Spatial Modelling of Deforestation Based on Social Driving Force in South Sulawesi and West Sulawesi from 1990 to 2016

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Abstract. Deforestation is a permanent change of forest cover area to non-forest cover area. Social factors contribute more to the occurrence of deforestation, so this study was directed to examine the social factors that drive deforestation. Research location selected based on the key vulnerability of deforestation profiles. This study only used moderately vulnerability and vulnerability profile. Data analysis in this research using PCA (Principal Component Analysis) Method. The results explained that the Spatial Deforestation Model in South Sulawesi and West Sulawesi have differences based on the vulnerability profile. The dominant deforestation profiles affected were population density, productive age and employment. Population density affects deforestation because the site is always experiencing an increase in population and is not balanced with the extent of its territory, especially on vulnerable profiles. Productive age is very influential and increasing. The employment is also one of the most influencing of deforestation. The field of education itself does not give a significant effect. The spatial model of deforestation based on social factors in South Sulawesi shows that in the same profile different influences were found. In West Sulawesi, social involvement tends to be the same for each profile. The influence of population, productive age and availability of regions has a significant influence on the incidence of deforestation.

Keyword: Deforestation, social economy, Principal Component Analisis (PCA)

1. Introduction

Indonesia is listed as one of the countries with a high deforestation rate [1]. The deforestation rate in 1990-1996 was around 1.91 million ha per year, and then increased significantly to 3.5 million ha/year in the period 1996–2000. In the period 2000–2003 the deforestation rate decreased to 1.1 million ha/year but then increased again to 1.2 million ha/year in the 2003–2006 period from Indonesia's forest area of 120.1 million ha based on yields [2]. The trend of Indonesia's deforestation decreased in the 1990-2000 period by 1.91 million ha per year to 0.65 million ha per year in the period 2000-2010 [3].

Deforestation occurs in almost all islands in Indonesia, including Sulawesi. The annual deforestation rate in Sulawesi is 2.7% of the total forest area in Sulawesi or in other words deforestation is 331,822 ha / year from the forest area of 12 million ha. These data make Sulawesi number 2 (two) the biggest deforestation after Kalimantan which has the largest annual deforestation
rate (7%) over the period 2000-2009 [2]. Areas that experienced significant deforestation were South Sulawesi and West Sulawesi [4].

Tropical environments with several factors can become a biodiversity habitat in regulating biogeochemical and hydrological cycles globally [5-9]. Deforestation events are influenced by various factors and are very complex. Deforestation groups two factors that cause deforestation in Indonesia, namely direct and indirect factors. The direct cause is logging activities with bad management, illegal logging, and forest fires. Indirect causes are socio-economic, policy and political issues [10].

Social factors and policies have a major influence on the distribution of deforestation. Population growth plays a major role in influencing the level of connectivity of forest landscapes [11]. Human activities in a number of conditions can also cause deforestation, in addition, increasing the level of community welfare can encourage an increase in the number of settlements.

Research on deforestation profiles is used as basic information to understand deforestation events in South Sulawesi and West Sulawesi. The profile of deforestation has been clearly described from 1990-2016. The data used is a spatial model of deforestation that is built on the trigger factors for deforestation. The spatial model of deforestation is a study that aims to identify and identify the driving force of deforestation in each profile of deforestation [12].

The drivers of deforestation are different profiles/regions. The driving force also affects the intensity of deforestation that is different in each region [13]. Some studies related to deforestation reveal that the main drivers of deforestation are agriculture, plantations and livestock [14].

Biophysical factors and levels of accessibility affect deforestation. In addition, deforestation is also influenced by population density factors. Opportunities for deforestation are higher in areas with high population densities. Opportunities for deforestation are higher with increasing population density [15,16]. The influence of developing regions also puts pressure on the existence of forests.

Research to recognize deforestation behavior in South Sulawesi and West Sulawesi is very important. This study was used to assess and predict deforestation events based on the drivers. For this reason, research on spatial deforestation models based on social factors in South Sulawesi and West Sulawesi is needed as an effort to overcome the problem of deforestation.

2. **Materials and Method**

2.1. **Research Location**

The location of the study was conducted in two provinces, namely the provinces of South Sulawesi and West Sulawesi. This study uses preliminary data from the Profile profile of deforestation in the two provinces [4]. The location of data research is seen in Figure 1.

![Figure 1. Research Location Map](image)

2.2. **Collecting Research Data**

The type of data used in this study is secondary data obtained from several planning documents, data taken from the Central Bureau Statistic in South Sulawesi and West Sulawesi. Other sources are taken from a collection of several journals, papers, related research and data sourced from relevant agencies.
Data obtained from this process are data on population, productive age, employment and education. This study uses 2 deforestation profile categories in South Sulawesi and West Sulawesi where the profile belongs to the category of "moderately vulnerable" and "vulnerable" [4].

2.3. The Processing and Analyzing Data

Sampling is done in areas that represent two deforestation profile categories (moderately vulnerable and vulnerable). Social variables collected in these two regions are population, productive age, employment and education. On each variable per region, scoring is carried out. This scoring aims to homogenize or facilitate the process of data collection by simplifying data (symbols). The scoring method produces standardized values. Standardization values range from 1 to 9 [17]. The standardization method follows the formula:

\[ \text{Score Std} = \frac{(\text{Score input} - \text{Score min})}{(\text{Score max} - \text{Score min})} + 1 \]  

Explanation:
- \( \text{Score Std} \): score of standardization
- \( \text{Score input} \): input score of i
- \( \text{Score min} \): minimum score
- \( \text{Score max} \): maximum score
- \( \text{Score stdmax} \): maximum new score
- \( \text{Score stdmin} \): minimum new score

Furthermore, standardized scoring results are processed using the PCA (Principal Component Analysis) method. This value is used to determine the weight of each variable. Determination of weight with PCA follows the equation:

\[ W_j = E_i . V_i / \sum E_i \]  

Explanation:
- \( W_j \): variable weight of j
- \( E_i \): Eigen value PC k of i
- \( V_{ij} \): Eigen vector PC of i variable of j

The weight of each variable in rescaling to total is formed for all variables. 1. The score and weight values formed for each variable are used to form multicriteria spatial models of deforestation based on mathematical functions. The spatial deforestation model is formulated as follows:

\[ Y : f (\text{KP, UP, PK, PDK}) \]  

\[ Y : \sum b_i x_i \]  

\[ \text{MDS} : W_1 . \text{KP} + W_2 . \text{UP} + W_3 . \text{PK} + W_4 . \text{PDK} \]

Explanation:
- \( W_n \): Weight of i
- \( \text{MDS} \): Spatial Deforestation Model
- \( \text{KP} \): Population Density
- \( \text{UP} \): Productive age
- \( \text{PK} \): Employment
- \( \text{PDK} \): Education

The spatial deforestation model of each profile will form different variations in the weight of each variable. This weight explains the magnitude of the effect of each variable on the occurrence of deforestation (driving force).

3. Result and Discussion

3.1. Area and Forest Area

South Sulawesi and West Sulawesi in 1990 has forest area 3,550,946.13 ha and the area 6,216,776.43 ha. The area and forest area of the research location can be seen in Table 1.
### Table 1. Area and Forest Area of the research location

| Number | District/City          | The Area (Ha) | Forest Area (Ha) |
|--------|------------------------|---------------|------------------|
| South Sulawesi Province |
| 1      | Selayar Islands        | 117,700,21    | 29,177,81        |
| 2      | Makassar               | 179,00,45     | 101,12           |
| 3      | North Luwu             | 759,100,82    | 460,875,90       |
| West Sulawesi Province |
| 4      | Mamuju                 | 801,400,44    | 45,317,21        |
| 5      | Polewali Mandar        | 202,200,38    | 34,930,75        |
| 6      | Mamasa                 | 297,200,12    | 143,967,75       |

Source: Ramadhan, 2017.

Table 1 above shows the area and forest area of several representative regions in each province. South Sulawesi is represented by the Selayar Islands, Makassar and North Luwu. West Sulawesi is represented by Mamuju, Polewali Mandar and Mamasa. Some of these districts/cities represent profiles of deforestation in vulnerable categories and are moderately vulnerable.

### 3.2. Driving Force

The causes of deforestation indirectly are called driving force [12]. Social issues are one of the drivers of deforestation. Human resources are the main factors that play a role in the process of converting forest land (deforestation) [10]. This is in line with the statement that the role of the population is a trigger factor for deforestation [18]. It should be known together that social understanding in social science refers to its object, namely society. In the Big Indonesian Dictionary, the word social means everything that is related to society [19].

This study uses 4 variables, namely population, productive age, employment and education. This was confirmed by several previous studies. The variable is a social factor. Social variables are a driving force in research on deforestation models [20]. Research reveals that what dominates deforestation is social factors [21]. Social factors more influence deforestation than biophysical factors in particular are population and productive age [12].

### 3.3. Population Factor

#### 3.3.1. Population Density

Population Density is the ratio between the total population and area. The population in South Sulawesi and West Sulawesi is always increasing, population data can be seen in table 3. Population density is a variable that is analyzed based on the area that shows the relationship between increasing population and land availability. Population density data can be seen in Table 2.

### Table 2. Population Profile Representative

| District/City   | 1990      | 2000      | 2010      | 2016      |
|-----------------|-----------|-----------|-----------|-----------|
| Polewali Mandar | 343,792   | 351,673   | 396,120   | 427,484   |
| Mamasa          | 64,584    | 65,178    | 140,080   | 151,830   |
| North Luwu      | 194,949   | 442,472   | 287,472   | 302,687   |
| Mamuju          | 179,530   | 289,647   | 336,973   | 372,258   |
| Makassar        | 944,372   | 1,100,019 | 1,338,663 | 1,449,242 |
| Selayar Islands | 98,489    | 103,596   | 122,055   | 131,605   |

Source: Center Bureau Statistic of South Sulawesi and West Sulawesi

The high population in South Sulawesi is Makassar City which reaches more than 1 million residents. This is because Makassar City is a capital city in South Sulawesi. The highest number of
residents in West Sulawesi is Polewali Mandar. Polewali Mandar is a meeting and immigration area between residents of South Sulawesi and West Sulawesi.

**Table 3. Population Density Profile Representative**

| Profile Representative | Population Density |
|-------------------------|--------------------|
|                         | 1990   | 2000   | 2010   | 2016   |
| Selayar Islands         | 0.86   | 0.88   | 1.03   | 1.28   |
| Makassar                | 52.76  | 61.45  | 74.78  | 80.95  |
| North Luwu              | 0.25   | 0.58   | 0.37   | 0.49   |
| Mamasa                  | 0.21   | 0.22   | 0.45   | 0.51   |
| Mamuju                  | 0.22   | 0.36   | 0.42   | 0.46   |
| Polewali Mandar         | 1.7    | 1.74   | 1.95   | 2.11   |

The two South Sulawesi regions that were made representative were Makassar and the Selayar Islands which had very high and low population densities.

3.3.2. **Productive Age.** Based on the Republic of Indonesia's Center Bureau Statistic standardization, the productive age categories are ages 15-64 years. The age grouping is based on residents who have been able to produce goods and services [22]. Since the years 1990-2016, the productive ages of South Sulawesi and West Sulawesi in several representative districts have continued to increase. Productive age data can be seen in Table 4.

**Table 4. Productive Age Profile Representative**

| District/City          | 1990      | 2000      | 2010      | 2016      |
|------------------------|-----------|-----------|-----------|-----------|
| Polewali Mandar        | 199.321   | 214.272   | 240.155   | 278.144   |
| Mamasa                 | 46.982    | 47.852    | 87.004    | 92.431    |
| North Luwu             | 35.322    | 58.870    | 135.553   | 189.138   |
| Mamuju                 | 160.550   | 221.274   | 219.318   | 176.892   |
| Makassar               | 501.775   | 611.007   | 723.310   | 940.129   |
| Selayar Islands        | 59.133    | 61.207    | 76.092    | 82.845    |

Sumber: Center Bureau Statistic of South Sulawesi and West Sulawesi

The representative profile in South Sulawesi always has an increase in productive age. The number of productive ages in North Luwu in the 1990s and 2000 periods was fairly small because in that period, North Luwu was still part of Luwu Regency (before the division of the area). While the representative profile in West Sulawesi, Mamaju District has experienced a decline in the number of productive ages at the end of 2016.

3.3.3 **Employment on representative profiles.** The number of employers in South Sulawesi and West Sulawesi is one of the social aspects that affect deforestation. The employment found in South Sulawesi and West Sulawesi has quite a variety. The type of employment is related to natural resources and regional potential. Data on the number of employers in several representative districts can be seen in Table 5.

**Table 5. The Employment on Representative Profile**

| Vocation          | 1990  | 2000  | 2010  | 2016  |
|-------------------|-------|-------|-------|-------|
| Representative Profile | 41.560 | 44.072 | 52.223 | 53.778 |
Vocation

| Location        | 1990   | 2000   | 2010   | 2016   |
|-----------------|--------|--------|--------|--------|
| Makassar        | 180.225| 209.039| 421.346| 661.971|
| North Luwu      | 36.333 | 40.873 | 67.299 | 76.004 |
| Polewali Mandar | 183.908| 175.193| 185.941| 193.339|
| Mamasa          | 132.977| 132.03 | 128.996| 103.196|
| Mamuju          | 157.768| 162.691| 171.62 | 182.926|

Source: Center of Bureau Statistic of South Sulawesi and West Sulawesi

The value of the number of employers in each representative profile is the result of summaries of various jobs, namely jobs in the fields of Agriculture, Forestry, Hunting and Fisheries, Pengelohan Industry, Traders (retail and restaurants), hospitality and community services.

3.3.4. Number of Students on Representative Profile. Education is one of the social aspects used as a variable, with the aim of analyzing its influence on deforestation events. The number of students in the representative profile can be seen in table 6, as follows:

| Representative Profile | Number of Students (year) |
|------------------------|---------------------------|
|                        | 1990 | 2000 | 2010 | 2016 |
| Selayar Islands        | 17.962 | 17.144 | 22.598 | 28.862 |
| Makassar               | 218.453 | 204.747 | 279.734 | 818.455 |
| North Luwu             | 19.28 | 21.684 | 40.078 | 35.708 |
| Polewali Mandar        | 68.155 | 48.472 | 75.115 | 74.863 |
| Mamasa                 | 56.568 | 19.255 | 48.493 | 51.566 |
| Mamuju                 | 34.643 | 10.308 | 79.44 | 56.181 |

Source: Center of Bureau Statistic of South Sulawesi and West Sulawesi

The data above is the result of summaries of elementary, middle and high school students. The average number of students is at the level of elementary school (SD), and junior high school (SMP). The number of high school students is lower. The number of students in several representative profile areas has increased.

3.4. Spatial Modelling of Deforestation

The spatial deforestation model is a technique for knowing and equipping knowledge of the problem of deforestation. The spatial deforestation model that is built takes into account social factors that cause deforestation events. Spatial models of deforestation in the provinces of South Sulawesi and West Sulawesi were carried out in each profile of deforestation. District/city areas that have the same profile will be represented by several districts/cities. The deputy is a district that is categorized as moderately vulnerable and vulnerable. The spatial model of deforestation is based on the calculation of eigenvalues. The eigenvalue of each location is different. The eigenvalue in this study can be seen in table 7 below.

| Representative Profile | The Eigenvalue |
|------------------------|----------------|
|                        | KP | UP | PK | PDK |
| Makassar               | 8.917 | 3.0955 | 1.893 | 0.0002 |
| Selayar Islands        | 2.883 | 6.984217 | 3.041 | 0.00041 |
| Polewali Mandar        | 1.131 | 5.6194 | 2.015 | 0.00004 |
| Mamasa                 | 0.576 | 4.719835 | 1.003 | 0.00001 |
| Mamuju                 | 1.6027 | 7.423996 | 3.045 | 0.0006 |
| North Luwu             | 0.2054 | 3.097123 | 1.7671 | 0.00084 |
Explanation:

KP : Population Density
Up : Productive Age
PK : Vocation
PDK : Education

After knowing the eigenvalue of the data analyzed using PCA, the weighting process is carried out. Determining the weight of each variable is seen based on eigenvalues. Weighting results can be seen in table 8 below.

Table 8. Weighting results based on PCA analysis

| Representative Profile         | Weight     |
|-------------------------------|------------|
|                              | KP         | Up         | PK         | PDK        |
| Makassar                      | 0.641248   | 0.222607   | 0.136131   | 0.00001    |
| Selayar Islands               | 0.223339   | 0.54105    | 0.235579   | 0.00004    |
| Polewali Mandar               | 0.129029   | 0.641086   | 0.22988    | 0.00004    |
| Mamasa                        | 0.091445   | 0.749318   | 0.159236   | 0.000006   |
| Mamuju                        | 0.132759   | 0.614961   | 0.25223    | 0.00004    |
| North Luwu                    | 0.040509   | 0.610817   | 0.348509   | 0.000166   |

The spatial model of deforestation can be seen from the weight values above. The weighting results of each representative are then compared to the total eigenvalues of each period.

3.5. Spatial Modelling of Deforestation on vulnerability profile on South Sulawesi

The profile of the vulnerability in South Sulawesi consists of 2 representatives. This selection is based on key deforestation vulnerability levels in each profile. Both of these vulnerability profiles have different proportions of forests, deforestation events, and deforestation rates. The profile of the representative of the vulnerability I is Selayar Islands Regency and the vulnerability representative II Profile is Makassar City. Based on the weighting technique with the PCA, the spatial deforestation model that was built on the profile of Represent I and the representative profile II was obtained:

MDS I = 0.223339 KP + 0.541050 UP + 0.235579 PK + 0.00004 PDK
MDS II = 0.641248 KP + 0.222607 UP + 0.136131 PK + 0.00001 PDK

Explanation:

MDS I : Spatial Modelling of Deforestation of vulnerability representative profile I
MDS II : Spatial Modelling of Deforestation of vulnerability representative profile II

The spatial deforestation model above explains that MDS I and MDS II have different characteristic models. MDS I reveal that the most influential is productive age. MDS I have a dominant population, productive age labor. MDS II is also influenced by employment variables. In this region, the dominant type of employment is the wood industry. Education becomes a less influential variable.

Unlike MDS I, MDS II is more influenced by population density. This is caused by high population density. This condition encourages deforestation. Population density causes a large demand for residential land. Productive age is also an influential variable. Productive age is an influential variable because this population category is a population that is able to employment with good production. Employment is the third variable that has an effect. MDS II in the field of employment, especially in infrastructure development will cause a reduction in the forest area. Educational variables are the same as MDS I which is not an overly influential variable.

The province of South Sulawesi, which is considered vulnerable, is in urban areas which are generally influenced by the drivers of development. It is different from the vulnerable category areas which are located outside the provincial capital, generally influenced by agriculture, forestry (illegal logging) and the wood industry. The two representative regions are different because the two regions have different forest areas.
3.6. **Spatial Modelling of Deforestation on moderately vulnerability profile in South Sulawesi**

The profile of deforestation in South Sulawesi which is categorized as moderately vulnerable is 13 districts. In the profile quite vulnerable, 1 representative profile was chosen, namely North Luwu Regency. Selection of North Luwu is based on the characteristics of the profile of deforestation and the availability of data at that location. Based on weighting techniques using PCA, the following spatial deforestation models are obtained:

\[
\text{MDS} = 0.040509 \times \text{KP} + 0.610817 \times \text{UP} + 0.348509 \times \text{PK} + 0.000016 \times \text{PDK}
\]

The deforestation model in moderately vulnerable profile is more influenced by productive age. Productive age always increases. The dominant age is 15-59 years old [23]. The second variable that is influential is employment. The dominating employment is agricultural (especially in oil palm plantations). Population density is the third variable that affects deforestation. This variable has no significant effect because the availability of land for settlements is still quite extensive. The population in each profile will always increase. Population density will have an influence on land use. Education has almost no effect on deforestation.

3.7. **Spatial Modelling of Deforestation on moderately vulnerability profile in West Sulawesi**

The profile of deforestation in moderately vulnerable categories in West Sulawesi is 3 regencies. The profile is moderately vulnerable to all districts as a representative profile. Vulnerability profiles not found in West Sulawesi. The representative profile is moderately vulnerable I, namely Polewali Mandar Regency, moderately vulnerable II, namely Mamasa Regency, and moderately vulnerable III, namely Mamuju Regency.

Based on the weighting technique with PCA, spatial modelling of deforestation was obtained in the moderately vulnerable representative profile I was:

- **MDS I**
  \[
  0.129029 \times \text{KP} + 0.641086 \times \text{UP} + 0.22988 \times \text{PK} + 0.00004 \times \text{PDK}
  \]

- **MDS II**
  \[
  0.884738 \times \text{JP} + 0.110560 \times \text{UP} + 0.04697 \times \text{PK} + 0.000003 \times \text{PDK}
  \]

- **MDS III**
  \[
  0.132759 \times \text{KP} + 0.614961 \times \text{UP} + 0.25223 \times \text{PK} + 0.00004 \times \text{PDK}
  \]

MDS I, MDS II and MDS III explain that the three variables (productive age, occupation and population density) have an influence or pressure on deforestation events. However, the most influential is the productive age. This is because the location is dominated by productive age residents, namely MDS I is dominated by ages 15-44 years, MDS II is predominantly aged 15-59 years and MDS III is 15-42 years. Productive age is very closely related to the expertise of its workforce [24]. The availability of productive age will further encourage deforestation. In addition, employment variables also influence deforestation. Employment becomes the second variable that influences after productive age.

The West Sulawesi Province generally has extensive forests. The area is a fairly new province. As a new province, this area requires a large enough area for development activities. West Sulawesi Province is a division area where the development process is centered on the agricultural sector and infrastructure development. Infrastructure development in developing and new areas must be based on good spatial planning and land use. Large forest areas will change rapidly if development does not refer to land use management and compliance with regional spatial planning.

4. **Conclusions**

The spatial model of deforestation based on social factors in South Sulawesi shows that in the same profile different influences are found. In West Sulawesi, social involvement tends to be the same for each profile. The influence of population, productive age and availability of regions has a significant influence on the incidence of deforestation.

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