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QUALITATIVE LOOP ANALYSIS OF SOCIAL-ECOLOGICAL CONNECTIVITY: THE CASE OF BIMA BAY, WEST NUSA TENGGARA

ANALISIS LOOP KUALITATIF TERHADAP KONEKTIVITAS SOSIAL-EKOLOGI: STUDI KASUS PADA TELUK BIMA, NUSA TENGGARA BARAT

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ABSTRACT

The coastal area of Bima Bay will continuously experience increased development for the next few years along with its city development as “Waterfront City” and as a tourism village by the decision letter of the West Nusa Tenggara governor. The data used in this research are primary and secondary data with a purposive sampling method. The analysis results show that: 1) the basic network model does not significantly differ from the simulation model, 2) loop analysis based on seven scenario simulations combines six nodes with the assumption that if node Up, Ad, Hp, P, and Jv is unavailable, so the nodes gaining negative effect are Tt, Ti, Sp, Il, Ic, and Dw. Sustainable management effort of the ecosystem in Bima Bay by observing the network connection between SES components to find out the component giving positive and negative effects in management policy-making. The simulation model using the goodness of fit test for model statistic obtains p-value 0.96 which means H_0 received since p-value 0.96 > 0.05 points. There need sustainable efforts to maintain the Bima Bay ecosystem by observing the impact of network relation across the components in SES to find out the component with positive and negative impact in making management policies.

Keywords: social-ecological system, loop analysis, a model of the goodness of fit, simulation model, coastal area.

ABSTRAK

Wilayah pesisir Teluk Bima dalam beberapa tahun kedepan akan terus mengalami peningkatan pembangunan seiring dengan pengembangan Kota Bima sebagai “*Waterfront City*” dan desa wisata melalui surat keputusan (SK) Gubernur Nusa Tenggara Barat. Data yang digunakan dalam penelitian ini adalah data primer dan sekunder dengan metode *purposive sampling.* Hasil analisis menunjukan bahwa: 1) model jaringan dasar secara signifikan tidak berbeda dengan model simulasi, 2) analisis loop berdasarkan 7 (tujuh) simulasi skenario menggabungkan ke-enam *node* dengan asumsi bahwa Up, Ad, I, Hp, P, dan Jv tidak ada, maka *node* yang mendapatkan pengaruh negatif adalah Ts, Ti, Sp, Il, Ic, dan Dw. Upaya pengelolaan berkelanjutan di ekosistem kawasan Teluk Bima perlu memperhatikan hubungan jaringan antar komponen SES untuk mengetahui komponen yang memberikan dampak positif dan negatif dalam pengambilan kebijakan pengelolaan. Hasil uji simulasi model jaringan dasar menggunakan uji kesesuaian model dengan *Goodness-of-fit for model statistics* diperoleh nilai *p-value* 0.96 berarti bahwa H_0 diterima karena nilai *p-value* 0.96 > 0.05. Perlu adanya upaya keberlanjutan di ekosistem kawasan Teluk Bima dengan memperhatikan dampak hubungan jaringan antar komponen dalam SES untuk mengetahui komponen yang memberikan dampak positif dan negatif dalam pengambilan kebijakan pengelolaan.

Kata kunci: sistem sosial-ekologi, loop analisis, kesesuaian model, model simulasi, wilayah pesisir.

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INTRODUCTION

The coastal area of Bima Bay will continuously experience increased development for the next few years along with the development of its city as "waterfront city" and as tourism village in accordance to the decision letter of the governor number: 050.13-336 the year 2019 on the establishment of 99 locations of tourism village in West Nusa Tenggara. The decision is assumed to enhance numbers of activities in Bima Bay site causing the increase of area utilization and causing implication concerning waters quality and coastal system (mangrove, seagrass, coral reef). The increase of activities in the bay area will increase area utilization causing implication on waters quality and coastal system (mangrove, seagrass, coral reef) (Asyiawati *et al*. 2010).

The distinct policy 2 of the regional government is that the government of Bima Regency and Bima City are assumed to cause imbalance relation between the social system and ecological system. Thus, holistic understanding regarding the interaction between human and the ecosystem around or the interaction occurs between ecological system (resources) and social system (human) which is known as a social-ecological system (SES), as described in some research (Anderies *et al*. 2004; Costanza, 1999; Berkes *et al*. 2000; Costanza *et al*. 2000; Dressel *et al*. 2018; Abram & Dyke 2018). According Gunderson *et al*. (2006), SES is a very broad concept of human and nature, where the ecological system in complex related to and influenced by one or more social system. The relation between the systems or SES as a whole is a complex adaptive system engaging many subsystems and some bigger systems (Cumming, 2011). The interaction consciously encourages human to make a choice as an individual or member for a collaborative team to make significant result distinction (McGinnis MD and Ostrom E, 2014). Thus, SES is an interaction between social structure and process with ecosystem unit involving coastal, mangrove, seagrass, coral reef, seashore and upwelling system (Andrianto, 2009 in Sjafrie, 2018).

In addition, the decision is assumed to cause the increase of people population at Bima Bay site, and utilization land causing implication toward waters and seashores ecosystem quality (mangrove, seagrass, and carol reef). The decision implication is comprehended as an imbalance relation between social and ecological system; thus, SES understanding is needed to explain the connectivity of numbers of substance include human as the organization actor and resource users, and natural resource component (Gonzales & Parrot, 2012). The relation between social and ecological system is mutually independent relation interacting dynamically to a social system that will make changes toward an ecological system and vice versa (Sjafrie, 2018).

In accordance with the above characteristics, it is urgently needed proper bay management for its sustainable use. Sustainable use efforts require management and understanding of the interaction between social systems and ecological systems as a management solution by paying attention to ecological and socio-economic sustainability. The inability to build a system will have a negative impact on the existence of resources in the bay, where the area and forms of use by the community are open (open access), even though the resources in the bay are already limited. The Bima Bay area is presumed to continue to experience increased utilization to increase the economy of the area around the area, but this economic increase has an impact on the destruction of the environment and coastal ecosystems.

Based on the understanding, it encourages the researcher to conduct research in Bima Bay relating to the relation between social and ecological system by adopting a conceptual model (Anderies *et al*., 2004). The conceptual model is modified and used as a reference to explain the relationship between the four components in SES comprising resources, resource users, public infrastructure providers, and public infrastructures. The objectives of this research are to find out relation between actors in the component and how the effect of the actors toward other actors in the component.

RESEARCH METHODS

Description of the Study Sites

The research was done in December 2019. The study site is Bima Bay area consists of Ambalawi sub-district, Asakota sub-district, Rasanae Barat sub-district, Palibelo sub-district, Woha sub-district, Bolo sub-district, and Soromandi sub-district of West Nusa Tenggara Province (Figure 1). Bima Bay is semi-closed waters linking directly to Flores Ocean with 184 km^2 wide and 78 km^2 long (DirPolAir NTB, 2017). The population of the coastal area was 185,419 and 190,736 in 2016 and 2018, respectively, featuring an increase of 1.03% (Statistic of Bima Regency 2019; Statistic of Bima Municipality 2019).

Bima Bay has potential benefit for fishery catching, fishery cultivation (brackish water and sea cultivation) and tourism. However, the management of the existing potential has not been integrated as each sector still focuses on its sector development without paying attention to other sectors' development. It is strengthened by regional regulation of West Nusa Tenggara Province number 12 the year 2017 on zoning plan for coastal areas and small islands in West Nusa Tenggara that establishes Bima Bay area as public cultivation zone, a tourism zone and a port zone. This regulation allegedly will have an impact on the development of fisheries and aquaculture.

Category and Data Source

The method used in this study is primer data of deep interview and field observation while the secondary data are based on related literatures and documents. The populations in this study include fishermen, farmers, collectors, and related agencies, totaling 40 interviews conducted using the purposive sampling method. The selection was based on certain criteria (Sugiyono 2013), including: small and traditional fishermen involved in fishing activities at the Bima Bay area; indigenous pond farmers and floating net cages; collectors; related institutions (regional development planning agency Bappeda, fisheries, marine and tourism services). The primary and secondary data are used as: 1) to build basic network model, 2) to detect influential node toward social-ecological system relation. Map of RZWP3K Nusa Tenggara Barat is shown in Figure 1.

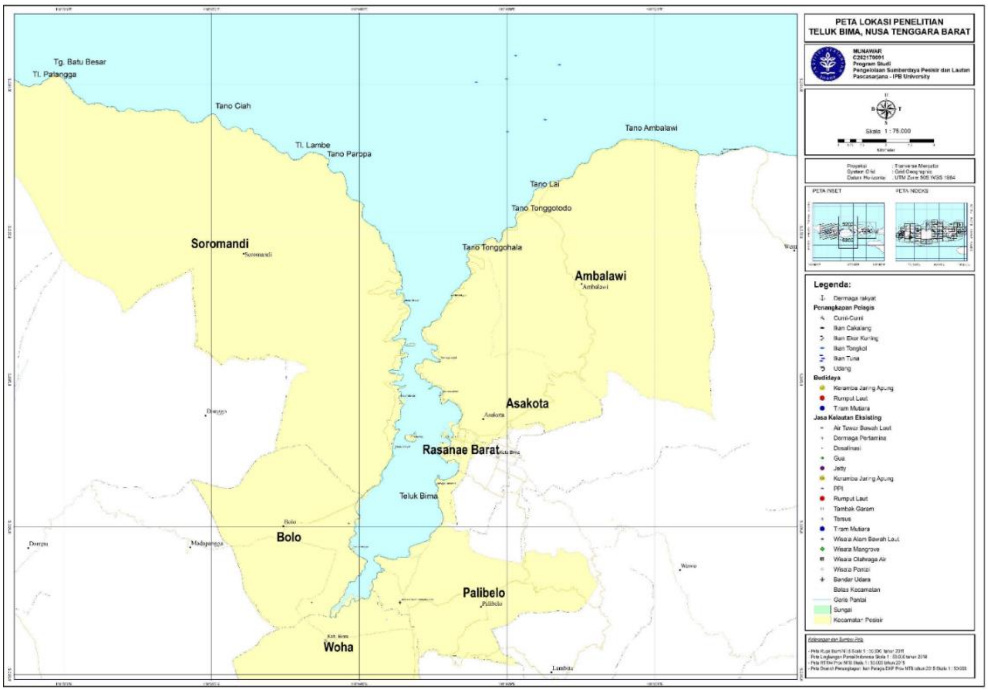

Figure 1. Study Site
(Source: Map of RZWP3K NTB, 2017)

The basic network model is adopted from conceptual framework by Anderies *et al*. (2004) in Figure 2. Nodes are labeled as public infrastructure (IP), public infrastructure providers (PIP), resources (R), resource users (RU), fisheries business (Up), fish (I), local regulations (Ad), shrimp (U), molluscs (M), small crabs (Rj), jetties (Dj), tourist destination (Dw), fishery products (Hp), number of ships (Jk), number of visits (Jv), cottage (Ts), infrastructure (Sp), tourism income (Ic), commodity (K), market (P), others stakeholder (Sl), domicile area (Wl), tourism manager (Pw), price (Pr), number of fishermen (Jn), fishery income (IPe), construction of public facilities (Sp), area of cultivation (Lt), fish landing (Ti), collecting income (Il), type of cultivation (Jb), number of cultivators (Jp), number of fishing gear (Jt).

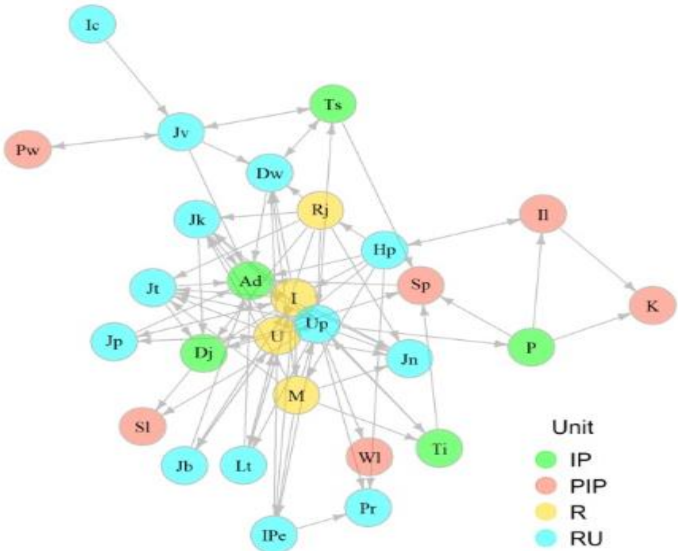

Figure 2. Basic Model of Network Analysis
(Source: Data Analysis, 2020)

Data Analysis

The data analysis used in this research has two steps such as: 1) network model simulation that is used to find out the goodness of fit value and basic network model with simulation or alternative model, and 2) loop analysis in R sna package, with R tools (Butts 2019). According to Thomas *et al*. (2012), simulation procedure comprises some steps such as: 1) randomly picked clarity configuration model; 2) group matrix based on random weight (a_{ij}) from F distribution that has been assigned to coefficients of relations other than zero; 3) eigenvalue that generates revalidation to understand attitudes on the system; and 5) matrix results are used to predict response on system disturbance.

Basic network model that needs a feasibility test of goodness of fit test for the statistic model is in R sna set application. The goodness of fit test is the compatibility level test of whether the basic network model and simulation results are different or not. Compatibility test of this model is based on the significant value of p-value>0.05. The determination of p-value is based on hypotheses with the assumption that if $H_0 \leq 0.05$ means the basic network model and network simulation are different (H_0 received). Meanwhile, when $H_1 \geq 0.05$, the basic network model and network simulation are not different (H_0 rejected). The simulation of basic network model will show other alternatives on the mean situation in accordance with group matrix generated from weight assessment. Then, model validation based on alternatives condition is done, and then select a stable model to be used as a model in running disturbance scenario to gain alternative model. Furthermore, the node with the highest relation value will be chosen from the result of a basic model to make scenario on an influential node or actor.

Loop modelling analysis is one of the approaches of complex social-ecological system analysis used to figure out sturdy framework in delivering direct or indirect influential assessment in a complex system (Kluger *et al*., 2015). Loop analysis is the relation between different components through graphic focused on numbers of relation character comprising value 1, -1, or 0 in network structure (Ortiz & Wolff, 2002) that may be involved between countable or uncountable social-ecological variable. There are some steps in analyzing network in loop analysis. Firstly, identifying variable (node), based on the results of research Munawar *et al*. (2020) related to ecological system contexts such as resources (fish, mollusk, shrimp, and small crab) and public infrastructures (market, PPI/TPI, tourist cottage, jetty, regional regulation). Secondly, identifying variable (node) of the social systems such as resources users (fishery catching, aquaculture and tourism) and public infrastructure providers (regional government, another stakeholder and collector or *palele*). Thirdly, understanding the most influential variable toward other nodes based oh matrix connection. The matrix used in this study is matrix *n x n* adjancency to understand each variable impact on other variables including the self-damping or self-variable that is able to identify negatively, positively, and with no relation or neutral.

The relation between different components or nodes in the related system is factually revealed with symbol "+", "-" and "0" that depict the type of influential variable (Kluger *et al*., 2015). The variable is thought as cycle representation between the relations marked by the arrow (Figure 3).

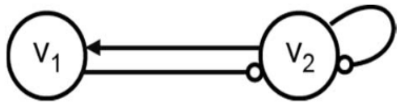

Figure 3. Cycle Representation between the Relations Marked by the Arrow

Figure 3. Loop analysis shows variable as cycle and relation between variables marked with an arrow and ended by the tip of the gives positive arrow (positive impact) or cycle (negative impact). Variable 1 (V1) shows negative impact on variable 2 (V2) while variable 2 gives a positive impact on variable 1. However, variable 2 is negative for itself or self-damping (Kluger *et al*., 2015). The use of loop analysis is needed to do to predict the level of relation impact between social system node and ecological system node in Bima by the site. The loop analysis result will give a depiction of condition-level on the most influential node toward the existing system changes to be used as a reference for stakeholder in making management policies. Accordingly, this study is aimed to do simulation concerning SES basic network model of Bima Bay and understand the influential nodes on system changes in Bima Bay sites, West Nusa Tenggara. The Loop analysis using software DIA.

RESULTS AND DISCUSSION

The result of basic network model simulation can be used to find out whether the relations between nodes in the network can be different or not and can be accounted for statistically. Basic network model and network simulation model (Figure 4) are then tested for the suitability of the model using the goodness of fit for the model statistic. The result of the goodness of fit for model statistic obtains p-value 0.96 (Table 1) that means H_0 rejected and H_1 received, since p-value 0.96 ≥ 0.05 points basic network model is significantly indifferent from a simulation model. The results of the simulation model and basic network are shown in Figure 5.

Table 1. Goodness-of-fit for Model Statistics

No		Obs	Min	Mean	Max	MC p-value
1	Edges	81	64	81.46	101	0.98
2	Nodematch unit	14	7	14.19	22	0.96

(Source: Data Analysis, 2020)

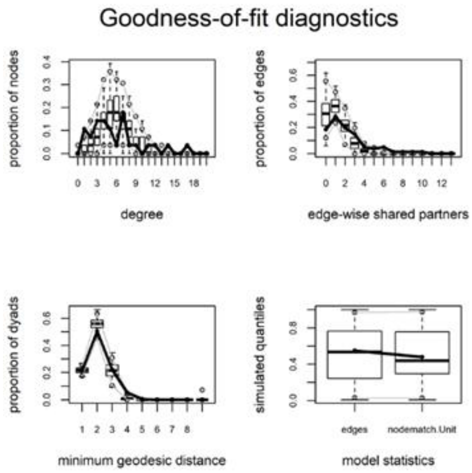

Figure 4. Basic Network Model and Model Network Simulation
(Source: Data Analysis, 2020)

It shows that the basic model is significantly different from the result of the simulation model, thus the basic model can be analyzed using loop analysis.

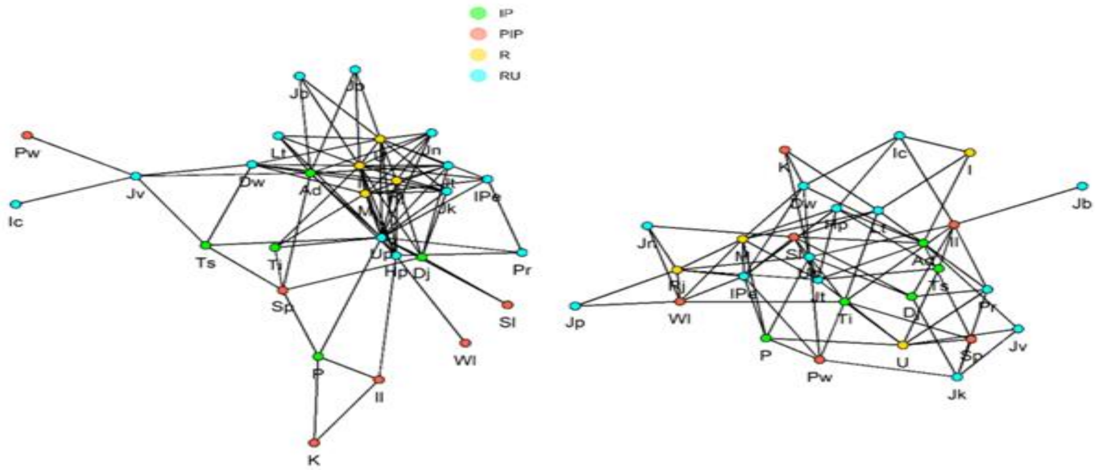

Figure 5. Simulation Model Suitability with the Data (Basic Network Edge)
(Source: Data Analysis, 2020)

Loop analysis result by simulating scenario on the six nodes having the highest relation and 1 combined node from the six nodes. The first scenario simulation on fisheries business (Up) is considered as unavailable, so the nodes negatively influenced are price (Pr) and commodity (K). It shows that the absence of fisheries business (Up) in Bima Bay will cause negative impact or the loss (Collapse) of the node of the price (Pr) and commodity (K) since price (Pr) and commodity (K) are highly influenced by the presence of fisheries business activity. Munawar *et al*., (2020), showed that fisheries business (Up) a significant relationship with other nodes in Bima Bay SES degree analysis. However, the absence of fisheries business gives positive impact or no effect by the absence of node Up like node Wl, Ts, Sp, Pw, P, Jv, Il, Ic, I, Hp, Dw, dan Ad. Meanwhile, node Jp, Jb, Lt, Dj, Rj, U, Jt, Ti, IPe, Jk, Jn, Sl, dan M are influenced by different proportion (Figure 6).

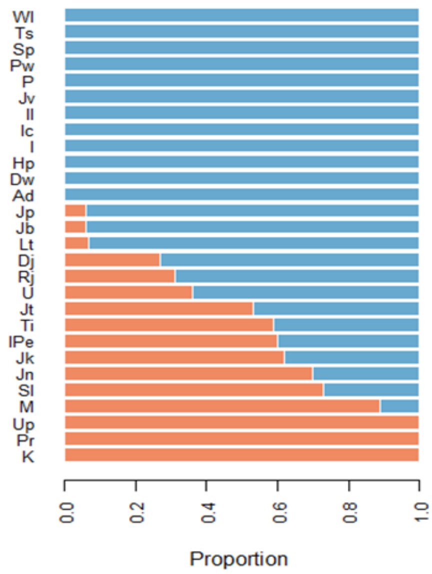

Figure 6. No Fisheries Business (Up) Node
(Source: Data Analysis, 2020)

In Figure 6 shown that brown shading, negatif response; blue shading, positive response. Proportion value of the impact node scenario with other nodes. The second scenario simulation, if regional regulation (Ad) node is assumed to be nothing, the one at risk of getting a negative impact is node K, Pr, Sp, and Wl. Meanwhile, node Up, Pw, P, Jv, Il, Ic, I and Hp are not influenced by the presence or the absence of node Ad and other influential nodes with different proportion. What interesting is that Bima Bay has been assigned as an area utilized for tourism. (Regional regulation RZWP3K West Nusa Tenggara). The presence of node Ad to sustain Bima Bay as tourism site is inversely proportional to people's longing who constantly make Bima Bay as a tourist attraction. It is shown in Figure 7 where the node of visiting number (Jv), tourism management (Pw), and tourism income (Ic) are not negatively influential due to the absence of node as yet it is positively influential.

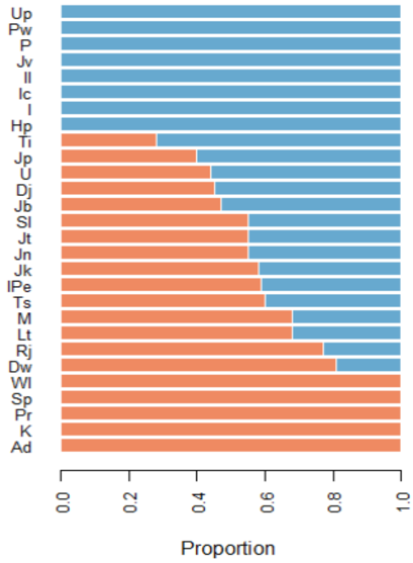

Figure 7. No Regional Regulation (Ad) Node
(Source: Data Analysis, 2020)

The third scenario simulation, if a node of fish (I) is assumed to be nothing, thus nodes that are at risk of negative impact or loss are K, Pr, and Wl. It indicates that node K, Pr and Wl are highly influenced by the presence or the absence of fish in Bima Bay. Meanwhile, the node giving positive impact by the absence of node I are Up, Ts, Ti, Sp, Pw, P, Jv, Il, Ic, Hp, Dw. What interesting is that positive relation between node I and node Up show that fisheries business (Up) will continuously exist, although fish (I) is unavailable. It clarifies that Up does not only depend on fishery product at Bima Bay to carry out the business activity, but also the supply of fish (I) from a place other than Bima Bay (Figure 8).

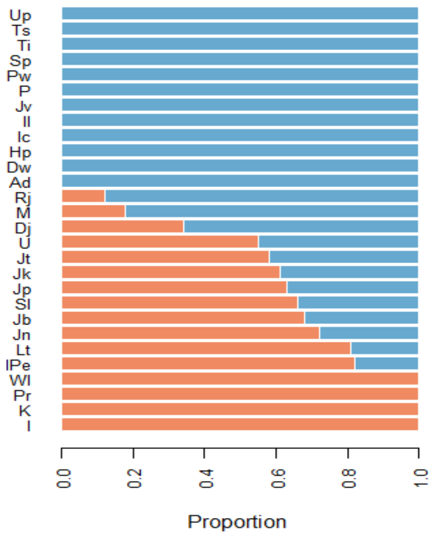

Figure 8. No Fish (I) Node
(Source: Data Analysis, 2020)

The fourth scenario simulation, if a node of fishery product (Hp) is unavailable, so the nodes negatively influenced are administration area (Wl) and collector or *palele* income (Il). It indicates that the absence of Hp will cause the loss of Il as there is no income from fishery product (Hp). Meanwhile, the node giving positive impact by the absence of node Hp are Up, Ts, Ti, Sp, Pw, Pr, P, K, Jv, Ic, I, Dw, and Ad. It shows that the presence or the absence of Hp gives a positive impact on the price (Pr) and Up, since it does not depend on fishery product from the waters of Bima Bay (Figure 9).

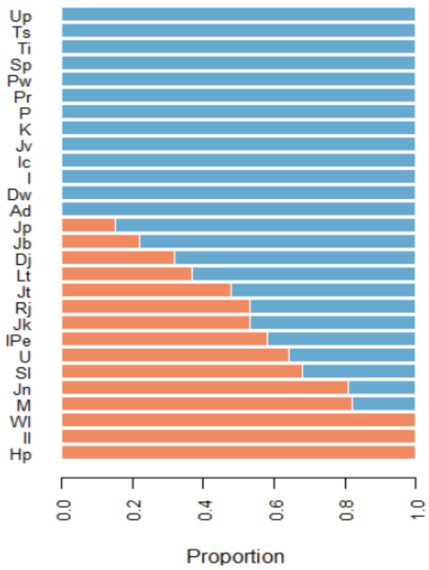

Figure 9. No Fishery Product (Hp) Node
(Source: Data Analysis, 2020)

The fifth scenario simulation is assumed if the node of a market (p) is unavailable, the nodes getting the negative impacts are price (Pr), commodity (K) and administration area (Wl) while the nodes getting positive impact are Up, Ts, Ti, Sp, Pw, Jv, Il, Ic, I, Hp, Dw, dan Ad. The interesting point of this simulation is that fish (I) and fishery product (Hp) give positive influence toward node P. It shows that the presence of P as transaction place for fishery and marine products is not the only choice in Bima Bay since the local society also market the fishery product to some collectors (*palele*) that are always available when the fishing fleet anchors. Besides, some of them sell the fishery product in the edge of Bima Bay (Figure 10).

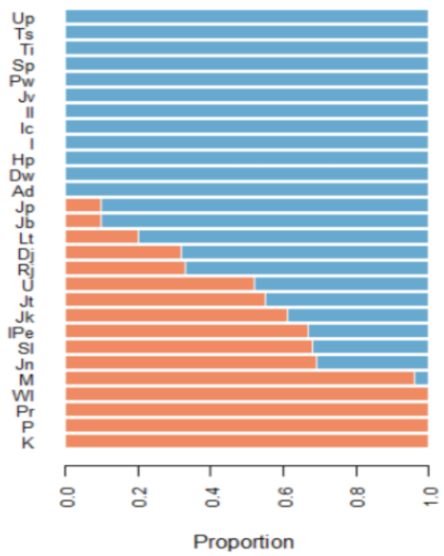

Figure 10. No Market (P) Node
(Source: Data Analysis, 2020)

The sixth scenario simulation, if a node of visiting number (Jv) is unavailable, thus the nodes getting negative impact are tourism (Ic), commodity (k), tourism manager (Pw), administration area (Wl). Whereas, the nodes positively influenced are Up, Ti, Sp, P, Il, I, Hp and Ad. What interesting from this analysis is that the absence of Jv will give negative influence or will cause the loss of node Pw since Pw highly contributes on the activities of Pw in managing tourism attraction (Figure 11).

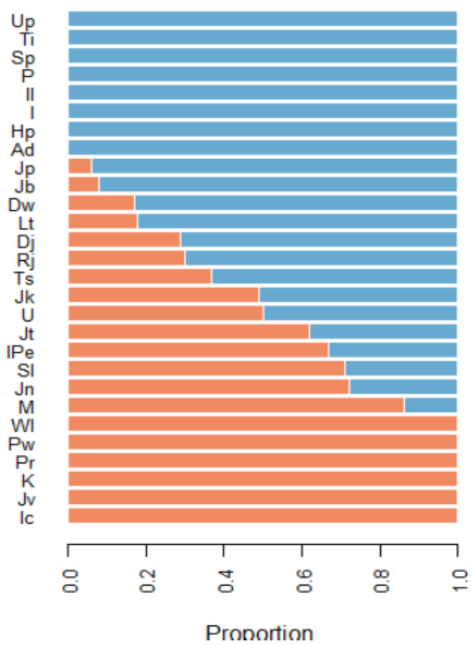

Figure 11. No Visiting Number (Jv) Node
(Source: Data Analysis, 2020)

The seventh scenario simulation merges the six simulations with the assumption that if Up, Ad, I, Hp, P and Jv are unavailable, the nodes getting negative impacts are Ts, Ti, Sp, Il, Ic, and Dw. Meanwhile, the nodes giving positive impact with the biggest proportion are Wl, Pr and K. The interesting thing is that price (Pr) node that is positively influenced shows that Pr will be negatively influenced at some points, for example, in the third scenario simulation. The absence of fish (I) node indicates that if fish (I) greatly overflow, so the price (Pr) is low and vice versa (Figure 12).

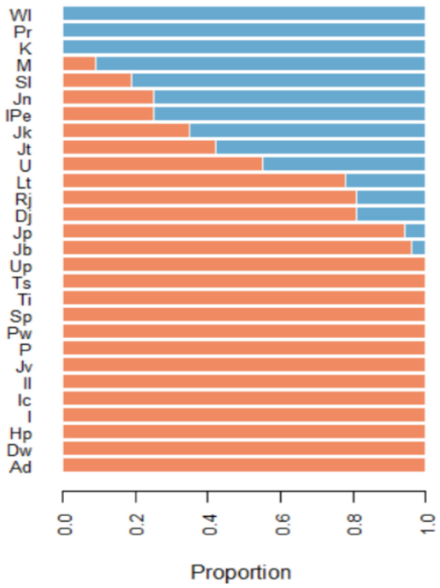

Figure 12. No node Up, Ad, I, Hp, P, and Jv
(Source: Data Analysis, 2020)

The discussion of scenario simulation at some nodes that gives positive, negative and neutral influence depicts that the presence of the nodes is needed to find out how much influence of node toward other nodes in system network using loop analysis explained in the graphic. It is in line with the explanation of Thomas (2012); Ortiz, Wolff (2002) saying that loop analysis explains the relationship between variables in a system in many disciplines of science and describing directly the role of feedback in the system. Kluger *et al*. (2015) stated that the loop model generated can be considered as an ideal generalization of a system, and its usage is mainly recommended for cases where there is unsuitable qualitative modeling. In this case, the loop model has been implemented to predict the changes in the natural system and respond to the error (Ortiz, 2008).

The effect of change of loop analysis of node network connection takes effect to the other nodes existence. Node positive effect in the network shows that the existence of a node in system is influential for the other node existence and vice versa. Further, Justus (2005) explains that loop analysis provides a method to determine on how the equilibrium variable model will respond toward extrinsic condition changes.

Based on the results of this study, interaction between human and resources in the coastal area Bima Bay is very important for understanding it is a social-ecological system. The complexity of social-ecological systems (SES) is rooted in the outcomes of node activities connected by network topology (Hu *et al*. 2017). Interaction between people, wildlife, and habitats is essential for the design of sustainable wildlife policies (Dressel *et al*., 2018). Understanding connectivity within these systems (i.e. among social and ecological actors) helps in establishing meaningful management strategies for the sustainable use of marine resources (Kluger *et a*l., 2019).

CONCLUSION AND SUGGESTION

Conclusion

The result of basic network model simulation using the goodness of fit test for model statistic obtains p-value 0.96 that means H_0 received since p-value 0.96 > 0.05 points that the basic network model is significantly indifferent from a simulation model. The result of loop analysis based on scenario simulation of the six nodes having the highest relation and 1 combined node from the six nodes. The first scenario simulation, when the fisheries business (Up) Node is unavailable, the nodes negatively influenced are price (Pr) and commodity (K). The second scenario simulation, if a node of regional regulation (Ad) is unavailable, so the nodes negatively influenced are node K, Pr, Sp, and Wl. The third scenario simulation, if a node of fish (I) is unavailable, the nodes negatively influenced are node K, Pr, and Wl. The fourth scenario simulation, If node fishery product (Hp), is unavailable, so the nodes negatively influenced are administration (WI), collector *(palele)* income (Il). The fifth scenario simulation, if the market (P) node is unavailable, the nodes negatively influenced are price (Pr), commodity (K) and administration area (WI). The sixth scenario simulation, if a node of visiting numbers (Jv) is unavailable, the nodes negatively influenced are tourism (Ic), commodity (K), price (Pr), tourism manager (Pw), the administration is (WI). The seventh scenario simulation merges the six simulations with the assumption that if node Up, Ad, I, Hp, P are Jv are unavailable, so the nodes negatively influenced are cottage (Ts), fish landing (Ti), construction of public facilities (Sp), collecting income (Il), tourism income (Ic), and tourist destination (Dw).

Suggestion

There need sustainable efforts to maintain Bima Bay ecosystem by observing the impact of network relation across the components in SES to find out the component with positive and negative impact in making management policies. Besides, there needs a revision on area utilization policies as stated in regional regulation of West Nusa Tenggara province number 12 the year 2019 on zoning plan for coastal areas and small islands (RZWP3K) with the use of tourism and ports, as well as the use of capture fisheries and cultivator.

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