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Evaluating the decision on choosing fishing ground for artisanal fisheries using spatial and Fuzzy DEMATEL in small islands: Sustainability driven

Syahibul Kahfi Hamid[a], Wellem Anselmus Teniwut[a*], Maimuna Renhoran[b] and Roberto Mario Kabi Teniwut[a]

[a]Fisheries Agribusiness Study Program, Tual State Fisheries Polytechnic, Langgur City, Southeast Maluku Regency, 97611, Indonesia
[b]Fishing Technology Study Program, Tual State Fisheries Polytechnic, Langgur City, Southeast Maluku Regency, 97611, Indonesia

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A B S T R A C T

The maintenance of a sustainable mechanism to curb the rate of overfishing in similar water zones is one of the major challenges facing artisan fisheries in small island regions. Several factors instigate the decision by local fishermen to potentially choose a location to explore. Obviously, the demand to address these triggers, particularly those with negative impact tendencies, has become paramount. This study, therefore, is aimed at mapping out fishing heat spots based on arrival, background of the fishermen, and available species. Subsequently, an evaluation is conducted to ascertain the criteria influencing the decision on a specific position and also to determine the consequences of their negative impact on marine resource sustainability and coastal community welfare. For these reasons, data from fishermen, sellers and local distributors were collected by using questionnaires, and analyzed to generate useful information on related fishing ground. Furthermore, experts were involved in providing expert assessment for Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL). The results showed significant insights and therefore offer support to help regulators preserve marine resources, especially by updating their decision making capacity for increased coastal community welfare. The direct implication of this research also serves as a basis for conducting traditional fisheries, estimated not only to meet economic impact, but also promote sustainable environment.

1. Introduction

The environmental and social factors, including culture and safety, are significant considerations during the decision making process in an effort to determine the possible position of fishing ground. These are not only applicable to fishermen in Kei islands, but also extend to counterparts across the world. The influences are predominantly economical, although, there is a behavioural tendency threatening sustainable biodiversity in certain marine waters, specifically among local fishermen. This is attributed to fishing activities that do not only affect the fish, but other non-targeted marine species (Hall & Mainprize 2005). In addition, conventional small-scale fishermen are more prone to adopt outdated knowledge and practices, rather than explore opportunities in modern technology (Defeo & Castilla, 2005; Castilla & Defeo 2001). This situation causes low catch range in coastal regions, hence instigates urgent need to preserve marine resources in small regions, including Kei Islands, Indonesia. Controlling the behaviour of fishermen is significant in averting possible crisis related to marine resources, and associated with illegal fishing or overfishing. This also tend to result to changes in the surrounding ecosystem (Myers & Worm, 2003; Netek et al., 2018). However, some recommended solutions include to reduce capture capacity (Barkin & DeSombre, 2013), zone heat spots (Client et al., 2010), upgrade technology expansion, and modify fishing behaviour (Pauly et al., 2003). The fishing capture potential in Kei Islands and Maluku Province is fast becoming a major income source for fishermen. However, considering current trends and conditions related to behaviour, fleets and techniques, including illegal fishing, the tendency of marine resource development for a particular fish specie, is expected

* Corresponding author.
E-mail address: wateniwut@polikant.ac.id (W. A. Teniwut)

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to decline in the next 8 - 10 years (Klein et al., 2010; Teniwut, 2016). Therefore, a study is crucial in order to maintain the level of marine resource sustainability, especially fishing. Furthermore, the use of modern technology is strongly advised in view of the complex factors influencing aquatic reserves. This triggers the requirement for multidisciplinary and multi-methodological approach towards tackling the specific problem (Ren et al., 2012; Kandakoglu et al;. 2009; Lee & Wu, 2014; Adamides et al., 2009). Regulating fishing grounds poses a complicated challenge. This is due to a high level dependency on sea. Nevertheless, coastal communities generally recognize the importance in preserving marine supplies, and therefore tend to offer support towards implementation of Marine Protected Area (MPA) (Hamid et al., 2017). The selection of MPA locations is very imperative in balancing environmental sustainability, economic resilience, and coastal community welfare. In general, there is need to improve performance and technological capacity in order to compete and boost income, both for fishing and aquaculture (Teniwut, 2018). Also, selecting the best solution to solve a problem with a high impact is necessary, despite several complex factors. Therefore, one method commonly applied is MCDM. The multi criteria decision making (MCDM) approach is widely used to resolve complex objectives and constraints (Wang et al., 2009; Rezaei, 2015; Kiker et al., 2005; Govindan et al., 2015; Zopounidis & Doumpos, 2002). A typical example is DEMATEL (Decision making trial and evaluation laboratory), and is extensively employed in identifying causal chain components of complex systems to describe critical factors influencing decision making (Gabus & Fontela, 1972). The method is applied in various fields including problem solving as either standalone or combined with other MCDM methods, for instance, intertwined e-learning (Tzeng et al., 2007), online stores (Chiu et al., 2013), airlines (Chen, 2016), vehicle maintenance (Vujanovic et al., 2012), tourism (Liu et al., 2012). The precision of DEMATEL is significantly improved with a combination of fuzzy logic based on the provided recommendations to actual field conditions, such as research conducted by (Wu et al., 2007; Chang et al., 2011; Lin, 2013). In addition, the study encapsulates the application of spatial analysis to process heat map data density for fishing ground in Kei Islands. This helps to comprehensively represent the locate spots with exceeding capacity and vice versa, and also enables deeper analysis of decision making in terms of determining fishing locations. Furthermore, the paper is divided into several sections, where the first part depicts the content of the Introduction as the primary reasons and justification for the study. The second shows the methodology comprised of various stages, analytical tools applied, and data collection techniques, while the third is result, and then fourth corresponds to the discussion. Finally, the fifth is the conclusion summarizing the research purposes, including limitations and implications.

2. Methodology

2.1 Study Locations

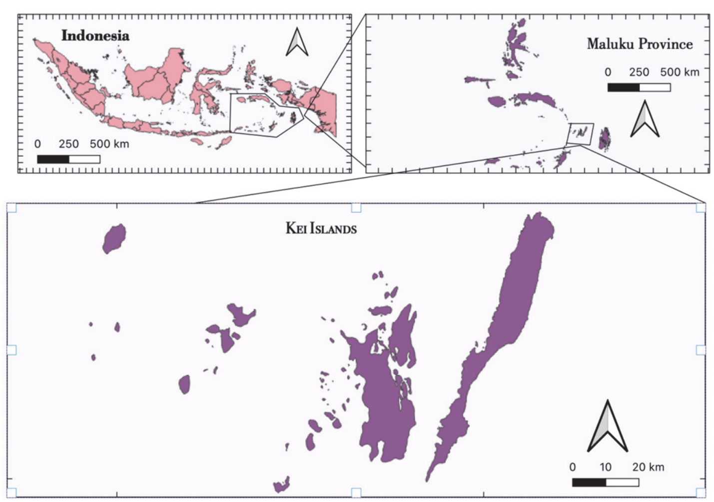

Fig. 1. Study Locations

Fig. 1 shows Kei Islands comprised of three large types, termed, Kei Besar, known as the largest island, Kei Kecil, and Dullah. Moreover, hundreds of small islands, both inhabited and abandoned, currently exist. Fisheries and agriculture are the two primary sources of coastal communities, where fisheries activities are the first and most consistent choice compared to fish farming and other related interest. The hereditary habits, economic drive, and available local markets are the primary contributing factors, irrespective of poor turnover due to lack of stable outcome, and limited managerial proficiency.

2.2 Data Collection

Two analytical tools were applied, including spatial analysis to represent heatmap of fishing ground locations, and DEMATEL with fuzzy logic measurements to determine the factors influencing the choice of spot. Also, two data collection methods were automatically selected, where the first indicates field survey using questionnaires and the second involves field verification on sellers, landing spots and fishing villages by collecting the fishing ground location data. These processes were conducted between June 2017 to June 2018 and about 3036 datasets were generated. Furthermore, for Fuzzy DEMATEL, the fishermen were requested to confirm reliable information through direct interview and discussion using questionnaires to provide guidance in order to minimize misrepresentation.

2.3 Spatial Analysis using Heatmap

The purpose of applying heatmap is to ascertain the range of fishing locations, especially for artisan fisheries activities. The results showed the location data with more or less fishing activities, while analyzing the various factors influencing the water selection. Heatmap is described as a graph data type comprising cells with specially assigned colors indicating the level of attribute base on use. In addition, the map highlights the phenomenon object distribution (Eck, 2005), while in contrast, is demonstrated as geographic clusters (Dempsey, 2014). Also, the graph is suggested as a geospatial data involving the use of certain colours to indicate concentration points (Yeap & Uy, 2014). However, this study processed heatmap using ArcGIS 10.5 with kernel density estimation (KDE).

2.4 Fuzzy Number

Fuzzy numbers are a set of unclear parts that are real numbers representing confidence intervals. A Triangular fuzzy number (TFN) contains these basic feature, where a fuzzy number $\tilde{A}$ on $\mathbb{R}$ is TFN when its membership function $\chi \in \tilde{A}, \mu_{\tilde{A}}(x): \mathbb{R} \rightarrow [0, 1]$ is equal to (van Laarhoven and Pedrycz, 1983):

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-k)/(m-k), & k \leq x \leq m \\ (w-x)/(w-m), & m \leq x \leq w \\ 0, & otherwise \end{cases}$$

The operational of two TFN appears as follows:

$$\tilde{A}_1(+)\tilde{A}_2 = k_1 + k_2, m_1 + m_2, w_1 + w_2 \qquad \tilde{A}_1(\times)\,\tilde{A}_2 = k_1k_2,\, m_1m_2,\, w_1, w_2$$
$$\tilde{A}_1(-)\,\tilde{A}_2 = k_1 - w_2, m_1 + m_2, w_1 + k_2 \qquad \tilde{A}_1(\div)\tilde{A}_2 = \frac{k_1}{w_2}, \frac{m_1}{m_2}, \frac{w_1}{k_2}$$

The study also involves the use of expression to measure the individual criteria with five basic linguistic terms, known as“absolutely important,” “very strongly important,“essentially important,”“weakly important”, and “equally important” with respect to a fuzzy five level scale (Chiou, 2001).

2.5 Fuzzy DEMATEL

DEMATEL is one of the known MCDM tools used in building and analysing structural models involving causal relationships between complex factors. More specifically, the method is based on a graph describing the condition of groups of factors acting as causes and those as affected known as 'diagraphs'. The DEMATEL fuzzy steps are as follows:

Step 1. Set goal and defining the evaluation criteria

The determination of goals and criteria used in this study. This stage indicates the pair-wise comparison scale was evaluated, and comprised of four levels representing "No influence", "Low influence", "High influence", and "Strongly high influence",

Step 2. Directed-relation matrix

The initial direct-relation matrix Z. Experts were asked to generate pairwise comparison, and then measured by criteria $C = \{C_i | i = 1, 2, \ldots, n\}$.

Step 3. Normalized direct-relation fuzzy matrix

The normalized direct-relation matrix X, is obtained by the formula (Wu & Lee, 2007):

$$X = s \cdot Z$$

$$s = \frac{1}{max_{1 \leq i \leq n} \sum_{j=1}^{n} z_{ij}}, \qquad i, j = 1,2, \ldots, n.$$

Step 4. The total-relation matrix

The total-relation matrix T is calculated by the equation:

$$T = X(1 - X^{-1}$$

Step 5. The sum of rows and columns

The sum of rows and columns are separately denoted as D and R within the total-relation matrix T by the formula:

$$T = T_{ij} \quad i, j = 1,2, \dots, n, \qquad D = \sum_{j=1}^{n} t_{ij}, \qquad R = \sum_{j=1}^{n} t_{ij},$$

Step 6. Analyse the result

Analyse the criteria into causal and effect diagram by mapping the dataset. Where, the horizontal axis (D + R), and the vertical axis $(D - R)$.

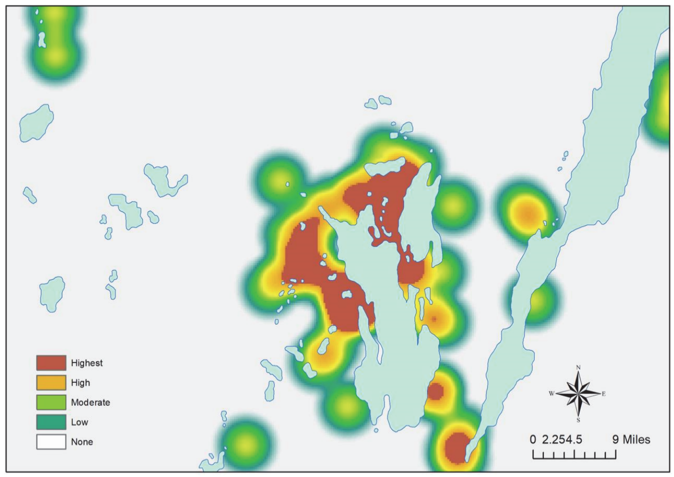

Fig. 2. Heatmap fishing ground in Kei islands for Artisanal Fisheries

3. Results

3.1 Heatmap Analysis

The field survey results were processed using the Kernel Density Estimation (KDE) approach. Figure 2 shows the heatmap fishing ground has been acquired in Kei Island. In addition, Pulau Kei Kecil, Kei Kecil Water Districts, Manyeuw and Hoat Sorbay in Southeast Maluku Regency, are locations with the highest fishing intensity by local fishermen for a one year period. As for Tual City, the areas around Dullah Island which is close to the Dullah Laut, were observed as the most visited spot. Also, Kei Besar Island, the waters around Feer Village in Kei Besar Selatan Subdistrict, Southeast Maluku Regency were the most preferred choice of fishing ground.

Table 1
Assessment on direct relation matrix T

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	3	3	2	3	4	2	4	3	3	3	4	4
C2	3	0	2	2	3	2	1	3	3	3	3	4	4
C3	4	2	0	2	3	2	1	3	1	3	3	4	4
C4	3	1	1	0	2	3	1	2	1	1	1	1	1
C5	3	2	3	3	0	3	1	3	3	2	2	2	3
C6	4	2	3	3	3	0	2	3	3	3	4	2	4
C7	2	1	2	1	2	2	0	2	2	2	2	2	3
C8	3	2	3	3	2	3	1	0	2	2	2	4	3
C9	3	1	1	1	2	3	1	2	0	4	4	2	3
C10	3	1	1	1	2	3	1	2	4	0	4	4	4
C11	3	4	3	1	3	3	3	2	4	4	0	2	3
C12	3	3	3	1	3	3	2	4	2	4	2	0	3
C13	4	4	4	1	3	4	3	3	4	4	4	2	0

3.2 Fuzzy DEMATEL

The criteria for choosing fishing ground spot on artisan fisheries include distance from the village (C1), information by other local fisherman (C2), information passed on by parents (C3), random trip (C4), seasons (C5), capacity of the fishing gears (C6), distance to local market (C7), village customary rights (C8), technology-based information (GPS and fish finder)

(C9), preliminary survey-based information (C10), targeting specific fish species (C11), avoiding conflict (C12), and areas widely known to have abundant of fishes (C13). These criteria emerged from the results of interviews with local fishermen and verification with researchers related to the field of capture fisheries.

Table 2
Normalized initial direct-relation fuzzy matrix (j)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	0.5	0.5	0.25	0.5	0.75	0.25	0.75	0.5	0.5	0.5	0.75	0.75
C2	0.5	0	0.25	0.25	0.5	0.25	0	0.5	0.5	0.5	0.5	0.75	0.75
C3	0.75	0.25	0	0.25	0.5	0.25	0	0.5	0	0.5	0.5	0.75	0.75
C4	0.5	0	0	0	0.25	0.5	0	0.25	0	0	0	0	0
C5	0.5	0.25	0.5	0.5	0	0.5	0	0.5	0.5	0.25	0.25	0.25	0.5
C6	0.75	0.25	0.5	0.5	0.5	0	0.25	0.5	0.5	0.5	0.75	0.25	0.75
C7	0.25	0	0.25	0	0.25	0.25	0	0.25	0.25	0.25	0.25	0.25	0.5
C8	0.5	0.25	0.5	0.5	0.25	0.5	0	0	0.25	0.25	0.25	0.75	0.5
C9	0.5	0	0	0	0.25	0.5	0	0.25	0	0.75	0.75	0.25	0.5
C10	0.5	0	0	0	0.25	0.5	0	0.25	0.75	0	0.75	0.75	0.75
C11	0.5	0.75	0.5	0	0.5	0.5	0.5	0.25	0.75	0.75	0	0.25	0.5
C12	0.5	0.5	0.5	0	0.5	0.5	0.25	0.75	0.25	0.75	0.25	0	0.5
C13	0.75	0.75	0.75	0	0.5	0.75	0.5	0.5	0.75	0.75	0.75	0.25	0

Table 3
Normalized initial direct-relation fuzzy matrix (y)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	0.75	0.75	0.5	0.75	1	0.5	1	0.75	0.75	0.75	1	1
C2	0.75	0	0.5	0.5	0.75	0.5	0.25	0.75	0.75	0.75	0.75	1	1
C3	1	0.5	0	0.5	0.75	0.5	0.25	0.75	0.25	0.75	0.75	1	1
C4	0.75	0.25	0.25	0	0.5	0.75	0.25	0.5	0.25	0.25	0.25	0.25	0.25
C5	0.75	0.5	0.75	0.75	0	0.75	0.25	0.75	0.75	0.5	0.5	0.5	0.75
C6	1	0.5	0.75	0.75	0.75	0	0.5	0.75	0.75	0.75	1	0.5	1
C7	0.5	0.25	0.5	0.25	0.5	0.5	0	0.5	0.5	0.5	0.5	0.5	0.75
C8	0.75	0.5	0.75	0.75	0.5	0.75	0.25	0	0.5	0.5	0.5	1	0.75
C9	0.75	0.25	0.25	0.25	0.5	0.75	0.25	0.5	0	1	1	0.5	0.75
C10	0.75	0.25	0.25	0.25	0.5	0.75	0.25	0.5	1	0	1	1	1
C11	0.75	1	0.75	0.25	0.75	0.75	0.75	0.5	1	1	0	0.5	0.75
C12	0.75	0.75	0.75	0.25	0.75	0.75	0.5	1	0.5	1	0.5	0	0.75
C13	1	1	1	0.25	0.75	1	0.75	0.75	1	1	1	0.5	0

Table 4
Normalized initial direct-relation fuzzy matrix (m)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	1	1	0.75	1	1	0.75	1	1	1	1	1	1
C2	1	0	0.75	0.75	1	0.75	0.5	1	1	1	1	1	1
C3	1	0.75	0	0.75	1	0.75	0.5	1	0.5	1	1	1	1
C4	1	0.5	0.5	0	0.75	1	0.5	0.75	0.5	0.5	0.5	0.5	0.5
C5	1	0.75	1	1	0	1	0.5	1	1	0.75	0.75	0.75	1
C6	1	0.75	1	1	1	0	0.75	1	1	1	1	0.75	1
C7	0.75	0.5	0.75	0.5	0.75	0.75	0	0.75	0.75	0.75	0.75	0.75	1
C8	1	0.75	1	1	0.75	1	0.5	0	0.75	0.75	0.75	1	1
C9	1	0.5	0.5	0.5	0.75	1	0.5	0.75	0	1	1	0.75	1
C10	1	0.5	0.5	0.5	0.75	1	0.5	0.75	1	0	1	1	1
C11	1	1	1	0.5	1	1	1	0.75	1	1	0	0.75	1
C12	1	1	1	0.5	1	1	0.75	1	0.75	1	0.75	0	1
C13	1	1	1	0.5	1	1	1	1	1	1	1	0.75	0

Table 5
Total-relation fuzzy matrix (j)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	0,0435	0,0435	0,0217	0,0435	0,0652	0,0217	0,0652	0,0435	0,0435	0,0435	0,0652	0,0652
C2	0,0435	0	0,0217	0,0217	0,0435	0,0217	0,0000	0,0435	0,0435	0,0435	0,0435	0,0652	0,0652
C3	0,0652	0,0217	0	0,0217	0,0435	0,0217	0,0000	0,0435	0,0000	0,0435	0,0435	0,0652	0,0652
C4	0,0435	0,0000	0,0000	0	0,0217	0,0435	0,0000	0,0217	0,0000	0,0000	0,0000	0,0000	0,0000
C5	0,0435	0,0217	0,0435	0,0435	0	0,0435	0,0000	0,0435	0,0435	0,0217	0,0217	0,0217	0,0435
C6	0,0652	0,0217	0,0435	0,0435	0,0435	0	0,0217	0,0435	0,0435	0,0435	0,0652	0,0217	0,0652
C7	0,0217	0,0000	0,0217	0,0000	0,0217	0,0217	0	0,0217	0,0217	0,0217	0,0217	0,0217	0,0435
C8	0,0435	0,0217	0,0435	0,0435	0,0217	0,0435	0,0000	0	0,0217	0,0217	0,0217	0,0652	0,0435
C9	0,0435	0,0000	0,0000	0,0000	0,0217	0,0435	0,0000	0,0217	0	0,0652	0,0652	0,0217	0,0435
C10	0,0435	0,0000	0,0000	0,0000	0,0217	0,0435	0,0000	0,0217	0,0652	0	0,0652	0,0652	0,0652
C11	0,0435	0,0652	0,0435	0,0000	0,0435	0,0435	0,0435	0,0217	0,0652	0,0652	0	0,0217	0,0435
C12	0,0435	0,0435	0,0435	0,0000	0,0435	0,0435	0,0217	0,0652	0,0217	0,0652	0,0217	0	0,0435
C13	0,0652	0,0652	0,0652	0,0000	0,0435	0,0652	0,0435	0,0435	0,0652	0,0652	0,0652	0,0217	0

Table 6
Total-relation fuzzy matrix (y).

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	0.0652	0.0652	0.0435	0.0652	0.0870	0.0435	0.0870	0.0652	0.0652	0.0652	0.0870	0.0870
C2	0.0652	0	0.0435	0.0435	0.0652	0.0435	0.0217	0.0652	0.0652	0.0652	0.0652	0.0870	0.0870
C3	0.0870	0.0435	0	0.0435	0.0652	0.0435	0.0217	0.0652	0.0217	0.0652	0.0652	0.0870	0.0870
C4	0.0652	0.0217	0.0217	0	0.0435	0.0652	0.0217	0.0435	0.0217	0.0217	0.0217	0.0217	0.0217
C5	0.0652	0.0435	0.0652	0.0652	0	0.0652	0.0217	0.0652	0.0652	0.0435	0.0435	0.0435	0.0652
C6	0.0870	0.0435	0.0652	0.0652	0.0652	0	0.0435	0.0652	0.0652	0.0652	0.0870	0.0435	0.0870
C7	0.0435	0.0217	0.0435	0.0217	0.0435	0.0435	0	0.0435	0.0435	0.0435	0.0435	0.0435	0.0652
C8	0.0652	0.0435	0.0652	0.0652	0.0435	0.0652	0.0217	0	0.0435	0.0435	0.0435	0.0870	0.0652
C9	0.0652	0.0217	0.0217	0.0217	0.0435	0.0652	0.0217	0.0435	0	0.0870	0.0870	0.0435	0.0652
C10	0.0652	0.0217	0.0217	0.0217	0.0435	0.0652	0.0217	0.0435	0.0870	0	0.0870	0.0870	0.0870
C11	0.0652	0.0870	0.0652	0.0217	0.0652	0.0652	0.0652	0.0435	0.0870	0.0870	0	0.0435	0.0652
C12	0.0652	0.0652	0.0652	0.0217	0.0652	0.0652	0.0435	0.0870	0.0435	0.0870	0.0435	0	0.0652
C13	0.0870	0.0870	0.0870	0.0217	0.0652	0.0870	0.0652	0.0652	0.0870	0.0870	0.0870	0.0435	0

Table 7
Total-relation fuzzy matrix (y)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0	0.0870	0.0870	0.0652	0.0870	0.0870	0.0652	0.0870	0.0870	0.0870	0.0870	0.0870	0.0870
C2	0.0870	0	0.0652	0.0652	0.0870	0.0652	0.0435	0.0870	0.0870	0.0870	0.0870	0.0870	0.0870
C3	0.0870	0.0652	0	0.0652	0.0870	0.0652	0.0435	0.0870	0.0435	0.0870	0.0870	0.0870	0.0870
C4	0.0870	0.0435	0.0435	0	0.0652	0.0870	0.0435	0.0652	0.0435	0.0435	0.0435	0.0435	0.0435
C5	0.0870	0.0652	0.0870	0.0870	0	0.0870	0.0435	0.0870	0.0870	0.0652	0.0652	0.0652	0.0870
C6	0.0870	0.0652	0.0870	0.0870	0.0870	0	0.0652	0.0870	0.0870	0.0870	0.0870	0.0652	0.0870
C7	0.0652	0.0435	0.0652	0.0435	0.0652	0.0652	0	0.0652	0.0652	0.0652	0.0652	0.0652	0.0870
C8	0.0870	0.0652	0.0870	0.0870	0.0652	0.0870	0.0435	0	0.0652	0.0652	0.0652	0.0870	0.0870
C9	0.0870	0.0435	0.0435	0.0435	0.0652	0.0870	0.0435	0.0652	0	0.0870	0.0870	0.0652	0.0870
C10	0.0870	0.0435	0.0435	0.0435	0.0652	0.0870	0.0435	0.0652	0.0870	0	0.0870	0.0870	0.0870
C11	0.0870	0.0870	0.0870	0.0435	0.0870	0.0870	0.0870	0.0652	0.0870	0.0870	0	0.0652	0.0870
C12	0.0870	0.0870	0.0870	0.0435	0.0870	0.0870	0.0652	0.0870	0.0652	0.0870	0.0652	0	0.0870
C13	0.0870	0.0870	0.0870	0.0435	0.0870	0.0870	0.0870	0.0870	0.0870	0.0870	0.0870	0.0652	0

Table 8
Crisp values Di+Ri and Di-Ri

Criteria	Di+Ri	Di-Ri	Criteria	Di+Ri	Di-Ri
C1	7.4104	-0.0067	C8	6.5412	-0.1934
C2	6.2236	0.4794	C9	6.2636	-0.3658
C3	6.3961	0.1443	C10	6.6402	-0.3480
C4	4.6939	-0.2476	C11	6.9392	0.0749
C5	6.4781	-0.0853	C12	6.6653	0.1454
C6	7.0946	0.0075	C13	7.4956	0.0127
C7	4.9566	0.2486			

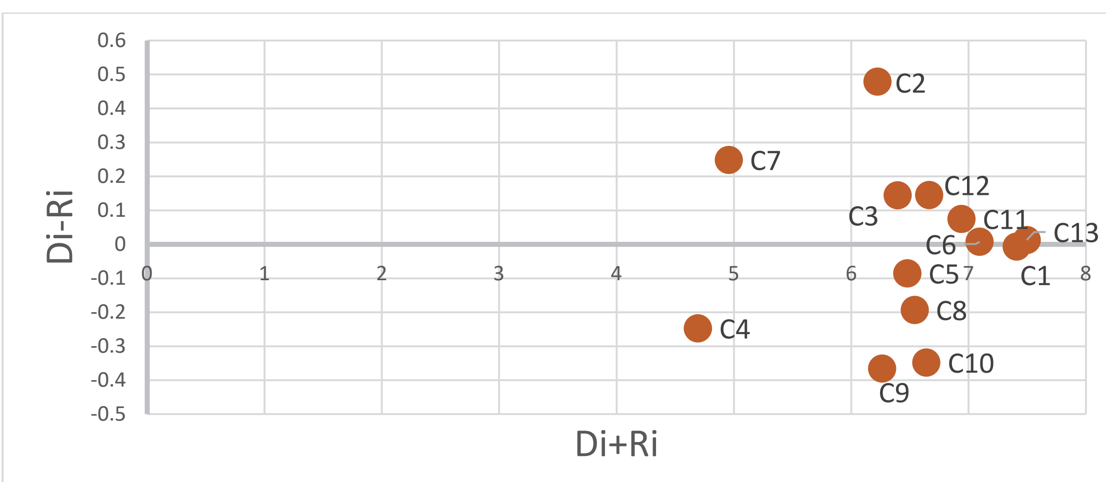

Fig. 3. Cause and effect diagram

Table 8 represents the results of local fishermen assessment on existing criteria. Furthermore, the three fuzzy values were divided into three parts (j, y and m) for the normalized core table of direct-relation fuzzy matrix (Table 2-4) and total-relation fuzzy matrix (Tables 5-7). Causal-effect calculation results show (Table 8 and Fig. 3) criteria acting as causal, were information obtained from other local fishermen (C2), information passed on by parents (C3), capacity of fishing gears (C6) , distance to local market (C7), targeting specific fish species (C11), avoiding conflict (C12), and areas widely known to have abundant of fishes (C13). While the criteria included in the effect category are distance from the village (C1), random trip (C4), seasons (C5), village customary rights (C8), technology-based information (GPS and fish finder) (C9), and preliminary survey-based information (C10).

4. Discussion

The results showed the fishing ground location in Kei Islands provides 3 densest spots to serve as fishing ground throughout the year. However, the condition possesses some consequences for the overall sustainable marine resources as this activity continues. Therefore, it is highly necessary to educate more fishermen in order to reduce the threat to fish supplies in this region. Several factors instigate the behaviour of local fishermen in choosing fishing locations. Habitual, economics and technological capacity are some of the primary drivers. The results of causal-effect diagrams provide comprehensive information recognizing the causal as the main concern due to the criteria in this category are very complex to modify (Hori & Shimizu, 1999). Therefore, the most influential factor considered is the information from other local fishermen (C2) due to the highest Di-Ri value acquired, followed by distance to local market (C7), and avoiding conflict (C12). Nevertheless, among the three highest causal factors, C12 has a greater Di + Ri value to favor C12 with a greater influence than the others. However, C13 observes the major Di + Ri value, in addition to obtaining the largest causal factor, while C9 is the effect factor due to highest Di-Ri. Therefore, the regional government serves as a policy maker for Southeast Maluku District and Tual City with the responsibility to address the seven existing causal factors. Subsequently, the purpose is to facilitate the education of local fishermen in coastal communities. This is achieved through the provision of extensive fishing spots close to market locations, as small areas potentially tend to result to conflict. The six effect factors can at any time turn into causal. Therefore, technology-based information (GPS and fish finder) (C9), and preliminary survey-based information (C10) are highly considered by their respective local governments more specifically. However, both factors are achieved by involving higher educational institutions to support in mapping the fishing locations and fishing ground density conditions. This is to prevent the problem of overfishing, and further sustain marine resources.

5. Conclusion

There are presently only three functional fishing locations, including the central sites on Kei islands. This lingering situation is a threat to sustainable marine resources and the entire water ecosystem. Therefore, the two regional governments in Kei Islands, Southeast Maluku Regency and Tual City, are advised to pay close attention to developing the knowledge of fishermen. One significant applicable recommendation is to establish fish hubs close to fishing villages. This is expected to prevent fishermen from exploring waters close to the local markets. In addition, the two local governments are encouraged to further improve on the application of modern technology, specifically in terms of mapping fishing potentials. This is important in analyzing the density of fishing locations due to lack of knowledge by local fishermen on marine potentials. These efforts are imperative in the context of the sustainable marine resources. Further researches are recommended to explore the results generated from conducting this investigation on the potential of marine resources and surrounding ecosystems in the waters of Kei islands.

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