THE DEVELOPMENT OF A GEOSPATIAL DECISION SUPPORT SYSTEM TOOL FOR MARINE SPATIAL PLANNING

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Abstract

The problems of marine spatial planning relate to the difficulties and time consuming in using any scenarios for sustainable development by using traditional spatial planning method, either manually or digitally. Geographical information system (GIS) software can implement a model of spatial planning by using any analytical function (Loucks and da Costa, 1991). However, the decision makers need a responsible, user friendly system to enable faster, accessible and accurate spatial information for better sustainable planning. The development of Spatial Data Infrastructure (SDI) that nationally links geospatial data among institutions may pave the way to the development of the tool that can utilize all of those geospatial data. In this case, Geospatial Decision Support Systems (GDSS) as a tool for online assessment of sustainable marine spatial planning have to be developed in advance. GDSS contains model, data and interfaces appropriate for the issues being address, which promote and encourage interaction and feedback which are dynamic and responsive to changes and lead to the better results (Loucks and da Costa, 1991). This study aims to assess the development of GDSS for marine planning purposes in the frame of National Spatial Data Infrastructure. The method of GDSS development was based on *System Development Life Cycle* / SDLC (Roebuck 2011), the analytical function of the model for GDSS was developed based on weighing factors. The result indicates that GDSS as part of the national SDI may increase the utilization of available datasets. However, its integration needs more policy management issues rather than technical ones.

Keywords: Geospatial Decision Support System (GDSS), NSDI, OLAP, marine spatial planning

1. INTRODUCTION

Nowadays, the need of available digital spatial data for all kinds of applications in the field of spatial activities have been rapidly growth. With the development of Information technology, the spatial data becomes more accessible for users by surfing the internet to collect datasets from a variety of sources with different types of application. This become the role of spatial data infrastructure (SDI) development in all over the world. In many countries, spatial data infrastructures (SDIs) are developed to facilitate the availability and access to spatial data for all levels of government, the commercial and non-profit sector, academia and citizens (Aalders and Moellering, 2001). SDIs assist to overcome the availability, access and interoperability of spatial datasets, and decrease the time and cost consuming. So, it is believed that a SDIs will provide any necessary spatial information to providers and users for planning and decision making purposes. This opportunity gives road to the development of Geospatial Decision Support System (GDSS) for any better spatial management purposes. For example, an infrastructure for Spatial Information in Europe - The INSPIRE that has been developed to support of good governance in promoting sustainable development, Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) (Vanderhaegen et al, 2005).

Nationally, Indonesia has developed the National Spatial Data Infrastructure (NSDI) ratified in Presidential Decree No 85/2007 and updating in Presidential Decree Number 27/ 2014. The geoportal has also been developed because of NSDI. However, the utilization of the NSDI to overcome national and global issues has not yet been developed. This provide opportunities to develop a such tools that will get benefit of NSDI and the geoportal, to provide online analysis system for any decision makers for better management of development program that use earth space as the objects.

Relating to the national issues of archipelagic state, such as Indonesia, that still has problems in marine and coastal issues, the marine spatial planning become crucial to overcome. Lots of conflict of interest has been occurred for years within the national coastal waters. The lack of connectivity between the upland and marine spatial planning is also one of the critical issues that create policy failure in marine management.

The problems of marine spatial planning relate to the difficulties and time consuming in using any scenarios for sustainable development by using traditional spatial planning method, either manually or digitally. In this case, the development of the Geospatial Decision Support Systems (GDSS) as tools for online assessment of sustainable marine spatial planning has to be developed in advance. GDSS contains model, data and interface appropriate for the issues being address, which promote and encourage interaction and feedback, dynamic and responsive to changes and lead to the better results (Loucks and da Costa, 1991). Therefore, this study aims to assess the development of GDSS for marine spatial planning purposes in the frame of National Spatial Data Infrastructure. Considering, the seasonal hazard of capture fisheries activities and marine culture is one of the solution for closed season in captured fisheries activities, seaweed culture has been considered as the most economic and technically acceptable by local fishermen. Indeed, this culture has been developed for years by local fishermen to support their way of living. Therefore, the marine spatial analysis based on seaweed culture will become the focus of the study.

2. METHOD

2.1. Development of GDSS

The development of GDSS for seaweed culture spatial planning was based on the System Development Life Cycle (SDLC). The development process starts with the identification of user requirement until the system evaluation and maintenance (ISRD, 2007). The development of SDLC based on Roebuck (2011) that consist of 5 phases, i.e.:

1. Requirement Analysis Phase

   The phase consists of collecting the software's needed for system development, such as the scope of the information's needed, functions, the performance capability and the interface design.

2. Design Phase

   The software design was focused on 4 (four) parts, there is data structure, software structure, detail procedure and the user interface characteristics

3. Implementation Phase

   Consist of software coding, there is the process of scrip programming to make the system work.

4. Integration Test Phase

This phase tested the programming code that was focused on the inner part of the software. The purpose of this step is to make sure that all the statements have been tested and the input has generated corresponding output. The test has two parts; there is an internal test aimed to explain that all of the statement has been tested and external test aimed to find errors and make sure that the output is in line with the expectations.

5. Utilization and maintenance

   The Process is done after the software has been used by the consumer. Improvement and revision will be done if there are any errors or malfunction.

The GDSS for seaweed culture spatial planning was developed as an online analytical process for assessing, analyzing and simulating the management scenarios of a theme of spatial planning. This tool also able to indicate the problems and its possible solution regarding the issues of environment/ ecologic and economic balance to achieve a sustainable development program. Therefore, the design phase of the detail procedures may consist of:

2.1.1. Development of the marine spatial planning for seaweed culture criteria

The Delphi method analysis was carried out to assess the variables of seaweed culture spatial planning. The first step of the Delphi method results in 13 variables for determining the area for seaweed culture, i.e. protected area, wave, pollution, substrate, depth, visibility, dissolved oxygen, salinity, pH, water nutrients, seeds availability, infrastructure, security, policy, investment coast, revenue and hydrologic aspects. The second Delphi method resulted in the weighing and scoring factors for oceanographic and management factors and the third Delphi method resulted in the socio-economic factors such as investment, revenue and the cost benefits parameters.

2.1.2. Development of the analytical model

In relation to above variables and criteria, the statistic analytical function has to be developed. Sutrisno (2014) developed the function as:

$$K_1 = \sum \{(bp_{1.1}.sp_{1.1}) + (bp_{1.2}.sp_{1.2}) + ...(bp_{1.n}.sp_{1.n})\}$$
$$K_2 = \sum \{(bp_{2.1}.sp_{2.1}) + (bp_{2.2}.sp_{2.2}) + ...(bp_{2.n}.sp_{2.n})\}$$

$$K_3 = \sum \{(bp_{3.1}.sp_{3.1}) + (bp_{3.2}.sp_{3.2}) + ...(bp_{3.n}.sp_{3.n})\}$$
$$K_4 = \sum \{(bp_{4.1}.sp_{4.1}) + (bp_{4.2}.sp_{4.2}) + ...(bp_{4.n}.sp_{4.n})\}$$

whereas:

$K_{1..n}$ = suitability classes *1 ..n (ha)*

$bp_{1..n}$ = weighing parameters *1 ..n*

$sp_{1..n}$ = scoring parameter *1 ..n*

the above functions results in the spatial suitability classes for seaweed culture, that can be classified into highly suitable, suitable, moderately suitable and not suitable. According to Sutrisno (2014), those classified variables then become an input for spatial potentiality analysis for sea weed culture:

$$P_1 = \frac{K_1 + K_2}{2} \qquad P_2 = \frac{K_2 + K_3}{2} \qquad N = \frac{K_3 + K_4}{2}$$

Whereas;

$P_1 .. P_n$ = Potential classes of *1.. n (ha)*

$K_1 .. K_n$ = Suitability classes in weighing and scoring. The range of scoring can be defined as:

$$vP_1 => P_1$$
$$vP_2 = P_2 ..., P_1$$
$$vP_3 = N ,..., P_2$$
$$vN =< N$$

Considering channel and marine management boundary (Act No 1/2014, Act no32/2014), the availability of the coastal waters then can be stated as:

$$Fs = vP - c - Z_i$$

Whereas:

$Fs =$ Available area for seaweed culture (ha)

$vP =$ seaweed culture area (ha)

$c =$ Channel (km)

$Z_i =$ boundary of zonation at I (km)

The site setting, should be done according to the equation of its availability classes:

$$Fs_i = vP_i - c_i - Z_i - O_i$$

Whereas:
$Fs =$ available area for seaweed culture class *i (ha)*
$vP_i =$ seaweed culture area at class *i (ha)*
$c_i =$ Channel for vP_i (km)
$Z_i =$ boundary of zonation at class *i (km)*
$O_i =$ other coastal waters utilization at the area of class *i (ha)*

To assess the physical potentiality of the coastal waters, the total management area should be acknowledged and can be defined as:

$$Fs_{Tot} = Fs_1 + Fs_2 + ..Fs_n$$

Meanwhile, for economic variables, the function that was carried out in the design can be explained as follow:

2.1.3. Bio-economic analysis developed based on absolute growth (Effendi, 2002)

$$\Delta W = W_n - W_0$$

Whereas:
$\Delta W =$ absolute growth of seaweed (gram)
$W_n =$ biomass weight at n (gram)
$W_0 =$ biomass weight at 0 (gram)
$n =$ time (days)

2.1.4. Daily growth rate (Penniman et al. 1986):

$$G(\%) = \left[\left(W_n / W_o \right)^{1/n} - 1 \right] x100\%$$

Whereas: $W_n = W_0(1+G)^n$, $G = \sqrt[n]{\frac{W_n}{W_0}} - 1$, $G = \left(\frac{W_n}{W_o}\right)^{1/n} - 1$, Then

$$\frac{dG}{dn} = \frac{1}{n}\left(\frac{W_n}{W_o}\right)^{\frac{1}{n}-1} = 0$$

2.1.5. Maximum economic revenue based on maximum biomass growth (Wade, 1985)

$$\pi = P_n W_n - C$$

Whereas:

$\pi =$ Revenue (IDR)

$P_n =$ price at n (IDR)

$W_n =$ biomass weight at *n(gram)*

$C =$ cost at n (IDR)

2.1.6. Financial analysis based on Net Present Value (NPV), the function according to Sutrisno (2012) is

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

Whereas:
t = time at 1,2, …
i = interest rate (discount rate)
$(1+i)^t$ = the discount factor

The criteria that can be used for this financial analysis

NPV > 0 = profitable
NPV = 0 = turnover
NPV < 0 = loss

2.2. Source of Data

The data that can be used for this online analytical process can be the data from the custodians of the national Geoportal or input from other sources.

For example, in the model, the data that was used is from the marine data from Geospatial information agency (BIG), Ministry of fisheries, Central Bureau of Statistic and field survey.

2.3. Interface Development

The user interface was developed based on human interface design principles (Wiwit, 2006). The principles of developing the interface using this method are:

a. The interface should reflect the mental model of the users, that combines the real-world experiences, software experiences and the general knowledge of the computer system which has been embedded in the users.

b. Feedback and communication. Should provide any feedback regarding the users' curiosity.

c. Consistency.

d. 'What you see is what you get' concept.

e. Aesthetic integrity. Information should be well organized and consistent with the best visual design principles.

f. Should consider the variety of dialog, structure, textual/number and graphics content, time and speed of display.

g. Compatibility of users, products, tasks, workflow.

h. Users friendly approach: familiarity, Simplicity, direct manipulation, control, flexibility and responsiveness.

2.4. Hardware and Software

Hardware and software that were used to develop or implemented the GDSS should at least has certain specification, i.e.:

A. Hardware need to support the stabilize of the running system at least may have: (1) windows server 2008 R2 for Operating system, (2) Intel Xeon 2 @ 2.5 GHz for Processor, (3) 4 GB Memory and 200 GB Hard disk.

B. Software: The Software that was needed to support this application has to be bundled in one application package MapServer for windows (MS4W) that consist of:

1. Apache web server: Responsible for serving the query of a user and give feedback value of the query. The result of a query will become a new window in the browser

2. Programming Scripting tools: the programming tools that were used in this application were the combine of PHP, JavaScript and html. PHP was an open sources software that used to developed the application, the script result from PHP was not being compile in this software but was directly interpreted by PHP interpreter and sent it to the html support by browsers. PHP that was used in this application may support the OOP (Object Oriented Programming).

3. MapServer: this software could translate the script Mapfiles (map) and translate the script into image in the web server. The software can:

    a. Display the spatial data in the format of Shapefile (ESRI), ArcSDE (ESRI), PostGIS and other vector formats by using library OGR;

    b. Display spatial data in raster format such as TIFF/GeoTIFF, EPPL7 and other raster formats by using library GDAL;

    c. Use quadtree in indexing the spatial data that is possible to accelerate the spatial operation;

    d. Customizable the output that can be arranged within a template;

    e. Select an pbyek based on value, points, area or other spatial types;

    f. Support rendering characters in the form of TrueType fonts;

    g. Support the tiled utilization of vector and raster data to speed the process;

    h. Describe automatic map elements, either scale, map index or legend;

    i. Describe the thematic map that was developed in a logic or regular expression;

j. Describe the label of each spatial object and do not overlap to each other;

k. Manage the configuration on the fly through the variables determined by the URL;

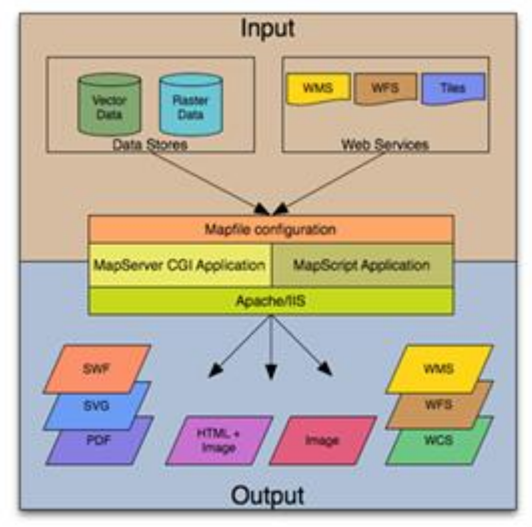
l. Handle many projection systems on the fly.

4. Saga is the open source software designed for Automated Geoscientific Analyses

2.5. System Development

The development of the system can be explained in Figure 1.

Figure 1. Illustration of GDSS System development



Source: Sutrisno et al, 2012

2.6. GDSS in SDIs Evaluation

Technical description and Dephi analysis was carried out to evaluate the prospect of GDSS for marine spatial planning and NSDI perform in a national geoportal.

3. RESULT AND DISCUSSION

3.1. The Utilization of GDSS

GDSS for seaweed culture spatial planning was developed as the online software for decision making processes. The result of online analytical process by using the spatial data from Geospatial information agency, Ministry of fisheries, the statistical data from Central Bureau of Statistic illustrate the ability of the software to fulfill such information for decision makers.

It can be seen form the Figure 2 that the users can used their sources of spatial and textual data for the best solution of spatial planning. Using the data of South Konawe regency – Southeast Celebes as the example, the status of coastal waters availability and its economic balance of the activity can be clearly identified for better marine spatial planning.

During the past years, the South Konawe regency become one of the highest production of seaweed, showing by Figure 3, that indicate the spatial zone of coastal waters into 3 classes, highly potential (P1), Moderately potential (P2) and limited potential (P3). However, the last assessment in this online analytical process by using the updating data illustrate the changing status of coastal water zone for seaweed culture planning, there is the seaweed culture activities that have been done for years within the area of interest is ecologically degrading. The status of coastal waters area has been classified as moderately potential (P2) and limited potential (P3) (Figure 2). The users or decision makers can further recognize from the GDSS system that the main problems caused the changing status were water pollution from upland nickel mining activities and the shallowing the water areas for P2, and upland nickel mining activities, the shallowing the water areas, visibility and lack of seed availability for P3. Therefore, according to the limiting factors, P2 can be stated as P_{pd} and P3 can be stated as P_{pdsv}, where *p* = pollution, *d* = depth, *s* = seed availability and *v* = visibility. These limiting factors must be managed by decision makers who still plan the area as seaweed culture zone, i.e. how to give such input to minimize the problems.

To obtain the availability area, the site planning should be assessed by using the channel and management boundary parameters. The assumption of this site planning that the coastal waters area is only developed for seaweed culture planning (Figure 4).

On the BAU condition (Figure 5), the economic assessment of the total seaweed culture assessment illustrate that The NVP> 0.002 for the seaweed culture, indicates some benefit still gain be obtained. An example of the seaweed culture sustainable management policy can be further assess using this GDSS system. For example, the decision makers can determine to reduce the impact of pollution, shallowing and visibility within the coastal water by coordinating the marine spatial planning with the upland spatial planning. The upland spatial planning should spatially determine the waste mining management area, reforestation of bare land and develop the green belt area along the rivers or cultivation zone to mitigate impact of water pollution and sediment transports. Indeed, the seeds of seaweed can be spatially planning along the river mouth that has been polluted and sedimentation free. Unfortunately, this sustainable management planning cannot be further assessed because it cannot be implemented yet. However, the benefit of GDSS for marine spatial planning has been fully recognized by this example.

Figure 2. Implementation of GDSS online analysis for Seaweed culture spatial planning

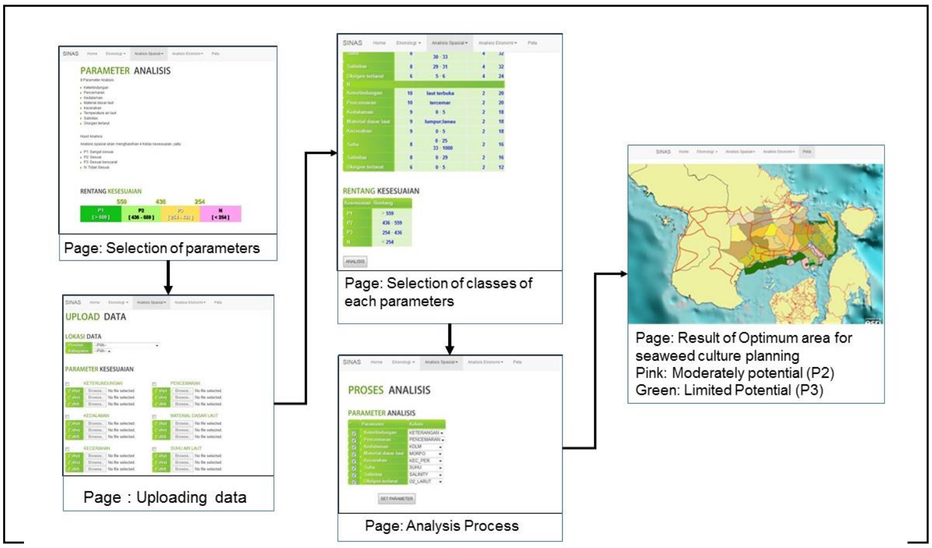
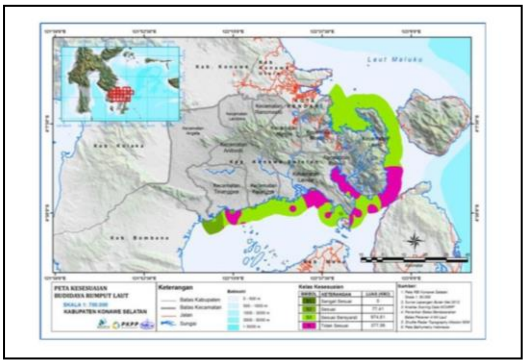
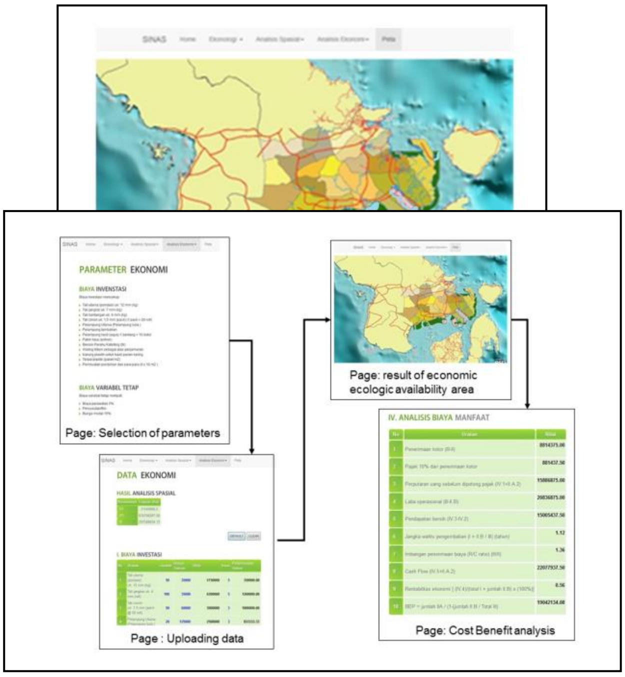


Figure 3. Sustainability analysis for previous assessment



Source: Rahadiati et al, 2012

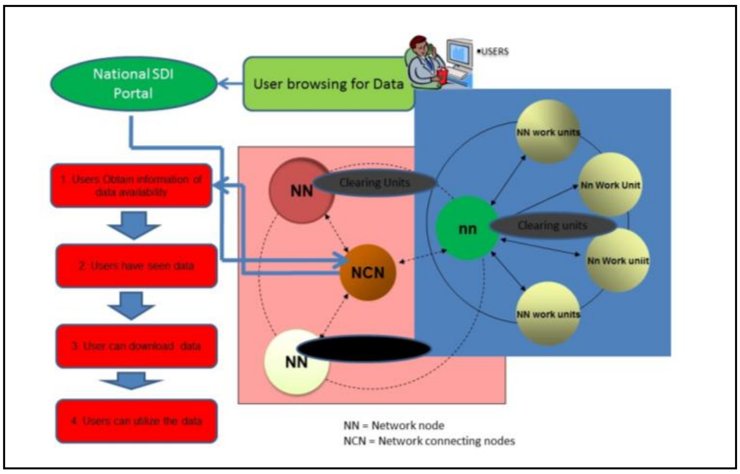
Figure 4. Available area for Seaweed culture spatial Planning



3.2. The GDSS and SDIs Assessment

SDIs is a device management system of spatial data that includes institutional, spatial data set, the standards and technical guidance, technology, legislation and policies, as well as the human resources needed to collect, process, store, distribute, and improve the utilization of spatial data (Bakosurtanal, 2007). This also support by Ruben (2012) that SDIs components are related to access, policies, standards and data, Basically the SDIs has been developed since the year of 2000 in Indonesia. Even an Indonesia geoportal has been established since then. The business process of the National SDIs can be seen in Figure 6.

Figure 6. National SDIs Business Process



The development of network nodes (NC) is the core of the SDIs, whereas the success is relying on the parameters of the clearing units, metadata, infrastructure network, web application/ network nodes portal, human resources, web services, the connection of network nodes and network connecting nodes (BIG, 2012). In central government, the nodes are governmental institutions and provincial government or other legal institutions, and the Network connected nodes (NCN) or the clearance house is Geospatial Information agency (BIG). Indeed, the provincial nodes can become the clearing units for regencies under the provincial authority.

Considering that the spatial data can be shared and downloaded by this National SDIs Portal, the GDSS software can be installed in the network connecting nodes units or in the National Geospatial Portal. The users can either used the spatial data from the custodians, i.e. BIG (basemaps or other thematic maps), thematic geospatial data from other institutions, their own institution or uploading their own data while applying the GDSS software for certain purposes such as Marine spatial planning. The data that can be used for the GDSS implementation can be seen in Table 1 based on BIG (2015).

An assessment of role of GDSS for Seaweed spatial planning indicate that this online software is strongly needed for the development of national SDIs, and indeed this software has been developed in the framework of national SDIs. However, there is seven factors that should be concerned in the development of the system, i.e. geospatial data enrichment, accessibility to data, standardized data, maintenance and integration. These factors are similar to the previous research of offline SDIs for forest fire that need to develop the infrastructure factors such as of data development, maintenance, integration, access to data, data management, coordination, working guidance, resource management and evaluation (Pratondo et al, 2007). However, the uncomplete regulations, security clearance and access to data still become the main problems that need more policy approach to overcome. Williamson et al (2003) states that The SDIs core components should consider more than technical and institutional issues such as access policies, access network, technical standard and SDI conceptual models. Meanwhile, Desses (2013) added data sharing policies are the main issues for the development of SDIs, and so did Sadahiro (2008) that added the data accuracy policies as part of the issues.

Table 1. Geospatial Data for Seaweed culture spatial planning

No	Data	Custodians
1	Basemap	BIG
2	Protection Zone	Primary RS data
3	Pollutions	Ministry of Environment and Forestry
4	Substrate	Center for research and development of Marine Geology, Ministry of energy and Mineral resources
5	Depth	BIG
6	Seed availability	South East Celebes Province
7	Infrastructure	The directorate general of Marine Transportation, Ministry of Transportation
8	Visibility	Primary RS Data
9	SST	Primary RS Data
10	Salinity	Center for research and of marine resources development, Ministry of Marine and fisheries resources,
11	DO	Center for research and development of marine resources, Ministry of Marine and fisheries resources,
12	Primary productivity	Primary RS Data
13	Security	Primary data
14	Channel	South East Celebes Province
15	Management Boundaries	BIG
16	Social data	Central Bureau of Statistic
17	Economic data	Central Bureau of Statistic and Primary data

4. CONCLUSION

GDSS with the online analytical process is the best software that can provide solutions for any spatial planning that use earth surface as the objects of development program. The implementation of this decision-making tool can be increased in its in line with the national SDIs framework. Some infrastructure factors should be developed in the development of GDSS in SDIs framework, i.e geospatial data enrichment, accessibility to data, standardized data, maintenance and integration. Further preparation and the its integration need more policy management issues rather than technical ones to have the best GDSS in SDIs framework.

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