MOLA Model for Optimization of Nickel Mining Management in North Morowali District

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Abstract. Geology of North Morowali Regency is dominated by ultrabasic rock compounds, most of which have weathered to form rich nickel. The Local Government has issued 52 letters of Nickel Mining Business Licence with a total area of 177,249.20 Ha. Issues for local government are: there are indications of overlapping of land Licences, areas for other limited uses, and many abandoned mine land. Local governments should have clear rules in the provision of Mining Business Licence in order not to cause spatial conflicts. Decisions must be supported by a system that can help local governments to minimize the occurrence of problems. The purpose of this research is to select mine land allocation by using MOLA (Multi Objective Land Allocation) Model. The method used is multicriteria analysis by weighting and scoring in Geographic Information System. The model results show scenario 2 with the proposed 80,000 ha mine area is the best choice, and recommended to the local government. The allocation of mining area is 69, 72%, so there is still 30, 28% for other used. In this scenario, mining area with Exploration Mining Business Licence status decreased 49.60%, while with Production Operation Mining Business Licence status decreased 24.41%.

1. Introduction

North Morowali Regency is an expansion of Morowali Regency, Central Sulawesi Province, officially endorsed on 12 April 2012. The Regency with the capital of Kolonedale has a land area of 10,004.28 km2 or 1,000,428 ha [1]. Geologically the area of North Morowali Regency is dominated by ultramafic rock compound, consisting of serpentinite metamorphic rock, peridotite igneous rocks, gabbro, and dunite partially covered by marine sediments ie coral limestones, clastic limestone, and claystone. Most of the ultrabasic rocks on the surface have been weathered to form laterite soils with a widespread and rich spreading of nickel minerals [11]. The process of forming the lateritic nickel precipitate begins with the process of weathering ultramafic rocks such as peridotite, serpentinite and dunite with mineral content of olivine, pyroxene, magnesium silicate and iron, making it very susceptible to weathering processes because these minerals are unstable [10].

The large potential of nickel causes many mining companies to apply for mining licences. As of July 31, 2013, the North Morowali Regency Government has issued 52 Mining Business License (MBL) for Nickel Minerals. A total of 52 MBLs, 28 MBLs with an area of 135,991 Ha are exploration status, while 24 MBLs of 41,258.20 Ha are Production Operations status [3]. Mining Business License Exploration status is a Licence given by local government to mining companies to conduct exploration (research). If considered a prospect, the government may issue a Production Operation status, which allows the company to mine and produce its mining products. The long time of Exploration status that has not been
changed into Production Operation status is due to the research but not the prospect or even the research has not been done at all.

The obligation to build a smelter contained in Law number 4/2009 on Minerals and Coal, among them regulating the export of unprofitable minerals and prohibits mining companies in Indonesia to export raw materials from January 2014 [7]. The government will give sanctions on halting contracts of work for mining companies in Indonesia that do not meet the obligation to build smelters by the end of 2014, according to the Ministry of Energy and Mineral Resources. Local governments must have clear rules in granting mining Licences so as not to cause spatial conflicts. Potential conflicts can arise against spatial patterns, forest areas, and existing land use. A system is needed that can help local governments to make decisions in minimizing the occurrence of spatial conflicts.

Geographic Information Systems have the capacity to integrate information from multiple sources into spatial contexts and are highly suited to support decision-making procedures. Geographic Information Systems can act as a tool to help decision makers evaluate alternatives, visualize options and explore specific alternatives. Ultimately, it is the decision maker, who determines the criteria, factors, constraints, individual weights and decision rules [9]. MOLA (Multi Objective Land Allocation) is a multi-criteria and multi object model for determining land allocation in a Geographic Information System [4]. This model is widely used for the determination of land allocation, such as nature reserves, tourist areas, but there is no utilization of this model for the selection of mine land allocation.

The objective of this research is to select the optimal allocation of mining land in the management of nickel mine in North Morowali Regency based on several scenarios using MOLA Model.

2. Materials and method
2.1. Research Location
The research location in North Morowali Regency of Central Sulawesi Province is shown by Figure 1. North Morowali Regency is bordered by: Tolo Bay in the east, Morowali district in the south, Poso district in the western, Tojo Una-una and Banggai district in the north.

![Figure 1. Location of North Morowali Regency](image-url)
2.2. Data Used
The material used in this study consists of several spatial data (maps), which consists of:

a. Map of Mining Permit until 2013, presented on the map scale 1: 250,000;

b. Map of the latest Forest Areas of Central Sulawesi Province in accordance with SK.635 / Menhut-II / 2013, presented on the map scale of 1: 250,000;

c. Land Coverage / Land Use Map scale1: 50.000, results of Landsat satellite image recording 2015.

d. Spatial Planning Map, which is spatial pattern North Morowali Regency 2014 of scale 1: 50.000.

2.3. MOLA Model
The method used is multicriteria analysis by weighting and scoring by using MOLA (Multi Objective Land Allocation) model in Geographic Information System. MOLA is a multi-criteria model and multi object to determine land allocation in a Geographic Information System [4]. The basic theory of MOLA is to solve multi-purpose land allocation problems for many cases [2].

2.4 Method of Analysis
The use of this model, the criteria used are to avoid possible conflicts that may occur in any object. The analysis in the MOLA model is basically done by weighting and clarifying the parameters used. Weighting is done to differentiate the influence of each parameter on the MOLA model that will be generated. Weighting is given in units of percent (%), high-impact parameters are given a high weight, and vice versa. Scoring is done to determine the rank of each class on each parameter. Scoring is made relatively from small to large. The class with the highest score means the most Licensed, and vice versa.

2.5 Weighting and Scoring
Weighting is a decision-making technique in a process that involves multiple factors simultaneously by weighting each of these factors. In this study, weighting is done subjectively with the determination based on certain consideration. The determination of the weight is subjectively based on the understanding of the process. Each factor has a different role indicated by the weight difference between these factors. Total weighting is 100%, and will be distributed to each parameter based on the factors that influence it. The greater the factors that affect the greater the weight will be given, and vice versa. The designated area in the Spatial Map is assumed to have the highest influence, so it is given 40% weight, then the second is the Forest Area Map with the weight of 35%, and the least the Land Use Map with 25% weight.

In the Spatial Map, the Mine Zone is given the highest score of 7, because it is in the space pattern intended for mining, it means that the area is most feasible to be maintained. In contrast, the residential area is considered to be the most vulnerable if evicted for mining, so it is given the lowest score that is 1. Forest Area, Other Use Areas (most likely, thus gave the highest weight 5. The Protected Area / Natural Protected Area are given the lowest weight that is 1. The existing land use, shrub is given the highest weight 5. Water body (lake, river) is the most unlikely area to be freed for mining area and given weight 1. Weighting of each parameter and scoring each class is presented in Table 1.

| Allocation Area (weight = 40%) | Score |
|-------------------------------|-------|
| Mine Area                     | 7     |
| Fishery Area                  | 6     |
| Plantation Area               | 5     |
| Dray land Farming Area        | 4     |
| Limited Production Forest Area| 3     |
| Permanent Production Forest Area| 2    |
7 Settlement Area 1
B Forest Area (weight = 35%) Score
1 Other Use Areas 5
2 Limited Production Forest 3
3 Production Forest 2
4 Protected Forest 1
5 Nature Reserve Area/Natural Protected Area 1
C Land Use (weight = 25%) Score
1 Shrubs 5
2 Agriculture 4
3 Plantation 3
4 Settlement 3
5 Forest 2
6 Water Body 1

2.6 Research Flow chart
Flow chart of research as presented in Figure 2. Spatial data used are Forest Area Map, Map of Mining Permit, Spatial Map, and Land Cover Map. All of the spatial data is overlaid to get the Analysis Area Map, then by weighting and scoring, processed using MOLA Model. Some scenarios are based on land needs assumptions, i.e. to get priority weight, in the end will be obtained the direction of map of land allocation in each scenario.

3. Results and Discussion
3.1 Scenario 1 (Mine Land Allocation 100,000 Ha)
The assumption in this scenario 1, the allocation of land for nickel mine area of 100,000 ha or about 87.15% of the area of North Morowali Regency (114,743.62 Ha). The assumption in scenario 1 is too
broad, since it leaves only 12.85% of land for other uses. Nevertheless, this scenario was created to give companies an opportunity already licensed by the local government to improve its management.

Based on the model results, it is known that nickel mine area with exploration status must be maintained at 67,445.70 Ha, with the company's name and its sub-Regency location as shown in Table 2. Compared to the previous status of 135,991 Ha, that is the reduction area of 68,545.30 Ha (50.40%). This reduction is quite significant, and is expected to address the issue of abandoned mine land, so that it can be converted for other uses.

Nickel mining area with Production Operation status to be maintained in this scenario is 32,678.96 Ha (Table 3). Compared with the status of the previous status of Production Operation that is 41,258.20 Ha, there is a reduction of 8,579.24 Ha (20.79%). This reduction is especially expected for mining sites that stop production because they can not afford to build their own smelters. The results of spatial model for scenario 1, both for Exploration status and Operation Production status are presented in Figure 3.

Table 2. Status of Exploration for Land Requirement 100,000 Ha.

| Num. | Mining Company               | Sub District | Area (Ha) |
|------|------------------------------|--------------|-----------|
| 1    | Anugrah Selaras Sejati       | Petasia      | 2,451.5   |
| 2    | Arnins Corporation           | Bungku Utara | 5,783.3   |
| 3    | Bangun Bumi Indah            | Mamosalato   | 2,794.3   |
| 4    | Bumi Indah Sultra            | Lembo        | 5,408.0   |
| 5    | Global Samudera Atlantik     | Petasia      | 85.8      |
| 6    | Graha Sumber Mining Indonesia| Petasia      | 45.0      |
| 7    | Lampion Alaskah Sekawan      | Soyo Jaya    | 74.9      |
| 8    | Latanindo Mining             | Petasia, Lembo| 5,171,4   |
| 9    | Mahkota Mega Lestari         | Soyo Jaya    | 688.8     |
| 10   | Pringgondani Berseri         | Mamosalato   | 14,158.9  |
| 11   | Pringgondani Berseri         | Mamosalato   | 234.6     |
| 12   | Samudera Megah Abadi         | Mamosalato   | 909.7     |
| 13   | Senamas Energindo Mining     | Bungku Utara | 14,417.4  |
| 14   | Sharon Sindo Sejahtera       | Petasia      | 86.7      |
| 15   | Sinosteel Indonesia Mining   | Petasia dan Lembo | 1,264.2 |
| 16   | Surya Borneo                 | Petasia      | 10,057.6  |
| 17   | Sumberjati Pratama Selatan   | Soyo Jaya    | 3,561.7   |
| 18   | Surya Borneo                 | Petasia      | 49.5      |
| 19   | Tiga Samudra Perkasa         | Mamosalato   | 202.34    |
|      | Total                        |              | 67,445.7  |

Table 3. Status of Operation Production for Land Requirement 100,000 Ha.

| Num. | Mining Company               | Sub District | Area (Ha) |
|------|------------------------------|--------------|-----------|
| 1    | Bangun Bumi Indah            | Petasia      | 149.7     |
| 2    | Bukit Makmur Istindo Nikeltama| Petasia Timur| 4,729.9   |
| 3    | Cahaya Murni Sejahtera       | Petasia      | 3,531.9   |
| 4    | Cipta Hutama Maranti         | Soyo Jaya    | 2,852.7   |
| 5    | Cocoman                      | Petasia      | 5,424.3   |
| 6    | Gema Ripah Pratama           | Soyo Jaya    | 148.4     |
3.2 Scenario 2 (Mine Land Allocation 80,000 Ha)

The assumption in scenario 2 is that the land allocation for nickel mine is 80,000 ha or about 69.72% from Morowali Regency (114,743.62 Ha). The assumption in scenario 2 is more realistic, i.e. the comparison between land for mine allocation (± 70%) and land for other uses (± 30%). The result of the model is known that the area of nickel mining area with the status of Exploration to be maintained is 48,414.42 Ha, with the names of the companies and the location of the Sub District as shown in Table
4. Compared with the status of the original mining permit which is 135,991 Ha, that is the reduction area of 87,576.58 Ha (64.40%). The nickel mine area with the status of Operating Production must be maintained for 31,186.99 Ha (Table 5). Compared to the status of Mining Permit originally covering 41,258.20 Ha, there was a reduction of 10,071.21 Ha (24.41%). The results of the spatial model for scenario 2, both for the Exploration status and the Production Operation status are presented in Figure 4.

Table 4. Status of Exploration for Land Requirement 80,000 Ha

| Num. | Mining Company                | Sub District | Area (Ha) |
|------|-------------------------------|--------------|-----------|
| 1    | Anugrah Selaras Sejati        | Petasia      | 19,0      |
| 2    | Arnins Corporation            | Bungku Utara | 5,097,3   |
| 3    | Bangun Bumi Indah             | Mamosalato   | 1,8       |
| 4    | Bumi Indah Sultra             | Lembo        | 85,9      |
| 5    | Global Samudera Atlantik      | Petasia      | 44,5      |
| 6    | Graha Sumber Mining Indonesia | Petasia      | 8,726,2   |
| 7    | Lampion Alaskah Sekawan      | Soyo Jaya    | 196,0     |
| 8    | Latanindo Mining              | Petasia, Lembo | 243,2   |
| 9    | Mahkota Mega Lestari          | Soyo Jaya    | 5,250,6   |
| 10   | Pringgondani Berseri         | Mamosalato   | 13,920,0  |
| 11   | Samudera Megah Abadi         | Mamosalato   | 688,3     |
| 12   | Senamas Energindo Mining      | Bungku Utara | 4,869,0   |
| 13   | Sharon Sindo Sejahtera        | Petasia      | 5,783,3   |
| 14   | Sinosteel Indonesia Mining    | Petasia dan Lembo | 713,0   |
| 15   | Sumberjati Pratama Selatan   | Soyo Jaya    | 884,2     |
| 16   | Surya Borneo                  | Petasia      | 1,6       |
| 17   | Tiga Samudra Perkasa         | Mamosalato   | 1,890,6   |
|      | Total                         |              | 48,414,4  |

Table 5. Status of Operation Production for Land Requirement 80,000 Ha.

| Num. | Mining Company                | Sub District | Area (Ha) |
|------|-------------------------------|--------------|-----------|
| 1    | Bangun Bumi Indah              | Petasia      | 149,82    |
| 2    | Bukit Makmur Istindo Nikeltama | Petasia Timur | 4,729,8   |
| 3    | Cahaya Murni Sejahtera         | Petasia      | 3,531,9   |
| 4    | Cipta Hutama Maranti           | Soyo Jaya    | 2,851,4   |
| 5    | Cocoman                        | Petasia      | 4,673,4   |
| 6    | Gema Ripah Pratama             | Soyo Jaya    | 148,4     |
| 7    | Genba Multi Mineral            | Petasia      | 220,2     |
| 8    | Ghanesa Wana Utama             | Mamosalato   | 215,5     |
| 9    | Halmahera International Resources | Petasia    | 310,9     |
| 10   | Hffmen International            | Petasia      | 338,4     |
| 11   | Integra Service Nusantara      | Soyo Jaya    | 154,5     |
3.3. Scenario 3 (Mine Land Allocation 60,000 Ha)

The MOLA model in scenario 3, the mine area that wants to be maintained is 60,000 Ha or 52.29% of the area of Morowali Regency (114,743.62 Ha). This scenario is designed to provide the widest possible opportunity for abandoned mine land to be converted into productive land. Many mining sites have been licensed since 2009 but are still abandoned.

The result of model in scenario 3 is obtained nickel mining area with status of Exploration Mining Permit is 37,645.51 Ha (Table 6). Compared with the status of the original Mining Permit (135,991 Ha), there was a reduction in the area of 98,345.49 Ha (72.32%). Many mining areas already have Licences with Mining Business status of Exploration but are still abandoned. The cause is suspected, the licence owner has never done any research at all because it does not have sufficient capital and or expertise, or has been done exploration but its potential is considered low.
Mining land with the status of Operating Production that must be maintained in scenario 3 is 21,621.46 Ha (Table 7). Compared with the status of Mining Operations previously 41,258.20 Ha, there is a reduction of 19,636.74 Ha (47.59%). Mining land with abandoned Production Operating status is generally after 2012, which is suspected as the company is unable to build smelters for mining companies that export, as required by the government. The spatial model for scenario 3, both for the Exploration status and the Production Operation status is presented in Figure 5.

Table 6. Status of Exploration for Land Requirement 60,000 Ha

| Num. | Mining Company            | Sub District | Area (Ha) |
|------|---------------------------|--------------|-----------|
| 1    | Arnins Corporation        | Bungku Utara | 5,688,4   |
| 2    | Bangun Bumi Indah         | Mamosalato   | 1,6       |
| 3    | Bumi Indah Sultra         | Lembo        | 3,447,3   |
| 4    | Global Samudera Atlantik  | Petasia      | 1,2       |
| 5    | Graha Sumber Mining Indonesia | Petasia  | 15,7      |
| 6    | Lampion Alaskah Sekawan  | Soyo Jaya    | 0,11      |
| 7    | Latanindo Mining          | Petasia, Lembo | 4,948,7  |
| 8    | Mahkota Mega Lestari      | Soyo Jaya    | 0,3       |
| 9    | Pringgondani Berseri      | Mamosalato   | 8,642,3   |
| 10   | Samudera Megah Abadi      | Mamosalato   | 826,2     |
| 11   | Senamas Energindo Mining  | Bungku Utara | 4,769,5   |
| 12   | Sharon Sindo Sejahtera    | Petasia      | 0,1       |
| 13   | Sinosteel Indonesia Mining | Petasia dan Lembo | 191,8 |
| 14   | Sumberjati Pratama Selatan | Soyo Jaya  | 1,837,3   |
| 15   | Surya Borneo              | Petasia      | 7,080,2   |
| 16   | Tiga Samudra Perkasa      | Mamosalato   | 194,8     |
|      | **Total**                |              | **37,645,5** |

Table 7. Status of Operation Production for Land Requirement 60,000 Ha

| Num. | Mining Company            | Sub District | Area (Ha) |
|------|---------------------------|--------------|-----------|
| 1    | Bangun Bumi Indah         | Petasia      | 149,9     |
| 2    | Bukit Makmur Istindo Nikeltama | Petasia Timur | 3,373,4   |
| 3    | Cahaya Murni Sejahtera 1  | Petasia      | 2,082,3   |
| 4    | Cipta Hutama Maranti      | Soyo Jaya    | 2,851,2   |
| 5    | Cocoman                   | Petasia      | 1,947,6   |
| 6    | Gema Riah Pratama         | Soyo Jaya    | 148,2     |
| 7    | Genba Multi Mineral       | Petasia      | 219,6     |
| 8    | Ghanesa Wana Utama        | Mamosalato   | 215,5     |
| 9    | Halmahera International Resources | Petasia   | 31,5      |
| 10   | Hffmen International      | Petasia      | 338,4     |
| 11   | Integra Service Nusantara | Soyo Jaya    | 154,6     |
| 12   | Integra Technology Nusantara | Petasia    | 520,4     |
| 13   | Itamarta Nusantara        | Petasia      | 3,666,9   |
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| Num. | Mining Company                | Sub District     | Area (Ha) |
|------|------------------------------|------------------|-----------|
| 14   | Karya Agung Permai           | Petasia          | 19,9      |
| 15   | Keinz Ventuta                | Petasia Timur    | 450,2     |
| 16   | Mulia Pacific Resources      | Petasia          | 243,9     |
| 17   | Persada Agung Inti Lestari   | Soyo Jaya        | 121,4     |
| 18   | Rezky Utama                  | Petasia          | 130,1     |
| 19   | Sarana Mineralindo Perkasa   | Lembo, Petasia Timur | 106,9 |
| 20   | Sumber Permata Selaras       | Petasia          | 55,8      |
| 21   | Sumber Permata Selaras       | Petasia Timur    | 3.895,0   |
| 22   | Sumber Swarna Pratama        | Petasia, Soyo Jaya | 72,7   |
| 23   | Tiga Utama                   | Mamosalato       | 659,3     |
| 24   | Trinusa Dharma Utama         | Petasia          | 167,4     |
|      | Total                        |                  | 21.621,5  |

Figure 5. Results of MOLA Model for scenario 3 (mine area of 60,000 ha)

3.4. Discussion
The scenario studied is 3 options, scenario 2 is the best choice, that is by maintaining 69,72% from North Morowali Regency area for mine land allocation, so there is still another 30,28% for other allocation of use.

In scenario 1 this is by maintaining the mining area with Exploration status of 67,445.70 Ha, or a reduction of 68,545.30 Ha (49.60%). The reduction of mining land will not have a significant impact on mining companies that have exploration. Exploration status that has not changed into Production Operation status due to 2 things. Firstly, the company holding Exploration does not conduct exploration activities at all because it does not have the financial capability and / or expertise, so the land becomes abandoned. Second, the company holding Exploration Business Mining Licence has conducted exploration activities, but it is suspected that the mine land is not prospective or not economically valuable.

For mining area under the status of Operating Production, the area maintained is 31.186.99 Ha, or there is a reduction of 10,071.21 Ha (24, 41%) The reduction of mining area with the status of Operation Production is still possible, since there are many companies which stopped the production operation.
because it does not have a smelter yet. In the Government Regulation of the Republic of Indonesia Number 1 (2014), the Contract Holder is required to refine the domestic mining products (Article 112C.1), and shall perform the processing and refining of domestic mining products (Article 112C.2) sales to a certain amount of abroad (Article 112C.3). The comparison of the MOLA model results for the 3 scenarios is presented in Table 8.

Table 8. Comparison of 3 MOLA model scenarios

| Area                                      | scenario 1 | scenario 2 | scenario 3 |
|-------------------------------------------|------------|------------|------------|
| Regency area (Ha)                         | 114.743,6  | 114.743,6  | 114.743,6  |
| Mine land allocation (Ha)                 | 100.000    | 80.000     | 60.000     |
| Mine land allocation (%)                  | 87,2       | 69,7       | 52,3       |
| Previous Exploration status (Ha)          | 135.991    | 135.991    | 135.991    |
| Exploration status (Ha)                   | 67,445,7   | 48,414     | 37,645,5   |
| Reduction (Ha)                            | 68,545,3   | 87,577     | 98,345,5   |
| Reduction (%)                             | 50,4       | 64         | 72,3       |
| Previous Production Operation status (Ha) | 41,258,2   | 41,258,2   | 41,258,2   |
| Production Operation status (Ha)          | 32,679,0   | 31,187,0   | 21,621,5   |
| Reduction (Ha)                            | 8,579,2    | 10,071,2   | 19,636,7   |
| Reduction (%)                             | 20,8       | 24,4       | 47,6       |
| Non-Mining land use (%)                   | ± 17       | ± 70       | ± 48       |
| Robustness                                | bad        | good       | bad        |

4. Conclusion

The MOLA model is good enough for mine land allocation, especially for mineral-rich areas. The MOLA model provides a solution, how much land should be allocated, where location, what kind of land, consideration of licensing status, and its relation to spatial planning. With this model can be determined how much area and where mining land will be allocated based on local government policy. Selection of mine land allocation is based on the rank and weight of each parameter used.

In this research, there are 3 scenarios, with proposed different mining land area, that is 100.000 Ha, 80.000 Ha, and 60.000 Ha. Scenario 2 with a proposed 80,000 ha mine is considered the best option, since it only allocates 69.72% of the total area of North Morowali Regency, while the rest (30.28%) can be utilized for other purposes. In this scenario 2, the mining area with Exploration status was reduced by 49.60%, while the status of Production Operation decreased by 24.41%.

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