Participatory land-use planning for strengthening the village land resources management: a case study of Gorontalo, Indonesia

A Nursafingi¹ ²
¹National Institute of Health Research and Development, Ministry of Health, Jakarta, Indonesia
²Conservation and Development, Burung Indonesia, Bogor, Indonesia

E-mail: afinursafingi@gmail.com ORCID ID: https://orcid.org/0000-0001-5009-7988

Abstract. Sustainable land management is crucial to ensure the availability of food, water, and clean air, especially to long-term support of human well-being and health. Continuous exploitation of land resources leads to land degradation and declines in agricultural productivity, biodiversity, and ecosystem services. This study aims to strengthen land resources management at the village level through a participatory land-use planning (PLUP) approach. The research location is at Moliliulo Village, Gorontalo. Current issues on land use and land management were collected using participatory rural appraisal (PRA) techniques. This information became a consideration in land use analysis conducted using a geographic information system (GIS). The approved future land use directions are about 88% forest (natural forest and agroforestry) and 12% non-forest (agriculture, coconut plantations, settlements, and water body). The land-use plan is essential for guiding the village government and the villagers on managing land resources. Additionally, it potentially strengthens the village development programs, social forestry management and resolves forest conflict. To ensure the implementation of land use planning, the village government should develop regulations on land use.

1. Introduction
Gorontalo is part of the Sulawesi Island that covers an area of about 1.2 million ha. Approximately 68% are forest areas consisting of conservation forest, protection forest, and production forest [1]. Since 1953, Gorontalo has become one of the transmigration destinations [2]. Its locations are generally distributed in the interior and directly adjacent to forest areas. Some of the transmigration settlements were even built-in locations that were previously forest areas [3].

The transmigration policy is associated with increasing the cultivation of crops [4] and led to forest degradation and deforestation [5]. The government must be wise in managing natural resources and implementing environmentally friendly development programs. This effort needs good spatial planning to support Gorontalo as a conservation province [6].

This study aims to strengthen land resources management at the village level through a participatory land-use planning (PLUP) approach. It is a bottom-up planning model expected to capture community aspirations of the lands. Many researchers use participatory rural appraisal (PRA) as a tool to execute PLUP. This method has been used in various studies involving the participation of local communities such as land use investigations [7], food production, nutrition, and safety investigations [8], and educational tools to empower sustainable communities’ processes [9]. We can integrate this method
with others to expand its use, such as gender analysis [10], geographic information system [11], remote sensing [12], and participatory design [13].

2. Research methods
2.1. Description of the study area
The study area is in Moliliulo village, about 45 km from Boalemo District capital, Gorontalo Province. Thirty percent of the road is a former logging concession road that crosses steep hills, has poor condition, and lacks maintenance. In the rainy season, it becomes difficult and dangerous for cars to pass, so that the villagers prefer using riverboats to reach the village. There is no internet access, and solar panels became the main electricity resources. In the past, this area was a production forest managed by a logging concession. The government decided to alter some forest areas to non-forest because there were occupations by villagers.

Figure 1. Study area.

The land cover of the study area was dynamic. Population growth led agricultural expansion in the forest area to be unavoidable. Implementing conventional farming systems for a long time, like
monoculture agriculture on sloping land and excessive use of chemical fertilizers has gradually degraded the fertility of lands. Some villagers forcefully opened the forest areas into new agricultural lands to increase crop yields. In 2018, the Minister of Environment and Forestry (MoEF) issued a community forestry scheme to resolve the forest conflicts. The permit covered 1,027 ha of the limited production forest managed by 160 families for 35 years.

2.2. Participatory land-use planning (PLUP)

We used participatory rural appraisal (PRA) for identifying land-use problems and future land use options. We facilitated this process to the 160 families for six months from July to December 2019. There were six chosen PRA tools to collect information and aspirations from the villagers.

**Table 1.** The expected information was obtained by using PRA tools [14].

| Tools                      | Target information obtained                                      |
|----------------------------|-----------------------------------------------------------------|
| Participatory mapping      | Natural resources and their problems                             |
| Participatory modeling     | Land topography and its problems                                 |
| Trend analysis             | Land-use change                                                  |
| Seasonal calendar          | Seasonal land use                                                |
| Matrix ranking and scoring | Options of land use, land cultivations, and commodities of       |
|                           | agriculture and forestry                                         |
| Transects                  | Additional information on land, its problems, and solutions       |

We provided printed maps of high-resolution imagery from Google Earth and forest area maps from MoEF for supporting the participatory mapping process. The villagers interpreted and manually drew the boundaries of each land-use class to produce a land-use map, forest area map, and community forestry map. This method is known as participatory mapping using scale maps and images [15].

We also interpolated the contour maps acquired from Geospatial Information Agency to create a digital elevation model (DEM) and hillshade. Hillshade is a technique for enhancing relief depiction in 2.5D or 3D display of spatial data [16]. The villagers can easily interpret general slopes from hillshade maps and draw them to produce slope maps. This method, known as participatory modeling, is a three-dimensional visual model which captures and integrates people’s knowledge and spatial information [14].

The villagers then overlaid these thematic maps (land use map, forest area map, community forestry map, and slope map) and made a simple analysis to produce a land-use plan map. To support this process, we used the trend analysis tool to record the history of land-use change and the calendar season tool to explore seasonal land use information. In addition, we also used a matrix ranking and scoring tool to identify land use options, soil conservation techniques, and the future prospective agricultural and forestry commodities. Finally, using the transect tool, we directly checked land-use conditions together with the villagers. Transects are observatory walks or treks across the fields to study natural resources, topography, indigenous technology, soils and vegetation, farming practices, problems, and opportunities [14].
2.3. Spatial data processing and analysis
Creating maps using manual techniques through the participatory mapping tool produced low-accuracy thematic maps. Therefore, we used GIS to diminish error, create high-accuracy maps, and further analyze to obtain future land use directives based on PRA outputs. This work was conducted in ArcGIS Pro version 2.5.0 [17].

Table 2. The thematic maps for overlay analysis input.

| Thematic maps       | Class                                           |
|---------------------|-------------------------------------------------|
| Land use            | Forest                                          |
|                     | Agroforestry                                    |
|                     | Low-density coconut plantation                   |
|                     | Medium-density coconut plantation                |
|                     | High-density coconut plantation                  |
|                     | Dryland agriculture mixed with shrubs            |
|                     | Settlement                                       |
|                     | Waterbody                                        |

Figure 2. Research flow diagram.
3. Results
3.1. Existing land use and topography
Two existing land use that dominated the research area are natural forest (4,001 ha or 71.5%) and dryland agriculture mixed with shrubs (1,380 ha or 24.7%). About 217 ha or 3.8% of the part consists of coconut plantation, agroforestry, settlement, and river.

The topography of the study area is varied. Generally, 13% is flat, and the 87% remaining is sloping. About 825 ha or 80% of dryland agriculture is on sloping land with corn as a major commodity. It shows that dryland agriculture is vital in the economy of the villagers.

![Existing land use map](image)

Figure 3. Existing land use map.

3.2. Land use problems and solutions
We identified two major land-use problems in the village. The first is deforestation and forest degradation. The high demand for food and wood as the implication of population growth has triggered the villagers to convert the forest into agricultural lands. They also illegally cut down trees for house-building materials.

The second problem is declining soil fertility and crop yields. The villagers have been using conventional agriculture for a long time. Clearing the land using slash and burn techniques in the dry season, intensive tillage, and utilizing excessive chemical fertilizer, pesticide, and herbicide have impacted declining soil fertility. They suffer losses because crop yields continue to decline.
We identified options for reducing forest pressure at once to improve soil fertility. It was the aspirations of the villagers acquired during the PRA process. Implementing soil and water conservation practices will potentially restore soil fertility and increase crops yield. In addition, implementing agroforestry systems will supply either food or wood demands in the future. Social forestry schemes expect to resolve forest conflicts and enable villagers to manage and utilize forest areas for a long time.

**Table 3. Land-use problems, drivers, and solutions.**

| Land use problems                  | Drivers                                      | Alternative solutions                      |
|-----------------------------------|----------------------------------------------|--------------------------------------------|
| Deforestation and forest degradation | - High demand for wood for house-building materials  
- Agricultural lands expansion | - Agroforestry system  
- Social forestry scheme          |
| Declining soil fertility and crops yield | - Intensive tillage  
- Monoculture farming  
- Excessive use of chemical fertilizer, herbicide, and pesticide | - Organic agriculture  
- Application of terracing on sloping land  
- Crop rotation  
- Agroforestry system          |

3.3. **Future land use directives**

There are two suggestions to improve the productivity of future land uses. First, alter existing land use to another. For example, change the monoculture agriculture in sloping land to agroforestry. Restore agricultural land in the protected forest area to the forest. Second, increase the productivity of existing land use with replanting and enrichment. For example, enrich the low-density coconut plantations with other prospective crops. We considered current land use, slope, forest area, and existing social forestry in making future land use directives. The villagers also plan to develop prospective agricultural and forestry commodities such as corn, coconut, durian, cashew, nutmeg, and jabon (*Anthocephalus cadamba* Miq.).
**Table 4.** Future land use directive.

| Existing land-use class                  | Slope (%) | Forest/ non-forest area | Existing social forestry | Future land use directive | Area (ha) |
|------------------------------------------|-----------|-------------------------|--------------------------|----------------------------|-----------|
| Forest                                   | >15%<     | HL                      | Forest                   | 1 150.04                  |
|                                          | >15%<     | HPT                     | Forest                   | 530.15                    |
|                                          | >15%<     | HPT                     | Forest                   | 2 312.60                  |
|                                          | >15%<     | APL                     | Forest                   | 8.35                      |
| Agroforestry                             | >15%<     | HPT                     | HKm                      | Agroforestry              | 0.77      |
|                                          | >15%<     | APL                     | HKm                      | Agroforestry              | 29.08     |
| Medium-density coconut plantation        | >15%<     | HPT                     | HKm                      | Agroforestry              | 2.95      |
| Low, medium, and high densities coconut plantation | >15%<     | APL                     |                          | Coconut plantation        | 83.43     |
| Dryland agriculture mixed with shrubs    | >15%<     | HL                      | Forest                   | 66.42                     |
|                                          | >15%<     | HPT                     | Agroforestry*            | 183.15                    |
|                                          | >15%<     | HPT                     | Agroforestry             | 480.16                    |
|                                          | <15%      | APL                     | HKm                      | Conservation agriculture  | 498.47    |
|                                          | >15%<     | APL                     | HKm                      | Agroforestry              | 151.40    |
| Settlement                               |           | APL                     | Settlement               |                            | 16.72     |
| Waterbody                                |           |                         | Waterbody                | 84.07                     |
| Total                                    |           |                         |                          |                            | 5 597.77  |

Forest area: HL (protected forest), HPT (limited production forest), HKm (community forestry)  
Non-forest area: APL (another use area)  
* Suggested for new social forestry area

We disseminated the future land use directive to the district, sub-district, and village government, Forest Management Unit officers, and villagers. Due to economic reasons and sustainable nature conservation in the future, they agreed and committed to implementing that planning. The village government will adopt the plan into village regulations and support the implementation using village funds.

![Figure 5. Future land use directive.](image-url)
4. Discussion

4.1. PLUP for supporting village development programs

In Indonesia, the village government is obliged to create six years development plan (Village Medium Term Development Plan/RPJMDes) and an annual development plan (Village Government Work Plan/RKPDDes). The village fund becomes the core budget resource for implementing these plans. The priority of using village funds is for physical development (including environment preservation) and community empowerment. The village government can adopt the land use planning into part of the village development plan. Thus, the cost of land-use planning implementation will be sustainable. In addition, village development becomes more focused and accommodates the aspirations of the village community.

4.2. PLUP for supporting social forestry management

Area mapped for land use planning covered both forest (including social forestry area) and non-forest. Future land use directives in the social forestry area can be a consideration for the forest manager for preparing forest management and utilization plans. For example, forested areas become protected blocks. Meanwhile, agricultural areas become utilization blocks.

4.3. PLUP for resolving forest conflict

Land use plan map gives information to the village community which areas potentially trigger forest conflict, such as agricultural lands in the production forest. They should propose these areas into social forestry. If the government issues the permit, they will get access to manage and utilize the forest area. In addition, they will receive guidance, assistance, and maybe direct funds from the government to increase the value of forest products.

5. Conclusion

The future land use directive is forest 4 067.56 ha, agroforestry 847.51 ha, coconut plantation 83.43 ha, conservation agriculture 498.47 ha, settlement 16.72, and water body 84.07 ha. The village government has signed the land use planning and committed to adopting the planning into village regulations and supporting the implementation using village funds.

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