Fishery sustainability study with sustainability window (SuWi) analysis in the South China Sea (Indonesia Fisheries Management Area 711)

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Abstract. Sustainable development can be defined in several different ways, but usually, the term refers to the definition given by the Brundtland Commission in the publication of Our Common Future. Sustainable development is often understood by relying on three pillars, namely environmental/ecology, economic and social. The demersal fishery in the South China Sea (Indonesia Fisheries Management Area / IFMA 711) became one of the supporting sectors of the economy of the fishermen communities around these waters. This study aims to analyze the sustainability of demersal fisheries with the Sustainability Window (SuWi) approach. Demersal fishery sustainability condition in the South China Sea (IFMA 711) waters tend to be better from year to year. However, the width of demersal sustainability window tends to be low and indicate the status of sustainability of demersal fish is not maximal in the South China Sea (IFMA 711). Therefore, care should be taken to manage demersal fishery in the South China Sea (IFMA 711).

1. Introduction
Fisheries management begin to grow, after a growing awareness on the importance of ecological sustainability based on the condition of the stock of fishery resources that tend to decline, such as that occurred in the decline of the stock of Pacific salmon, California sardine, and Peruvian anchovy [1]. FAO released an analysis related to the decline in global annual fish landing growth in the 1980s, and in 1990 a decline of 3% of global annual catches compared to the previous year [2].

This trend continued in the next few years and between 1990 and 1992, global landings fell by an average of 1.5% per year [3]. Overfishing has caused a total collapse of many fisheries including important species [4,5]. In addition, excessive exploitation of fisheries has led to the reduction of biodiversity, and ecosystem function [6]. On the other hand, most coastal communities in the world depend on marine resources. Marine products, such as fish, are an important source of protein for about a billion people worldwide [7,8,9,10]. Management efforts to reduce overfishing have been widely pursued, but very little progress has been made due to the general inability to bear the short-term economic and social costs [11].

In an economic perspective, fisheries exist to meet social and economic demands and one would hope to find that impacts on fishery resources have resulted in measurable social and/or economic benefits [12]. However, in terms of sustainability issues, the economic crisis symptoms in some of the above-described fisheries should be considered to produce solutions for economic sustainability [13].

From a social point of view, fisheries are seen as a means to generate economic benefits. The role of fisheries as a source of employment, especially in rural or remote areas, has also been given high priority.
In this case, the social aspect of fisheries will be very important to understand. One of the main features of fisheries in recent decades, related to social crises, has been the introduction of modern fishing technologies and also the increasing trade globalization affecting fishing communities. Modernization of the fishery has two faces that actually contribute to the welfare of the fishing communities, while others have caused social problems associated with the depletion of fishery resources [14]. According to [15], in the North Atlantic and the Mediterranean, there has been a decline in the quality of life and living standards among many fishing communities, as has been experienced in some areas of Southeast Asia [16]. From this, the science of fisheries itself progressively diverts their attention from single species to ecosystem approaches, from a micro to a macro perspective, increasing the need to quantify the impact of fishing on natural and man-made systems [11,17].

Ensuring sustainable fisheries and community development requires the integration and harmonization of environmental, social and economic issues that can, in turn, lead to an effective management plan [18]. The purpose of this research is to analyze demersal fishery sustainability condition using environmental or ecological integration through estimation of demersal, social, and economic resource condition with SuWi (Sustainability Window) analysis. Measuring different dimensions of sustainability is not easy because there is no general method that has been developed for that purpose.

2. Tools and methods
2.1. Data collection
Data for the analysis of demersal dominance and demersal fisheries sustainability level in the South China Sea (IFMA 711), obtained from secondary data in the form of production and production value of marine catch fishery, and fisherman's welfare level presented by the price indices received by fisherman for period 2007 to 2015.

2.2. Data analysis
2.2.1. Resource Domain Analysis. Production data and production value of marine capture fisheries, both demersal resources and other fishery resources located in the South China Sea (IFMA 711) and national are expressed in the form of drawings and graphs and described descriptively. This quantitative descriptive analysis is used to determine the level of dominance in terms of production and economic value of demersal fish resources in the South China Sea (IFMA 711). This information is important to understand the priorities of demersal fisheries management in the South China Sea (IFMA 711).

2.2.2. Sustainability windows (SuWi) analysis. Simultaneous analysis of three dimensions of sustainability can be done using a new analysis tool, Sustainability Window (SuWi), developed by Jyrki Luukkanen [19]. Suwi's approach does not postulate the type of relationship between the development of different sustainability dimensions that will be tested with empirical data. Suwi's goal is to analyze the three-dimensional developments in the case study area and to see if they simultaneously meet the Brundtland Commission type sustainability criteria [20]. Sustainability Window is a new analytical tool for assessing the sustainability of development simultaneously in three dimensions (environmental, economic, and social). This analytical method provides information on the maximum and minimum economic development required to keep the direction of social and environmental development toward a more sustainable goal. With the Sustainability Window (SuWi) method, it is easier to analyze sustainability using different indicators and different time periods so that comparative analysis becomes easy. This new method is also possible to analyze the dynamics of sustainability and changes over time from the thickness (figure 1).
It provides a new perspective to analyze the sustainability trends and impacts of the underlying sustainability policy. The width of Sustainability Window (SuWi) for demersal fish resources in the South China Sea (IFMA 711) can be obtained from the difference between Sustainability Window maximal demersal fishery (SWD711max) and Sustainability Window minimum demersal fishery (SWF711min), calculated by using the following equation with indexed data:

$$SWD_{711}^{\text{max}} = \frac{E_k n D_{711 \tau_1}}{EID_{711 \tau_1}} EID_{711 \tau_0}$$  \hspace{1cm} (1)$$

and

$$SWF_{711}^{\text{min}} = \frac{E_k n D_{711 \tau_1}}{SIF_{711 \tau_1}} SIF_{711 \tau_0}$$  \hspace{1cm} (2)$$

Which EknD711 is an index of demersal fishery production value in the South China Sea (IFMA 711), EID711 is a demersal fish capture index in the South China Sea (IFMA 711), and SIF711 is an acceptance index of fishermen who conduct fishing activities in the South China Sea (IFMA 711).

The thickness of Sustainability Window (SuWi) of demersal fish resources in the South China Sea (IFMA 711) compared with the thickness of Suwi of national demersal fish resources and national capture fisheries to determine the demersal fish resources sustainability position in the South China Sea (IFMA 711). The thickness of the national demersal fishery SuWi is calculated using the following equation with indexed data:

$$SWD_{\text{max}} = \frac{E_k n D_{\tau_1}}{EID_{\tau_1}} EID_{\tau_0}$$  \hspace{1cm} (3)$$

and

$$SWF_{\text{min}} = \frac{E_k n D_{\tau_1}}{SIF_{\tau_1}} SIF_{711 \tau_0}$$  \hspace{1cm} (4)$$

Which EknID is a national demersal fishery production value index, EID is a national demersal fishery capture index, and SIF is an accepted index of fishermen conducting fishing activities in Indonesian
waters. Meanwhile, the thickness of SuWi capture fisheries at the sea nationally is calculated using the following equation with indexed data:

\[ SWF_{max} = \frac{EknIF_{t1}}{EIF_{t3}} EIF_{t0} \]  

and

\[ SWF_{min} = \frac{EknIF_{t1}}{SIF_{t1}} SIF_{t0} \]  

Which EknIF is a production value index of national capture fisheries at the sea, EIF is national capture fishery index and SIF is an accepted index of fishermen who conduct fishing activities in Indonesian waters.

By applying the Sustainability Window (SuWi) analysis into the dynamic model (figure 2), a demersal fisheries sustainability position in the South China Sea (IFMA 711) can be obtained compared to the national demersal fisheries and capture fisheries in the Indonesian Ocean.

3. Results
3.1. Analysis of production priority
Fishery Management Areas in Indonesia have enormous potential to be managed and utilized. The potential of this great fishery resources can be seen from the production of marine capture fisheries. There are 3 groups of species that dominate biomass from the sea, which are small pelagic fish resources, large pelagic fish resources, and demersal fish resources, which are small pelagic fish resource has the largest dominance proportion. The South China Sea (IFMA 711) is one of the waters that have the enormous potential of capture fisheries resources, especially demersal fishery. Figure 2 presents the quantities of demersal fish resource production that dominate capture fisheries in the South China Sea (IFMA 711).

![Figure 2. Demersal fish production in South China Sea to the average of national production of demersal fish 2005-2014.](image)

Based on figure 2, this condition makes demersal fish resources as a resource that has an important and decisive role in terms of biomass on the sustainability of capture fisheries in the South China Sea (IFMA 711). Nationally, demersal fisheries production in the South China Sea (IFMA 711) is above the average of demersal fisheries production of all the Indonesian Fisheries Management Areas (IFMA) which currently amounts to 11 of IFMA.
3.2. Analysis of economic priority

The capture fisheries sector in the South China Sea (IFMA 711) has a significant economic contribution to the Indonesian economy through the GDP of the marine capture fisheries sub-sector. Figure 3a presents the average percentage of the value of capture fisheries production in the South China Sea (IFMA 711) with 11.3% of the total value of national capture fisheries production for the period 2005 to 2015. Percentage of production value in capture fishery produced by the South China Sea (IFMA 711) is quite significant by looking at the comparison of economic contribution to 10 other Indonesian Fisheries Management Areas (IFMA). Much of the value of capture fisheries production in the South China Sea (IFMA 711) was contributed by demersal fisheries, with a percentage of 32.6% to 41% for the period 2005 to 2015 (figure 3b).

![Figure 3a](image-a)

**Figure 3a.** The proportion of economic value: (a). The Economic value of catchment fisheries in the South China Sea (IFMA 711) to the Economic value of National catchment fisheries; (b). Economic value of demersal catchment fisheries in the South China Sea (IFMA 711) to Economic value of catchment fisheries in the South China Sea (IFMA 711).

3.3. Sustainability evaluation

Sustainability window (SuWi) change analysis can be done during the time available information on trends related to sustainable development. Figure 4 illustrates the change in the minimum and maximum values of the sustainability window (SuWi). The maximum value of Sustainability Demersal fishery...
window in the South China Sea (IFMA 711) is obtained by comparing the value of demersal fishery production to the magnitude of its production. Since 2007, the maximum demersal fisheries sustainability window (SuWi) value in the South China Sea (IFMA 711) has increased rapidly until 2013. The 2014-2015 period has experienced a significant upward trend, possibly due to a decrease in demersal fisheries production in the South China Sea IFMA 711), but on the other hand, there is an increase in the production value of demersal fish resources.

Figure 4. Change of upper limit (SWD711max) and lower limit (SWD711min) of Sustainability Window (SuWi) of demersal fish in the South China Sea (IFMA 711).

The lower limit of the demersal fisheries demersal in the South China Sea (IFMA 711) tended to be constant until 2009, indicating an increase in production values and indices received by fishermen but not significantly changed. The 2009 to 2010 period increased and then again declined until 2011, indicating that in 2009 to 2010 there was an increase in the value of demersal fishery production in the South China Sea but not accompanied by a significant increase in the index received by fishermen, but this is the opposite for 2010 until 2011. In the period of 2011 to 2013, tends to rise due to temporal increase in the intensity of demersal fishery production value in the South China Sea (IFMA 711) on the index received by fishermen living around the South China Sea (IFMA 711). The time period 2013 to 2015 tends to be constant, which is an implication of the change or increase in the value of the index received by fishermen which are comparable to the change or increase in the value of demersal fisheries production in the South China Sea.

The maximum value of sustainability of national demersal fisheries and national capture fisheries tends to be the same until 2013. However, in 2014 to 2015, national demersal fisheries tend to rise significantly while national catch fisheries tend to be constant. This condition is caused by the intensity of national capture fishery production per production value tends to rise, while the production of national demersal fishery per production value tends to decrease (figure 5).
Figure 5. Change of upper limit of demersal fish (SWDmax) and upper capture fisheries limit (SWFmax) to lower limit (SWFmin) of national capture fisheries Sustainability Window (SuWi).

Figure 6. The thickness of Sustainability Window (SuWi) from demersal fish in the South China Sea (WSWD711), national demersal fishery (WSWD), and national capture fisheries (WSWF).

Figure 6 illustrates the comparative trends related to sustainable development of national marine fisheries, national demersal fisheries, and special demersal fisheries in the South China Sea (IFMA 711). The maximum value of sustainable economic growth appears to be quite critical, in 2008 showing the thickness of demersal fishery Sustainability Window (SuWi) in the South China Sea (IFMA 711) tended to rise, but then declined since 2009. Then, 2010 showed significant thickness, with a sharp rise taking place in 2014. The demersal thickness trend of demersal fisheries in the South China Sea (IFMA 711) tends to be similar to the national demersal fisheries. This condition indicates that national policies on demersal fisheries will have a significant impact on demersal fisheries in the South China Sea (IFMA 711). From 2007 to 2015, national fisheries Sustainability Window (SuWi) thickness tends to increase and higher than demersal fisheries in the South China Sea (IFMA 711). However, since 2014, the opposite is true with the demersal Sustainability Window (SuWi) in the South China Sea higher than national fisheries and national demersal fisheries.
4. Discussions

National capture fisheries production is dominated by three groups of fish species, namely small pelagic, large pelagic, and demersal. Demersal fish resources dominate the production and economic value of capture fisheries production in the South China Sea (IFMA 711). Capture fisheries, especially demersal fishery, is one of the most dependable fishing venues for fishing in the South China Sea (WPP NR 711), so it needs to be managed in such a way, including managing resources that are natural inputs for the sustainability of the fishery business. [21] state that capture fisheries are managed within a wide range of institutional structures (policies) and include the granting of rights to fish resources that take into account the moral-social aspects.

In 2010 to 2015, the distance range of thickness SWD711min and SWD711max tended to increase significantly the percentage of the thickness level. This indicates that policies enforced during that period support the improvement of demersal fish resource sustainability in the South China Sea (IFMA 711). Similarly, for SWDmax (demersal) and SWFmax (capture fisheries) thickness ranges, each compared to SWFmin, which tends to widen as the year increases. The fishery resource utilization policy of both sea-catching fishery in general and demersal fishery shows improvement in sustainability as shown by the increasing of SuWi thickness level for each fishery.

[19] in his research on sustainable development in China with the SuWi method, obtained a sustainable window thickness level between 0 and 1.2. Based on the existing graph with 2007 base year, the level of thickness of window of national fisheries sustainability between 0 - 0.28; while the level of demersal fishery sustainability window width at IFMA 711 in 2007 s / d 2010 between 0 - 0.04 with increase of thickness level SuWi happened in 2011 until 2014 that is equal to 0.14 – 0.32 and significant increase of thickness of SuWi to 0.84 occurs in 2015. With the level of thickness SuWi tend to increase from 2011 to 2015, it can be said the condition of demersal fishery sustainability, especially in the South China Sea gradually recovered. However, the level of thickness of SuWi that tends to have a value below 1, indicates the need to be careful in managing demersal fisheries in the South China Sea (IFMA 711). So the management policy made should be more consider the ecological condition of its fishery resources. The thinness of this sustainability window, can be caused by several things, such as the high pressure of fishing by the rampant illegal fishing activities in this waters (according to the research results in chapter 5), which puts pressure on the condition of ecological and social indicators of demersal fisheries in the South China Sea (IFMA 711).

Law no. 45 of 2009 on an amendment to Law no. 31 of 2004 concerning fisheries, granting additional authority to fishery supervisors to perform special actions in the form of burning and/or sinking of foreign flagged fishing vessels with sufficient initial evidence [22]. This policy has succeeded in suppressing the number of foreign-flagged illegal fishing actors doing fishing especially in South China Sea (IFMA 711). The combination of punishment methods had a significant impact on the number of fisheries violations. The decline in the number of illegal fishing actors has resulted in the scarcity of fishery production in the flag state of illegal fishing vessels, causing high prices of fishery commodities in the country. This condition also affects the rising prices of fish resources in Indonesia as a consequence of the increasing demand for Indonesian capture fisheries from other countries. So that has an impact on improving the welfare of fishermen, especially fishermen who do activities in the South China Sea (IFMA 711). To this end, this policy has had a positive effect on the sustainability of demersal fisheries in the South China Sea (IFMA 711).

In an effort to maintain the sustainability of fishery resources, the Indonesian government through the Ministry of Marine Affairs and Fisheries issued a regulation on the moratorium on fishing activities on fishing vessels whose construction is done abroad [23]. This policy has been effective since its enactment in 2014 and has had a very significant impact, especially on demersal fisheries activities in Indonesia. The rate of growth and life time of demersal fish resources that tend to be faster and shorter than other resources, leads to demersal fisheries being more responsive to existing policies. The adopted fisheries management policy has an impact on the significant increase of sustainability level in demersal fisheries especially in South China Sea (IFMA 711) compared to national fisheries.
5. Conclusions

Based on the SuWi analysis, the condition of demersal fishery sustainability tend to be better from year to year in the South China Sea (IFMA 711). However, the width of demersal sustainability window tends to be low and indicate the status of sustainability of demersal fish is not maximal in the South China Sea (IFMA 711). Therefore, care should be taken to manage demersal fishery in the South China Sea (IFMA 711).

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