SPATIAL DISTRIBUTION OF WOOD EXTRACTION RISK IN RUVU NORTH FOREST RESERVE TANZANIA
(Distribusi Spasial Kerawanan Penebangan Pohon di Ruju North Forest Reserve Tanzania)

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ABSTRACT

Deforestation and forest degradation have been occurring rapidly in Ruju North Forest Reserve (RNFR), Tanzania. The main cause of deforestation in this area is tree biomass (wood) extraction for charcoal and fuelwood. The objective of this study is to produce the wood extraction risk map of RNFR reflecting the spatial distribution of the risk. The wood extraction risk map of RNFR was generated by combining and weighting four input maps: biomass risk map, distance risk map, accessibility risk map and slope risk map. Respectively, 34% and 45% areas of RNFR have high and medium wood extraction risk. It means that wood extraction activities potentially will be continuous in the most parts of RNFR area.

ABSTRAK

Deforestasi dan kerusakan hutan telah berlangsung secara cepat di di Ruju North Forest Reserve (RNFR), Tanzania. Penyebab utama deforestasi di kawasan tersebut adalah pengambilan biomas pohon (penebangan) untuk pembuatan arang dan kayu bakar. Tujuan dan penelitian ini adalah untuk membuat peta kerawanan penebangan pohon di RNFR yang menggambarkan distribusi spasial dari tingkat kerawanan tersebut. Peta kerawanan penebangan pohon ini dibuat dengan mengkombinasikan empat peta input, yaitu peta kerawanan berdasarkan potensi pohon (biomas), peta kerawanan berdasarkan aksesibilitas, dan peta kerawanan berdasarkan kondisi topografi. Penggabungan keempat peta input tersebut disertai dengan pembrobohan. Hasil penelitian menunjukkan bahwa secara berurutan 34% dan 45% area di RNFR memiliki tingkat kerawanan penebangan pohon yang tinggi dan sedang. Hal ini berarti bahwa kegiatan penebangan pohon berpotensi untuk terus terjadi di masa-masa yang akan datang di sebagian besar area di RNFR.

Keywords: Wood extraction risk, wood extraction risk map, spatial modeling, Ruju North Forest Reserve.

Kata kunci: Tingkat kerawanan penebangan pohon, peta kerawanan penebangan pohon, spatial modeling, Ruju North Forest Reserve.

I. INTRODUCTION

1.1. Background

Deforestation is one of the primary causes of global environmental change (Geist and Lambin, 2005). The amount of world’s deforestation increased from 7.5 million hectares annually in 1979 to 13.2 million hectares in 1991 (Myers, 1994 gathered by Bawa and Dayanand, 1999). In the period of 1990–2000, global
deforestation rate increased to 14.6 million hectares per year (Sengupta and Maginnis, 2005). Deforestation continues at the high rate in the period of 2000-2005. South America suffered the largest net loss of forests between 2000 and 2005 (around 4.3 million hectares per year), followed by Africa, which lost 4.0 million hectares annually (FAO, 2005).

One of the countries in Africa suffering a high deforestation rate is Tanzania. Forests area of Tanzania was around 44 million hectares in 1993, covered half of Tanzania (Muzendo, 2007). In 2005, the forests area declined to 35.257 million hectares, covered 39.9% of Tanzania (FAO, 2005). Tanzania loss 4.123 million hectares of forests between 1990 and 2000 with the deforestation rate 1% per year (FAO, 2005). In the period 2000-2005, the deforestation rate increased to 1.1% per year, reducing forest area from 37.318 million hectares to 35.257 million hectares (forests loss 2.061 million hectares).

Most of forest loss in Tanzania (70%) can be attributed to woodfuel consumption (charcoal and firewood) (Makundi, 2001 gathered by Mwangambwa, 2007). The energy economy in Tanzania is largely focused on collecting, distributing, and consuming woodfuels (fuelwood and charcoal). As much as 90% of all primary energy consumed in Tanzania is biomass based (UNEP, 1997).

Ruvu North Forest Reserve (RNFR) is one of the forest area in Tanzania that has a high rate of deforestation based on the comparison between satellite images of 1995 and 2003, estimated 3796 hectares forest area of RNFR in 1995 had completely gone in 2003. Around 3016 hectares of woodland area had also gone between 1995 and 2003. RNFR reserve is surrounded by 9 villages: Buma, Kromo, Zinga, Karage, Mapinga, Vikwa Pangani, Msangani and Kongowe. Like the other Tanzanian people, people in those villages have a high dependency to wood biomass as their energy source. Fuelwood is their major fuel for cooking.

The villagers also produce charcoal for commercial purpose. The high rate of charcoal consumption in urban areas (especially in Dar es Salam) supports the high market demand of charcoal. The average consumption of charcoal per capita per year in Dar es Salam was 0.5 m³. This amount is equal to 0.4 ton of wood (Ishengoma and Ngaga, 2000 cited in FAO, 2000). The high market demand of charcoal in Dar es Salam has attracted some villagers around RNFR to produce charcoal as their primary or secondary livelihood. The need of fuelwood and charcoal, both for subsistence and commercial purposes, pushes the villagers to enter the forest reserve to cut trees. The evidence of tree felling and charcoal making is easily found in the entire forest reserve area, even in the central parts of the reserve.

Due to the facts mentioned above, it is important to assess wood extraction risk of RNFR, as well as to produce the risk map. This risk map will give information about spatial distribution of wood extraction potential in the forest reserve. By using this map, the forest managers can arrange the priorities in controlling and monitoring wood extraction activities. In some cases, like in RNFR, management priorities need to be determined because of the lack of human resource, time, funding and management tools.

1.2. Objectives

The objectives of this study are:
1. To assess wood extraction risk of RNFR.
2. To create a wood extraction risk map of RNFR reflecting the spatial distribution of the risk.

II. METHODS

2.1. Study Area

This research was conducted in Ruvu North Forest Reserve (Figure 1) from May to June 2007. Ruvu North Forest Reserve
2.2. Data

Some maps of RNFR were used in this study, namely biomass map, DEM, road map and village map.

2.3. Methods

In general, the purpose of risk assessment and risk mapping is to forecast the risk potential as well as to plan the preventive actions. In forestry field, risk assessment and risk mapping have widely performed in various types of risk, such as fire risk (Cherviaco et al., 1999; Stambaugh et al., 2007), weed risk (Groves et al., 2001) and disease risk (Research Agency of The Britain's Forestry Commission, 2007).

Wood extraction risk map of RNFR was created by considering four input maps, namely biomass risk map, accessibility risk map, distance risk map and slope risk map. The method of the wood extraction risk mapping is summarized in Figure 2.

III. RESULTS AND DISCUSSION

3.1. Biomass Risk Map

Biomass risk map was generated from biomass map by classifying it into four risk classes, namely very low risk, low risk, medium risk and high risk. The biomass data as well as the biomass map of RNFR was cited from Sumarga (2007). The higher a pixel contains the biomass, the more attractive the wood in this pixel to be extracted. Hence, this pixel was classified in the higher risk class. In order to quantify the risk classes, each class was given a score as described in Table 1. Based on this classification, the biomass risk map of RNFR is described in Figure 3.

3.2. Accessibility Risk Map

Accessibility risk map was generated from road map by calculating the straight distance and then classifying it into four
risk classes, namely very low risk, low risk, medium risk and high risk. The closer the distance of a pixel to the road, the easier this pixel to be reached. Hence, this pixel was classified in the higher risk class. The furthest point to the villages in RNFR is 9251 m. The classification of accessibility risk in RNFR is described in Table 2. Based on the classification, the accessibility risk map of RNFR is described in Figure 4.

3.3. Distance Risk Map

Distance risk map was generated from village map by calculating the euclidean distance and then classifying it into four risk classes, namely very low risk, low risk, medium risk and high risk. There are 9 villages surrounding RNFR, namely Buma, Kiromo, Zinga, Karege, Mapinga, Vikawe, Pangani, Msangani and Kongowe. The closer the distance of a pixel to the village, the easier this pixel to be reached. Hence, this pixel was classified in the higher risk class. The furthest point to the villages in RNFR is 9251 m. The classification of accessibility risk in RNFR is described in Table 3.

3.4. Slope Risk Map

Slope risk map was generated from DEM by calculating the slope in degrees and then classifying it into two classes, namely medium risk and high risk. The gentler the slope of a pixel, the easier this pixel to be passed through. Hence, this pixel was classified in the higher risk class. The steepest slope in RNFR is 5.35°. The classification of slope risk in RNFR is described in Table 4. Based on the classification, the slope risk map of RNFR is described in Figure 6.

Figure 2. Flow chart of wood extraction risk mapping
Table 1. Biomass risk classification

<table>
<thead>
<tr>
<th>Land Cover Type</th>
<th>Mean Biomass (ton/ha)</th>
<th>Risk Classes</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrubland</td>
<td>2.416</td>
<td>Very low risk</td>
<td>1</td>
</tr>
<tr>
<td>Thicket</td>
<td>5.436</td>
<td>Low risk</td>
<td>2</td>
</tr>
<tr>
<td>Grassland</td>
<td>31.721</td>
<td>Medium risk</td>
<td>3</td>
</tr>
<tr>
<td>Woodland</td>
<td>59.694</td>
<td>High risk</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2. Accessibility risk

<table>
<thead>
<tr>
<th>Distance to road (m)</th>
<th>Risk Classes</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 1500</td>
<td>Very low risk</td>
<td>1</td>
</tr>
<tr>
<td>1001 – 1500</td>
<td>Low risk</td>
<td>2</td>
</tr>
<tr>
<td>500 – 1000</td>
<td>Medium risk</td>
<td>3</td>
</tr>
<tr>
<td>&lt; 500</td>
<td>High risk</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3. Distance risk classification

<table>
<thead>
<tr>
<th>Distance to villages (m)</th>
<th>Risk Classes</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 8000</td>
<td>Very low risk</td>
<td>1</td>
</tr>
<tr>
<td>6001 – 8000</td>
<td>Low risk</td>
<td>2</td>
</tr>
<tr>
<td>4000 – 6000</td>
<td>Medium risk</td>
<td>3</td>
</tr>
<tr>
<td>&lt; 4000</td>
<td>High risk</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 4. Slope risk classification

<table>
<thead>
<tr>
<th>Slopes (°)</th>
<th>Risk Classes</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 2.5</td>
<td>Medium risk</td>
<td>3</td>
</tr>
<tr>
<td>≤ 2.5</td>
<td>High risk</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5. Weights of input maps

<table>
<thead>
<tr>
<th>Input maps</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass risk map</td>
<td>4</td>
</tr>
<tr>
<td>Accessibility risk map</td>
<td>3</td>
</tr>
<tr>
<td>Distance risk map</td>
<td>3</td>
</tr>
<tr>
<td>Slope risk map</td>
<td>1</td>
</tr>
</tbody>
</table>

By using the weight, the pixel values of wood extraction risk map were calculated by the following formula:

Wood extraction risk = (4 * value of biomass risk) + (3 * value of accessibility risk) + (3 * value of distance risk) + (1 * value of slope risk)

Based on the formula, the minimum value of wood extraction risk map was 13 \((4 * 1) + (3 * 1) + (3 * 1) + (1 * 3))\) and the maximum value was 44 \((4 * 4) + (3 * 4) + (3 * 4) + (1 * 4))\). Finally, this map was reclassified into four risk classes by using equal interval. The classification of wood extraction risk map is described in Table 6.

Table 6. Classification of wood extraction risk map

<table>
<thead>
<tr>
<th>Pixel Values</th>
<th>Risk Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 – 20</td>
<td>Very low risk</td>
</tr>
<tr>
<td>21 – 28</td>
<td>Low risk</td>
</tr>
<tr>
<td>29 – 36</td>
<td>Medium risk</td>
</tr>
<tr>
<td>37 – 44</td>
<td>High risk</td>
</tr>
</tbody>
</table>

3.5. Wood Extraction Risk Map

Wood extraction risk map of RNFR was generated by combining all of input maps (biomass risk map, accessibility risk map, distance risk map and slope risk map) using raster calculator. Before being added, all of input maps were weighted by considering their importance to the final map. In such a modelling, the reason behind assigning weight to the input maps is to give extra significance to certain input maps (Hussin, 2007). An input map will be given a higher weight if it relatively has more influence to the final map than the other input maps. The weights of input maps used are listed in Table 5.

Figure 8 shows that most of area in RNFR (79 %) have the high and medium wood extraction risk. Field observations revealed wood extraction evidence in many parts of RNFR, even in the central parts of the reserve. Some wood extraction evidence (especially for charcoal making) in RNFR is presented in Figure 9.
Figure 3. The biomass risk map of RNFR

Figure 4. The accessibility risk

Figure 5. The distance risk map

Figure 6. The slope risk map

Figure 7. The wood extraction risk

Figure 8. Percentage of area of wood extraction risk classes in RNFR
Wood extraction in RNFR is mainly done for charcoal making and fuelwood consumption. Charcoal is the blackish residue consisting of 85% 95% carbon obtained by removing water and other volatile constituents from wood (Wikipedia, 2007). Hence, tree species with high wood density (carbon content) are more preferred for charcoal. Most of the remaining tree species presently found in the reserve are less preferred for charcoal. Those species have low wood density so that they result in low efficiency for charcoal making. In spite of the fact that most of the remaining trees are less preferred for charcoal, some trees with high DBH are potentially liable to cut, at least for fuelwood consumption. That is because no preferred trees are left. Charcoal making and fuelwood consumption have become a daily activity for some people living around the reserve.

A wood extraction risk map will be a good tool for preventing wood extraction activities in RNFR. RNFR managers need to give more attention to areas which have high and medium wood extraction risk. Those areas need to be given high priority in applying management programs.

IV. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusions

Respectively, 34% and 45% areas of RNFR have high and medium wood extraction risk. It means that wood extraction activities potentially will be continuous in the most part of RNFR area.

4.2. Recommendations

Patrol and monitoring need to be performed intensively in the area with high wood extraction risk. It is also important to built check points to prevent and control wood extraction activities. Those programs need to be combined with the other programs, such as agroforestry with useful tree species for charcoal, reforestation, community empowerment, developing alternatives for energy consumption and law enforcement.

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