV=0: The business is assumed neither profitable nor loss-making.

Internal rate of return (IRR)

IRR is the value of an interest rate that makes the NPV of a business equal to zero. Mathematically, IRR was expressed by the following formula **(Kadariah *et al*., 1999)**:

$$\text{IRR} = \text{i}_1 + \left(\frac{\text{NPV}_1}{\text{VPV}_1 + \text{NPV}_2}\right)(\text{i}_2 - \text{i}_1)$$

Where:
i_1 = interest rate that produces NPV > 0
i_2 = interest rate that produces NPV < 0
NPV_1 = NPV at interest rate i_1
NPV_2 = NPV at interest rate i_2

The criteria interpreations are:
1. If IRR > applicable interest rate, then the business is assumed feasible; and

2. If IRR < applicable interest rate, then the business is assumed not feasible.

Benefit-cost ratio (B/C ratio)

B/C ratio is the comparison between the present value total of net profits in years where net profits are positive with net profits that are negative. The formula used was:

$$B/CRatio = \frac{\sum_{t-1}^{n} \frac{(B_t - C_t)}{(1+i)^t}}{\sum_{t-1}^{n} \frac{(C_t - B_t)}{(1+i)^t}}$$

Where:
B = profit
C = cost
i = discount rate
t = period
B_t = benefit in a certain period, and
C_t = cost in a certain period

The feasibility criteria are:
B/C ≥ 1, means the business is feasible to run
B/C < 1, means the business is not feasible to run

Return of investment (ROI) analysis

Return on investment (ROI) is the ability of capital invested in total assets to generate net profits. The formula used to calculate ROI was:

$$ROI = \frac{Benefit}{Investment} x100\%$$

Profit analysis

Profit analysis aims to determine the amount of profit obtained from a business activity carried out. Business income in the development of boat bagan fisheries was calculated by using the following formula:

$$\pi = TR - TC$$

Where:
π = profit
TR = total revenue
TC = total cost
With business criteria:
TR >TC: Profitable business.

TR <TC: Business experiences losses.
TR = TC: Business at equilibrium (break-even point).

Payback period (PP) analysis

Payback period (PP) is a period required to recoup investment expenditures using cash flow **(Umar, 2003)**. Payback period (PP) is the ratio between investment expenditures and profits, the results of which are in units of time. PP calculations were carried out using the formula:

$$PP = \frac{\text{Investment Expenditures}}{\text{Profits}} \text{x1 year}$$

Business benefit analysis

Business benefit analysis is used to measure the extent to which the bagan fishing business is beneficial to fishers. This benefit analysis is divided into season categories, namely fishing season and normal (regular) season. The formula used was:

$$\text{Fishers'income} = \left(\frac{\sum \text{npxp}}{\sum \text{k}}\right) \Big/ \sum \text{wm}$$

Where:
$\sum np$ = total sales value (Rp)
p = proportion of fishers's profit sharing (%)
$\sum k$ = number of bagan fishers (person)
$\sum wm$ = time in a season (month)

The results of the analysis of fishers's monthly income was discussed by comparing it with the regional minimum wage (RMW) of North Maluku Province, and then the following criteria were determined:
If fishers's income > UMP then the business is highly profitable.
If fishers's income = UMP then the business is moderately profitable.
If fishers's income < UMP then the business is low profitable.

RESULTS

Bagan description

The main components of a boat bagan are a boat, equipment, fishing gear, and electricity. A one-boat bagan has a frame on both sides that functions as a place to hang fishing nets, while a two-boat bagan has a frame between one boat and another as a place to hang fishing nets. A one-boat bagan is permanently installed in the fishing area so it

needs to be equipped with a delivery boat that is used as transportation from the base to the bagan and vice versa on each fishing trip. This is different from a two-boat bagan which is mobile so it does not use a delivery boat. A two-boat bagan is equipped with an outboard motor that is hung on one of the boats which functions as a driving force so that it can go to the fishing area and return to the base on each fishing trip (Fig. 2).

Fig. 2. (a) One-boat bagan and (b) two-boat bagan operating in Kao Bay, Halmahera

The measurement results showed that the size of the one-boat bagan was larger when compared to the two-boat bagan. Each boat bagan was equipped with a roller that functioned as a rotating tool for pulling the rope on the fishing gear (net) when operated. The bagan fishing gear was made of netting (polypropylene) with a mesh size of 5mm. The netting was designed in a rectangular shape with the length and width adjusted to the size of the frame on each bagan. The length and width of the one-boat bagan fishing gear (netting) were larger when compared to the two-boat bagan. Each boat bagan was equipped with a generator engine that functions as a power generator. The operation of the boat bagan was highly dependent on light, because it functioned as a lure for schools of fish to gather in the desired area, and also for lighting for the crew while working. The use of electricity for one boat bagan was greater when compared to two boat bagan, both in engine capacity and the number of light balloons (Table 1).

Table 1. Specification of one-boat and two-boat bagan

No	Component	Dimension	
		One-boat Bagan	**Two-boat Bagan**
1	Boat (Perahu)		
	1. Length (m)	13.3-25	11-15
	2. Width (m)	1.5-2.5	0.9-1.55
	3. Depth (m)	1.8-2.6	0.9-2.50
2	Instruments (hard ware)		
	1. Delivery boat	1 unit	-
	2. Boat engine (unit)	40 HP, 1 unit	40 HP, 1 unit
	3. Anchor (unit)	1-2	1-2
	4. Anchor weight (kg)	70-170	45-75

	5. Roller number (unit)	2-7	2-4
3	Fishing gear		
	1. Material	warring	waring
	2. Warring length (m)	13-33	9-25
	3. Warring width (m)	10.5-24	9-11
4	Electricity		
	1. Electric generator (unit)	1	1
	2. Generator capacity (watt)	3,000-9,800	2,500-7,000
	3. Lamp number (unit)	30-180	30-79
	4. Lamp wattage (watt)	18-75	18-30

Boat bagan monthly production

Monthly production is the average production obtained by the bagan each month for one year. The average monthly production is used to explain the pattern of development of bagan production each month. The research found that the average production of one-boat bagan ranged from 616-2,600kg/ unit while the two-boat bagan ranged from 1,023-2,467kg/ unit. Based on the production trend, it showed that the production of one boat bagan and two boat bagan experienced two phases, namely the high production phase and the low production phase (Fig. 3).

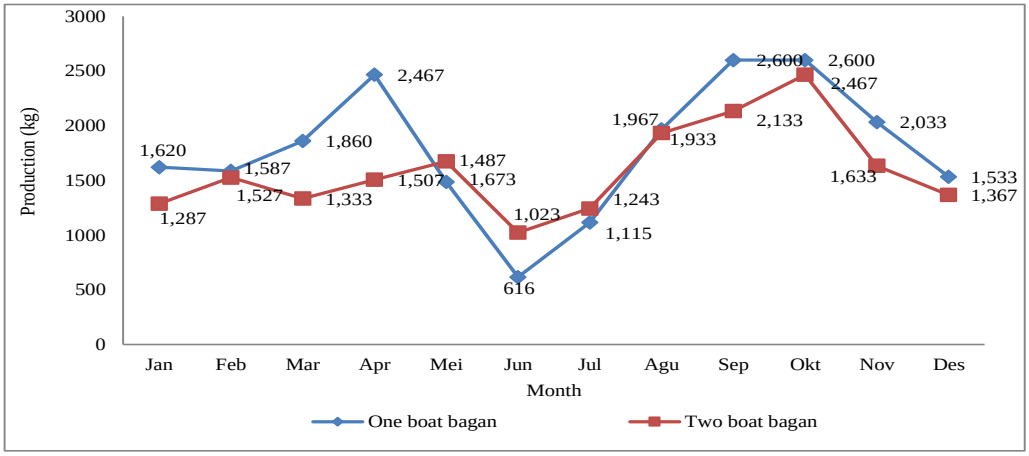

Fig. 3. Year 2022 production trend of one-boat and two-boat bagan at Kao Bay

Boat bagan productivity

The productivity of the boat nets referred to in this study is the comparison between the amount of production (kg) and the number of fishing efforts (trips) using the boat nets during one month. Sampling was conducted on fishers using one-boat and two boat bagan, 15 respondents each.

The number of operations for one-boat bagan ranged from 10 to 20 trips per month, with an average of 12 trips, while the two-boat bagan ranged from 10 to 15 trips,

averaging 13 trips. The catch volume for one-boat bagan ranged from 1,200 to 4,800 kg, with an average of 2,827 kg per month, whereas the two-boat bagan produced between 800 and 4,200 kg, averaging 2,560 kg per month. The productivity of both one-boat and two-boat bagans ranged from 80 to 400 kg per trip. On average, the productivity of the one-boat bagan was 243 kg/trip, while the two-boat bagan averaged 203 kg/trip (Table 2).

Table 2. Fishing trips, production, and productivity of one-boat and two-boat bagan operating at Kao Bay

One Boat				Two Boat			
Respon-dent	**Trip**	**Production (kg)**	**Productivity (kg/trip)**	**Respon-dent**	**Trip**	**Production (kg)**	**Productivity (kg/trip)**
1	10	3,600	360	1	10	4,000	400
2	15	3,600	240	2	15	3,000	200
3	15	2,400	160	3	10	1,600	160
4	20	1,600	80	4	15	2,400	160
5	10	2,000	200	5	15	3,600	240
6	10	2,800	280	6	15	1,800	120
7	15	4,800	320	7	15	4,200	280
8	10	4,000	400	8	10	1,600	160
9	10	1,200	120	9	10	2,400	240
10	10	3,600	360	10	15	3,000	200
11	10	3,200	320	11	15	4,200	280
12	15	3,000	200	12	10	800	80
13	10	3,200	320	13	15	1,800	120
14	10	1,600	160	14	10	2,000	200
15	15	1,800	120	15	10	2,000	200
Range	10-20	1,200-4,800	80-400		10-15	800-4,200	80-400
Average	12	2,827	243		13	2,560	203

Feasibility of single boat business

The average investment cost for a single boat business is 8,968 USD, consisting of 7 components, and for a two-boat business is 5,643 USD, consisting of 6 components. For a single boat, the highest investment value is on the boat itself, with a proportion of 46.81%, followed by the accompanying boat and the outboard motor, each accounting for 20.78% and 20.61%. For a two-boat business, the investment proportion for the boat and motor components is higher, at 54.43 and 32.76%, respectively. However, there is no accompanying boat component in the two-boat setup (Table 3).

Table 3. Average investment values for single and two-boat businesses

No	Component	One Boat (USD)	Proportion (%)	Two Boats (USD)	Proportion (%)
1	Main Boat	4,198	46.81	3,072	54.43
2	Accompanying Boat	1,863	20.78	-	-
3	Outboard Motor	1,849	20.61	1,849	32.76
4	Fishing Gear	474	5.28	298	5.28
5	Generator Engine	418	4.66	295	5.23
6	Electrical Installation	83	0.92	68	1.21
7	Other Equipment	84	0.94	62	1.09
	Total	8,968	100.00	5,643	**100.00**

The average fixed costs in the single boat business consist of depreciation and maintenance costs. The total fixed costs for a single boat are 1,187 USD, consisting of 897 USD for depreciation and 290 USD for maintenance. The total fixed costs for a two-boat setup are 940 USD, consisting of 564 USD for depreciation and 376 USD for maintenance. Depreciation and maintenance costs are highest for the boat and outboard motor components. For a single boat, the boat depreciation cost reaches 46.81% and the motor 20.61%, which is higher than for a two-boat setup where the boat reaches 54.43% and the motor 32.76%.

Table 4. Average annual fixed costs for one and two-boat bagan businesses

No	Component	One Boat (USD)	Proportion (%)	Two Boats (USD)	Proportion (%)
A	**Depreciation Costs**				
1	Main Boat	420	46.81	307	54.43
2	Accompanying Boat	186	20.78	-	-
3	Outboard Motor	185	20.61	185	32.76
4	Fishing Gear	42	4.66	30	5.23
5	Generator Engine	47	5.28	30	5.28
6	Electrical Installation	8	0.92	7	1.21
7	Other Equipment	8	0.94	6	1.09
	Total	897	100.00	564	100.00
B	**Maintenance Costs**				
1	Main Boat	87.49	28.95	205	54.43
2	Accompanying Boat	38.84	12.85	-	-
3	Outboard Motor	48.16	15.94	123	32.76
4	Fishing Gear	43.53	14.41	20	5.23
5	Generator Engine	49.36	16.33	20	5.28
6	Electrical Installation	17.29	5.72	5	1.21
7	Other Equipment	17.52	5.80	4	1.09
	Total	302.19	**100**	376	**100**
	Grand Total	1,236.82		940	

The variable cost components consist of fuel costs, supplies, and crew wages. The total variable costs for a single boat amount to 20,232 USD, which is smaller than for two

boats, amounting to 14,018 USD. The highest variable cost component is crew wages, reaching 68.03% for a single boat and 60.83% for two boats. Additionally, fuel costs reach 26.40% for a single boat and 33.13% for two boats (Table 5).

Table 5. Annual variable costs for bagan fishing businesses in Kao Bay

Component	One Boat (USD)	Proportion (%)	Two Boat (USD)	Proportion (%)
Fuel	5,341	26.40	4,644	33.13
Supplies	1,128	5.58	846	6.04
Crew Wages	13,763	68.03	8,528	60.83
Total	20,232	100	14,018	100

Revenue for the bagan fishing business comes from the catch. Total revenue for a single boat amounts to 25,392 USD, while for two boats it is 17,055 USD. Revenue is higher during the fish season, with 15,778 USD for a single boat and 12,372 USD for two boats, compared to the regular season with 9,614 USD for a single boat and 4,683 USD for two boats. Revenue from squid is significantly higher compared to mixed fish species (Table 6).

Table 6. Revenue for bagan fishing businesses in Kao Bay

Fishing Season	Catch Type	Revenue (USD)	
		One Boat	Two Boat
Fish Season	Squid	14,283	11,443
	Mixed Fish	1,494	929
	Total	15,778	12,372
Regular Season	Squid	8,644	4,013
	Mixed Fish	971	671
	Total	9,614	4,683
	Grand Total	25,392	17,055

The NPV for a single boat is 12,056 USD and for two boats is 4,554 USD, indicating that both NPVs are greater than the commercial business standard (NPV>0). The IRR for a single boat (25.94%) and for two boats (16.42%) is higher than the prevailing bank interest rate (12%). Both setups have a B/C ratio > 1, which are 1.09 and 1.05, respectively. The ROI parameter for a single boat is 16.00 and for two boats is 17.08, which is greater than the required value (> 1). The profit earned from the single boat business is 28,155 USD, and from the two-boat business is 12,337 USD. Based on calculations, the payback period is 8 months for the single boat and 7 months for the two-boat setup (Table 7).

Table 7. Feasibility of one and two-boat bagan fishing businesses in Kao Bay

Parameter	One Boat	Criteria	Two Boats	Criteria
NPV	12,056 USD	Feasible	4,554 USD	Feasible
IRR	25.94%	Feasible	16.42%	Feasible
NET B/C	1.09	Feasible	1.05	Feasible
ROI	16.00	Feasible	17.08	Feasible
π	28,155 USD	Feasible	12,337 USD	Feasible
PP	8 months	Feasible	7 months	Feasible

Benefits of the business to the fishermen

The benefits of the fishing boat business to the fishers are crucial for the sustainability of the business. The boat business is calculated based on the amount of revenue according to the season within a year. The fish season and the regular season each last for six months, affecting the income earned by fishers. Based on Table (8), the income of fishers during the fish season is higher compared to the regular season. During the fish season, fishers with two boats earn more income compared to those with a single boat.

Table 8. Benefits of the bagan fishing business to fishers

Component	Fishermen's Income (USD)	
	Fish Season	Regular Season
Single Boat		
Total Business Revenue	15,778	9,614
Fishers' Income (50%)	7,889	4,807
Number of Fishers (5 people)	1,578	961
Fishers' Monthly Income	263*	160**
Two Boat		
Total Business Revenue	12,372	4,683
Fishermen's Income (50%)	6,186	2,342
Number of Fishers (5 people)	2,062	781
Fishers' Monthly Income	344*	130**

*Fisher's income > Minimum Wage; highly beneficial business.
**Fisher's income < Minimum Wage; less beneficial business.

DISCUSSION

The catch from boat bagan operations in Kao Bay consists primarily of squid and small pelagic fish species. **Muhammad *et al.* (2022)** reported that the dominant species include squid (*Loligo* sp.), selar (*Selaroides* sp.), kembuang (*Rastrelliger* spp.), pepetek (*Leiognathus* sp.), layur (*Trichiurus* sp.), tembang (*Sardinella fimbriata*), and lompa

(*Thryssa* sp.), with squid (*Loligo* sp.) accounting for 41.30% of the total catch. The high proportion of squid is attributed to their predatory nature, as they are actively caught while hunting prey **(Thenu *et al.*, 2013)**. Their diet includes small fish such as anchovies and shrimp **(Gustaman *et al.*, 2012)**, as well as plankton **(Ahmad *et al.*, 2013)**. Squid also exhibit distinct behavioral patterns—remaining near the seabed during the day and dispersing through the water column at night—making them highly responsive to light attraction during nighttime fishing **(Tasywiruddin, 1999)**.

Monthly production refers to the total catch per fishing trip averaged over each month. These values were obtained from the monthly averages of sampled bagan units throughout a year. Based on trends, fishers categorize production into two phases: the fish season and the regular season. Production fluctuates, forming two peak phases—March to May and September to November—and two low phases—June to August and December to February. **Luasunaung (2011)** observed similar seasonality in anchovy (*Stolephorus* sp.) fishing with boat bagan in Dodinga Bay. These fluctuations are likely influenced by seasonal wind patterns. **Nontji (2002)** explained that Indonesian waters are affected by monsoonal winds—west and east monsoons—with transitional periods between them. The first peak production phase coincides with the West–East transition (March–May), and the second with the East–West transition (September–November).

Boat bagan productivity is calculated as the catch per trip per month. One-boat bagan units typically operate 10–20 times per month, while two-boat units operate 10–15 times, indicating that not every day is used for fishing. Productivity ranges from 80–400 kg/trip for both types, with one-boat units averaging 243 kg/trip and two-boat units averaging 203kg/ trip. This higher productivity in one-boat bagan units is largely due to their larger size and broader fishing coverage, which increases efficiency. Assuming a selling price of 1.11 USD/kg, each trip yields at least 224 USD, confirming the profitability of the bagan fishery.

The bagan fishery in Kao Bay is classified as a small- to medium-scale business based on investment value. **Raihanah *et al.* (2011)** defined medium-scale fisheries as those with investments in the hundreds of millions of rupiahs. **Taeran (2014)** highlighted investment as a primary indicator of business scale, with complete vessels and gear representing medium- to large-scale operations.

Investment represents the initial cost required to launch the business. One-boat bagan units require higher investment due to their size, which necessitates larger gear, more powerful lighting, and supporting equipment. Additionally, these units include an accompanying boat, unlike the two-boat setup.

Operational costs play a critical role in sustaining bagan operations. **Gaus *et al.* (2023)** emphasized that operational costs significantly impact economic sustainability. These include both fixed and variable costs. Fixed costs such as depreciation and maintenance are based on the useful life of gear, motors, and generators—typically 5 years. Some components like electrical systems and supporting equipment are replaced

annually. Variable costs are higher for one-boat bagans due to larger component capacities. A key variable cost is fishers' wages, which are shared 50% after deducting expenses. Fuel—another major cost—is determined by engine power, bulb quantity, and energy usage. Lower costs include food and cigarettes, varying by crew size per trip.

Annual revenue fluctuates with the fishing season, with higher returns during peak months. Revenue is also influenced by species composition, with squid generating higher earnings than mixed catches.

Sustainability depends on mutual benefits for both investors and fishers. Investors need sufficient returns to justify and continue their capital commitments, while fishers need reliable income. Investment feasibility is evaluated using several financial indicators. The NPV values of one-boat and two-boat bagan units exceed standard thresholds, indicating sound investments that offer significant net returns, even when accounting for interest rates. **(Soeharto, 2002)** noted that higher NPV values correlate with better profitability.

The IRR values of 25.94% (one-boat) and 16.42% (two-boat) both surpass the prevailing 12% bank interest rate, suggesting excellent profitability even if loans are used. This ensures that profit margins can easily cover annual interest costs. **(Batista *et al.*, 2015; Prabowo *et al.*, 2012)** emphasized that investment returns must be high enough to offset operational and financial risks. Field data show that civil servants and traders who operate bagan units often rely on bank loans for capital.

Both bagan types also show B/C ratios above 1—1.09 for one-boat and 1.05 for two-boat—indicating that revenues exceed total costs, ensuring profitability. Return on Investment (ROI) is also strong, with 16.00 (one-boat) and 17.08 (two-boat), driven by net profits and recoverable investments of 8,968 USD and 5,643 USD, respectively. Given a 10-year operational period, these investments can be recovered early. **Rahmi *et al.* (2013)** and **Mustaruddin *et al.* (2014)** noted that ROI is a key factor for investors with limited capital.

The total profit over 10 years is 28,155 USD for one-boat bagans and 12,337 USD for two-boat bagans. These figures account for net earnings after investment. Annual profits decline slightly after the fifth year due to replacement of major components. The annual profits are 4,104 USD (one-boat) and 2,118 USD (two-boat), comparable to the 3,336 USD/year reported for East Halmahera bagans **(Karman *et al.*, 2023)** but lower than the 5,716 USD/year reported in West Halmahera **(Kadir *et al.*, 2019)**.

The payback period, the time to recoup investment through profit, is 8 months for one-boat bagans and 7 months for two-boat units—faster than the 10 months and 28 days reported in Tolitoli Regency **(Sandi *et al.*, 2022)**. **Antika *et al.* (2014)** defined a payback period under 3 years as favorable. **Widodo and Syukuri (2005)** emphasized that shorter payback periods reflect smoother capital turnover and healthier businesses.

The sustainability of the bagan fishery also hinges on the income of fishers. Seasonal changes significantly impact monthly earnings. During peak fishing seasons,

income for one-boat and two-boat bagan fishers was 263 USD and 344 USD, respectively—well above the 2023 North Maluku minimum wage of 183 USD. However, during regular seasons, income fell to 160 USD and 130 USD, respectively, below the minimum wage threshold.

Despite strong investment indicators and seasonal profitability, the bagan fishery faces two major challenges: lack of subsidized fuel (BBM) and limited access to capital. Solutions include establishing a dedicated fuel station for fishers (SPBUN) at the fishing base and expanding access to credit through government-appointed financial institutions.

The sustainability of the bagan business is also determined by its benefits to fishers, measured by their monthly income. Fishermen's income is significantly influenced by the fishing season. Fishermen's income during the fish season is higher compared to the regular season. During the fish season, the income for single boat and two-boat bagan fishers is 263 USD and 344 USD, respectively, far exceeding the North Maluku provincial minimum wage for 2023 of 183 USD. However, during the regular season, income is lower (160 USD 130 USD).

Although the boat bagan fishing business is sustainable based on investment criteria and benefits to fishers, it faces challenges related to the lack of subsidized fuel (BBM) and difficulty obtaining business capital. The solution is to establish a general fuel station for fishers (SPBUN) at the bagan base location. Additionally, government-appointed financial institutions are needed to open credit access, allowing fishers to obtain business capital.

CONCLUSION

The average productivity of the one-boat and two-boat bagan fishing gears was relatively high, at 243 and 203kg/ trip, respectively. This can provide social and ecological benefits to fishermen, investors, traders, and industries, especially those processing squid. The one-boat and two-boat bagan fishing businesses were found quite feasible as they met investment criteria, even when using loan capital from financial institutions, because the net profit to be obtained was viable, and the IRR value was higher than the prevailing bank interest rate (12%). The B/C ratio was consistently greater than all financing spent to support its operations. The business had a high return on investment (ROI), and the capital recovery period was very fast. Boat bagan fishers' income was higher than the provincial minimum wage during the high season, but lower during the regular season. For the boat bagan fishing business to be sustainable, fishers need to increase fishing trips, while investors need to facilitate the availability of government-subsidized fuel stations.

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