Spatial Harmonization Model Between Production And Conservation in a Forest Landscape
(Case Study in Tesso Nilo Forest Landscape in Riau Province, Sumatra, Indonesia)

Sri Mariati
PhD Student, Postgraduate Program on Environmental Science, University of Indonesia, Indonesia

Haryoto Kusnoputranoto
Department of Environmental Health, Faculty of Public Health and Postgraduate Program on Environmental Science, University of Indonesia, Indonesia

Jatna Supriatna
Department of Biology, and Research Center for Climate Change, University of Indonesia, Indonesia

Raldi Hendro Koestoer
Ministry of Economic Affairs, Republic of Indonesia

Abstract

A spatial Planning between production and conservation is very important in a forest area consisting of the functions of production, limited production and conservation as well as the surrounding community. Illegal logging and forest land use change to illegal residential and palm plantations resulted in the loss of wildlife habitat, and human conflict with wildlife. The purpose of this study is to construct a model that has the level of sustainability of protected areas to production in the future and has resistance or resilience to climate change. SMCA (Spatial Multi Criteria Analysis) becomes an alternative method in the spatial analysis. Combined GIS software applications already include MCA (Multi Criteria Analysis) therein including ArcGIS 10 software which has a spatial analysis tool with an overlay weighting system (overlay Weighted). On the development of spatial models, SMCA becomes important in any simulation scenarios that has been set up so that a different choice of different models can be analyzed for decision making. Tesso Nilo forest area becomes forest research model because it has 3 different functions at once and is currently experiencing a very high deforestation in the world. We use seven criteria: the aspect of distance from the river, distribution of wildlife such as elephants and sumatran tigers, the park boundary, industrial forest concessions, oil palm land suitability, slope and distance from the road. The result of simulation A shows the overall distribution of wildlife that has the highest value and distribution wildlife in industrial forest and limited production forest becomes dominant. then the results of the simulation B, conditions such as business as usual with this model will continue to happen until the deforestation of natural forests. The results of C simulation show solution to the problems existing in Tesso Nilo Forest. C simulation results can be used as an alternative for decision makers.

Key words: model, spatial planning, conservation, production, spatial multi criteria analysis.

Introduction

Sumatra, as one of the islands for Indonesia, is located in the West part. It was densely forested as recently as 1950, but then clearance began in the lowland areas, where topography and soil fertility were most favorable to human settlement and agriculture. Clearance for plantation crops was carried out in the colonial era and then continued to transmigration programs in the 1970s-80s. Thus the activity encroached largely in lowlands or on gently sloping foothills. Commercial logging concentrated first in lowland forests, which were accessible, commercially valuable, and had the greatest potential for large-scale development. Unfortunately, lowland forests are also the most biologically diverse, harboring many of the most prized tree and animal species in Sumatra (Supriatna et al., 2002).
Since early 1970s, Sumatra Island has lost 6.6 mil ha of forest or 557,000ha per year due largely to legal and illegal logging activities; conversion of natural forests to industrial plantations, and forest encroachment by communities. Of this total, 2.6 million ha were natural tropical rain forest (Margono, et al., 2012). Riau Province suffered the largest area loss around 30% (approximately 5 million ha) Nanggroe Aceh Province suffered the second largest loss of 21.7% (approximately 3.6 million ha). Riau province has not only approximately 8.6 million ha of forest remaining (Pemerintah Provinsi Riau, 2010) but also the highest rate of loss around 42% between 1990 and 2010 (Margono et al., 2012). Within Riau province, Tesso Nilo Forest block is the largest block of forest remaining (377,387 ha) consisting mainly of lowland tropical rain forest, heat forest and peat swamp forest (Mariati, 2004).

Tesso Nilo forest harbor was very high biodiversity. Gillison (2001) studied the plants in 200 m² samples and found 218 species. This study indicates that the forest is one of the richest diversities of plants in the world. The lowland forest is an important habitat for endangered species such as the Sumatran tiger (Panthera tigris sumatrae) and Sumatran elephant (Elephas maximus sumatranus). However, as large areas of this habitat have been converted into palm oil, pulp-paper wood plantations and settlements; as a consequence, conflicts between humans and biodiversity protection have increased (Margono et al., 2012).

In Tesso Nilo, serious conflicts between production and protection of biodiversity, ecosystem functions and cultural values began after the construction of two road corridors, namely: Baserah and Ukui between 2000 and 2012. WWF and many other NGOs have tried to quantify the forest and biodiversity loss from the criss-crossed roads that resulted from these two major road corridors. The study attempts to explore the rate of deforestation in Tesso Nilo forest by mapping the extent of deforestation, and by calculating the rate of deforestation post road construction. Moreover, the discussion would refer to policy implications towards mitigation improvement of forest loss. Shortly the study focuses on the spatial planning approaches on optimal land-usage in Tesso Nilo forest area.

Methods
In this context, sound spatial approach between production and conservation would be worth-while to be implemented. Spatial planning between production and conservation covering forest area consists of the functions of production, limited production and conservation functions as well as the surrounding community. Considering spatial conflicts between wildlife and humans, and also conflicts between economic interests and conservation, one would need to conduct a study to find the best spatial arrangement in order to halt ro reduce deforestation and wildlife conflicts with humans in Tesso Nilo Forest Block. In addition, it is necessary to balance between production activities by companies, while, the activities sound protecting biodiversity, ecosystem function, and the priority of social culture in The forest area.

Spatial organization and systems have been used in devoping countries for discovering issues in bi-regional conflicts (See http://faculty.nelson.wisc.edu/silbernagel/docs/Silb_inTressbook05.pdf). Thus Spatial approaches might give solution to ensure environmental sustainability and support the coordination of the territorial impact of sectoral policies. See MP3EI in www.ekon.go.id (2013). It is believed that spatial planning is an effective and important tool in sustainable development to synchronize social, environmental, and economic aspects. Integrated spatial planning system could reduce the impacts of environmental destruction caused by purely economic purposes.

The development of spatial models is of importance in the simulation of each scenario that has been set up, so that a different choice of models could be analyzed for decision making. Tesso Nilo forest area becomes a research model because this forest has 3 different functions at once and is currently experiencing very high deforestation in the world (see Figure 1).
For a balanced spatial arrangement model between production and conservation systems, the study employs Spatial Multi Criteria Analysis (SMCA) in ArcGIS 10 software. SMCA is one of the methods in the decision making process for the planning area by using system simulation/scenario with multiple aspects. Decision Theory is a logical assessment done when one is faced with a number of decision options. For natural resource managers, decision-making for the effective allocation of natural resources is often followed by uncertainty.

Hence the decision makers would have a high risk in evaluating a dynamic environment with a complex impact of human interventions. Along with the rapid development in the science of decision-making, GIS began to be used as a tool in the process of collaborative decision-making, particularly in the context of decision making for resource allocation (Malczewski, 1999).

The steps in the SMCA (Malczewski, 1999) are as follows:
1. Setting goals.
2. Identification and grouping criteria (factors/constraints) (in accordance with the policies/regulations).
3. Scoring for each aspect.
4. Standardization of scores for aspects.
5. Weighting for aspects.
6. Suitability maps (Stakeholder preferences/Alternative)

Based on the data set that has been determined, the grouping criteria are, among others:
1) Representation of Biodiversity Criteria:
a. Protected key wildlife habitats (Sumatran Tiger (*panthera tigris sumatrae*) and Sumatran Elephant (*elephas maximus sumatranus*).
b. Must include the distribution of wildlife (Sumatran Tiger (*panthera tigris sumatrae*) and Sumatran Elephant (*elephas maximus sumatr anus*).

Determination of representative habitat for key wildlife (Sumatran Tiger (*panthera tigris sumatrae*) and Sumatran Elephant (*elephas maximus sumatr anus*) is determined by the following steps:

a. Knowing the number of Sumatran elephants and tigers in Tesso Nilo forest (data source: WWF Indonesia, 2012)

b. Mapping the results of a ground check conducted by WWF Indonesia about the existence of (Sumatran Tiger (*panthera tigris sumatrae*) and Sumatran Elephant (*elephas maximus sumatr anus*)).

2) Criteria of Spatial Characteristics:

a. Slope of more than 30% being constrained to be protected.

b. Maximum hydrologic connectivity.

   Determination of hydrologic connectivity based on Law Number 41 Year 1999 on Forestry article 50, paragraph 3 (c) that the stream buffer areas to be protected are:

   1. 100 meters from major rivers.
   2. 50 meters from the creek.

b. Access roads (involving 3 scenarios)
   
   Three scenarios are based on interviews and questionnaires with indigenous leaders and head of Tesso Nilo National Park Authority. The three scenarios are as follows:
   1. Scenario 1: all existing roads in the area Tesso Nilo forest are used (open).
   2. Scenario 2: all existing roads is used except the road in the Tesso Nilo National Park.
   3. Scenario 3: the entire road is used except Ukui corridor that borders the National Park and all existing roads in the National Park.

3) Production Criteria

   a. Industrial Forest concessions
      
      The entire Industrial Forest concessions in the area of Tesso Nilo forest.

   b. Land suitability for Oil Palm.
      
      b.1. Value 1 = it is not suitable for production
      b.2. Value 2 = moderately suitable areas for production
      b.3. Value 3 = fairly suitable area for production
      b.4. Value 4 = area corresponding to the production

   For the analysis of land suitability for Industrial Plantation Forest (IPF) and Palm Oil, this study uses Idrisi software with Multi Criteria Evaluation tool in model development tool, using criteria from the Department of Agriculture (2003) in Supriatna *et al.*, (2008).

   Land suitability algorithm of Idrisi is:
   
   \[ S = \sum w_i x_i \] ................................................................. (1)

   Where:
   
   S is Conformity
   Wi is the weight of factor i
   Xi is the criterion score of factor i

4) Communities Criteria

   a. Rural areas
   
   Rural areas were excluded from Tesso Nilo forest area.

   Scenarios set:
   
   There are three scenarios used which are:
Scenario A: optimum conservation
Scenario B: optimum production
Scenario C: optimum production and conservation.

Simulation of each scenario uses trade off namely by taking into account criteria of cost and benefit to the road network, river network, slopes and landforms.

Simulation for scenario A: Optimum Conservation:
a. Hydrologic connectivity area must be protected
b. The ranges of targeted wildlife should be protected (elephants and Sumatran tigers) (elephants and Sumatran tigers (*elephas maximus sumatranus* and *panthera tigris sumatrae*).  
c. Production area must be conducted outside the conservation area (oil palm and acacia outside the National Park) 
d. Slope of > 30% should be included as the protected area  
e. Rural areas are excluded from the conservation area.  
f. Production area functioning as a stepping stone becomes wildlife corridor for protected animals.  
g. Open road network access to the conservation areas should be restricted.  
h. The entire area of Tesso Nilo National Park should be maintained.

2. Simulation for scenario B: optimum production
a. Ranges of high-value wildlife in the production area must be protected
b. Acacia should be included in all areas of production.  
c. The use of land for palm oil plantation should be incorporated in production area and the National Park (National Park area constraint in phase 1) 
d. Rural areas must be removed from the forest area  
e. Buffer area of hydrologic connectivity in the acacia production area becomes a green belt.  
f. Road access is open

  a. Buffer area of hydrologic connectivity in the acacia production area becomes a green belt .
  b. The area of hydrologic connectivity should be protect.  
  c. Rural areas are excluded from the conservation area.  
  d. Production area functioning as a stepping stone becomes wildlife corridor for protected animals.  
  e. National Park area must be protected (constraint).  
  f. Industrial forest concessions must include all.  
  g. Palm oil plantations areas outside the National Park should be included.

In detail, the steps are as follows:
1. Distance from river
   The first criterion is the distance group from the river, assuming that the closer to the river, the area should be protected as seen in the Tesso Nilo forest in blue color (score 9), which is close to the river (50 meters), while the area which is far from the river is indicated by pink colour (score 1) or more than 100 meters. The values and results of the stream criteria can be shown in Figure 2.
Basic considerations for the standardization of the criteria is “benefit” standardization which means the farther the distance from the river, the less benefit to be protected. For factors of distance group from the river, this research includes riparian values protected by the law of 50 meters and 100 meters (Act 41 of 1999 on Forestry).

2. Elephants and Sumatran tiger (*Elephas maximus sumatranus and Panthera tigris sumatrae*) distribution

The second criterion is distribution of elephants and Sumatran Tigers (*Elephas maximus sumatranus and Panthera tigris sumatrae*). The value is adjusted to the daily and annual cruising of Sumatran elephant and Sumatran tiger to the value of 1 for a distance of any point where the wildlife is 2 kilometers left and right, the value of 5 for a distance of 4 kilometers and 9 for a distance of 6 kilometers. The result is shown in Figure 3.
The orange color indicates a distance of more than 6 kilometers from the point where the wildlife is. Blue colour indicates a distance of 6 kilometers from the point where the wildlife is. Light blue colour indicates a distance of 4 kilometers from the point where the wildlife is. Brown colour indicates a distance of 2 kilometers from the point where the wildlife is.

3. Buffer Zone of Tesso Nilo National Park
The third criterion is the buffer area of Tesso Nilo National Park with the assumptions that National Park is an area that is not disturbed. Assumed value is the value of 1 for non-National Park, the value of 5 is for the National Park buffer zone, and a value of 9 is for the National Park. The result can be shown in Figure 4. The green color is a non-national park; pink is a buffer zone and purple is National Park.

4. Criteria for Industrial Timber
The fourth criterion is the group of IPF in Teso Nilo forest region with the assumption that there is a section on the concession area protected for wildlife corridor. The assumed value is the value of 1 for the region outside the industrial forest and the value of 9 for the area within the industrial forest. The result can be seen in Figure 5.
5. Suitability Criteria for Palm Oil Plantation

Factor of land suitability for oil palm plantations is based on the criteria used by the Department of Agriculture (2003). Supriatna et al., (2008) by using Multi Criteria Evaluation at the Idrisi software, found that almost the entire region of Teso Nilo quite suitable for palm oil plantations (colored green). The results can be shown in Figure 6.

In figure 6. Brown and light green colors indicate enough suitability of the land. Dark blue color indicates the suitability of the land and light blue color shows the discrepancy of land since it borders the Tesso Nilo National Park in mauve.

6. Slope
The sixth criterion is the slope group assuming that more than 30% slope must be protected in accordance with the criteria of protected forest. The given values are as follow: the value of 1 for the slope of 0-8%, the value of 5 for the slope of 8-30%, and the value 9 for the slope which is more than 30%. The result can be shown in Figure 7.

Figure 7. Criteria of Slope

7. Road Distance
Different roads are used for each scenario.
Scenario road 1 is open access to all roads as shown in figure 8
Scenario road 2, Access Road in National Park is closed, see figure 9.
Scenario road 3, road in national park and road borders with national park is closed as seen in figure 10.

Figure 9. Scenario 2 for road

RESULTS
1. Simulation Scenario optimum conservation

The process of simulation A (optimum conservation) is done by determining 7 selected aspects with weights for each factor that has a value that is more important (trade-off). In the simulation scenario A, the optimum conservation, the highest of the weight value is the distribution of elephants and Sumatran tigers by 35% and the second best is Teso Nilo National Park by 23%, the third rank is the road distance by 15%. The results of the simulation using SMCA for weight based trade-offs on scenario A, the optimum conservation Teso Nilo forest area, can be shown in Figure 11.

![Figure 11. Result of Scenario A, optimum conservation](image1)

The results of scenario A with the position of the weight distribution of wildlife elephants and Sumatran Tigers dominating in the area of industrial forest production, the blue color is the area of distribution of elephants and Sumatran tiger in suitable (blue) area of 96.227 ha, while the distribution area of elephants and Sumatran tiger with considerable appropriateness category (light green) is an area of 221.698 ha, and non suitable category (in red) is an area of 60.053 ha. Teso Nilo National
Park to buffer zone is protected due to Ukui road corridors and road in Tesso Nilo National Park is closed. Distribution of Elephants and Tigers areas appear almost in the entire National Park area and Timber Estate within 2 km to 6 km.

In this scenario, the value of the distribution of elephants and tigers shows high and the value of the National Park is expected to retain the remaining biodiversity in forest areas Tesso Nilo. Thomson et al., (2009) stated that maintaining biodiversity is a key to maintain forest resilience. Biodiversity in forest ecosystems is associated with underlying productivity, durability and stability over time and space. Biodiversity increases long-term durability and resilience of forest ecosystems, increases production and improves the stability of their primary ecosystems at all scales.

2. Process Simulation results of Scenario optimum production
The process of simulation B (optimum production) is implemented by changing the weights on the aspects and taking into account the interests of optimum production with the use of trade-offs. The results of the simulation of the SMCA for spatial planning at Tesso Nilo forest area as shown in Figure 12. Scenario B is the optimum production. On this scenario, the highest value is industrial timber weighting 31%. The second sequence is a road that uses all the existing access road weighing 18%. The third sequence is a 15% distribution of wildlife. The weighted overlay results show the results of current land use in the region Tesso Nilo Forest, which is widely suitability for plantation area of 253.731 ha.

3. Process Simulation results of Trade off
Process Simulation in Scenario C (trade off) is the weighting for conservation and production by using a trade-off. In this scenario, the optimum production and conservation use method of scenario road 2, where all existing access road to Tesso Nilo National Park is closed and the other is open. This scenario results indicate that the park will remain, plantation forests also remain on the current concession areas and wildlife distribution remain in the industrial forest concessions covering an area of 140.971 ha.
Discussion

From our analysis using scenario A, it shows that dominance polygons of red and blue which means the possibility of more conservation area and wide distribution of wildlife. In this scenario, the area will be more protected and elephants and tigers will get more habitat. Considering habitat of those 2 charismatic species are declining rapidly in Tesso Nilo, many conservationists will be in favor of this scenario. Supriatna et al. (2002) stated that Sumatra forest is in the stage of emergency, therefore any efforts to save a piece of forest block in this island is appreciated. If we are using this scenario, we can save not only the existing habitat in this area but also possible extended area in the future. From this scenario, we can save many fragmented forest patches in to good corridor for wildlife home ranges as suggested by WWF (2012). The chance for those two charismatic species to survive will be greater if we use this scenario. However, many production forest will have to be sacrificed their possible extended production.

Based of the results of scenario B, however, the red and blue colors are separated with such a configuration of Tesso Nilo forest land use. Red color indicates areas of industrial forest, blue color indicates the dominance of forest rights and national parks. Due to the existence of a dominant path in blue, polygons appear on either side of the access road. In this scenario, optimum production can be achieved but with the expenses of conservation area and former logging concessions that have been disputed between local and central government jurisdiction. This scenario will be in favor of private sectors that have already had licences to convert the forest. If this scenario is chosen, those charismatic wildlife in this area will be cornered in only Tesso Nilo National Park. This park will be isolated from other forest block in the Riau province. The Tesso Nilo Park then becomes an island park. It means that those animals that have very wide home ranges such as elephants and tigers will be restricted in their ranges. The consequence is that wildlife conflicts will be increased (Groom et al., 2006). Supriatna (2008) stated survival of the wide home range of species will be difficult to survive in the small isolated forest.

In scenario C, the choice of this model is to harmonize the space between production and conservation in Tesso Nilo forest areas. The choice of this model could guarantee the existence of protected areas in the future. It also provides good habitat of those charismatic animals in the corridor forest and can drive those animals from industrial forest concession into protected forest and national park. The scenario C is in accordance with the Decree of the Minister of Forestry 70/Kpts-II/95 about setting Spatial Timber Estates in Article 4, it is stated that: (1) The area of principal crops set + 70% of the unit Timber Plantation; (2) seed crop acreage set + 10% of a unit Timber Plantation; (3) The area of
Designation of conservation area up to 10% at the Forest Estate Concession aims to: 1) Preservation of biodiversity and ecosystems (ecosystem representation, diversity of species, buffer zone forest conservation / protection, etc.) if available on plantations. 2) Protection of water system (riparian, buffer hydrology and flood control). 3) Prevention of forest fire (fire break, wind break, water points). 4) Preservation of important ecosystems and genetic resources for the community. 5) Wildlife corridor towards natural forest (conservation forest, protected forest and limited production forest). 6) The source of water, food source community. 7) Habitat species of flora and fauna are protected (see http://www.dephut.go.id/uploads/files/70_95_ind.pdf). Thus efforts to create harmony between production and conservation area in Tesso Nilo forest area can be realized if it is done with the above requirements for all existing plantation concessions in forest areas Tesso Nilo.

The optimum choice of alternative models of production and conservation requires the National Park area has clear boundaries and has a 500 meters buffer zone (if already delineated) and 1000 meters (if not delineated) of production area. Changes in landscape that have occurred in Tesso Nilo forest have profound consequences for conservation. In Tesso Nilo forest current conditions, its natural landscape has changed from a natural forest into a forest area of industrial crops such as oil palm and residential areas, these changes have reduced many protected wildlife habitat even eliminate good biodiversity of flora and fauna that have low life staying power.

Bennett and Saunders (2010) said that the destruction and fragmentation of habitat are major factors in the global decline of species, native plant and wildlife communities and ecosystem processes change. Changes usually occur disproportionately in areas that have a flat or low altitude and more productive soil. Conservation in fragmented landscapes can be enhanced by protecting and increasing the amount of habitat, improve habitat quality, improve connectivity, manage the disorder in the wider landscape, planning for the long term, and learn of conservation actions undertaken. Forupt et al., (2008) said that efforts to restore damaged ecosystems typically emphasize on structural aspects of biological diversity, such as species richness and abundance. An alternative is to emphasize the functional aspects, such as interaction patterns between species. It also needs to be seen how the damage occurred, so that habitat restoration can be done well.

The optimum model of production and conservation aims (Figure 13) to align conservation forests and production forests, where the distribution of elephants and tigers existed in timber plantation concession survive at the wildlife corridor. The corridor is a bridge from the isolated condition of wildlife habitat due to habitat fragmentation caused by illegal logging of natural forests to make a settlement and oil palm plantations. For the settlements that exist in the national parks must be relocated in order to avoid conflicts with wildlife. Forests with high biodiversity will have a high resilience or resistance to climate change, and the concept of forest management and sustainable conservation can be achieved. Hannah et al., (2009) studied in South Africa resulted that plants change the biological properties especially the distribution ranges due to climate change. This will ultimately change the distribution pattern of animals that depend on these plants.

Conclusions
Results of spatial modeling using optimum production and conservation scenarios show an alignment between production and conservation and protecting wildlife habitat and distribution in the area of timber plantation. This alternative model selection could resolve the problems in Tesso Nilo forest, such as halting illegal logging with clear boundaries, cooperation with the company for the protection of wildlife distribution such as Sumatran Elephants and Tigers. Tesso Nilo forest management scheme using optimum model of production and conservation forests to harmonize conservation and
production forests, which will in turn saving biodiversity rich forests and support high resilience forest against the impact of climate change.

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