Environmental impact of private forest management in Central Lombok, West Nusa Tenggara

Ryke Nandini1,2

1 Non Timber Forest Products Technology Research and Development Institute
   Jl. Dharma Bhakti No. 7, Ds. Langko, Kab. Lombok Barat, West Nusa Tenggara, Indonesia. Phone/Fax. +62-370-6175482.
2 e-mail: rykenand@yahoo.com

Abstract. Community forestry has several impacts on the environment, both physical and social economics. This study aims to determine the environmental impacts of private forest activities in Central Lombok, especially on runoff and soil erosion. The hydrological modelling approach operating Soil and Water Analysis Tools (SWAT) was used to describe the hydrological response such as runoff and soil erosion that occurs as the impacts of private forests. The results revealed that runoff and soil erosion observed in 2008-2014 had the same trend, with a polynomial pattern that increases at the beginning of the measurement and drops at the end. It means that the longer the age of the private forest, the higher runoff and soil erosion will be reduced and the better the quality of the environment. Thus, intensive private forests need to be development to improve environmental quality.

1. Introduction
Private forest is an alternative to improve the condition of land so that it has a better function. Ecologically, private forests have a role in mitigating climate change where different types of land cover will provide variations in carbon stock, biodiversity, and soil fertility [1, 2, 3]. The success of improving land coverage also makes private forests as a suitable model for regional rehabilitation especially for watersheds [4]. Private forests will increase farmers’ income, since they can provide greater benefits than seasonal crops [3], even though income from timber products has not fully been able to sustain economic needs due to dynamic timber prices [5].

In Central Lombok, the potential of private forest land that can be developed is quite large, reaching 1,702.2 ha [6], with types of plants that can be developed include Paraserianthes falcataria, Swietenia mahagoni and Tectona grandis. Based on the results of a land use map analysis issued by the Ministry of Environment and Forestry in 2013, many private forests were developed in land use in the form of mixed dryland agriculture. [7] stated that the average erosion value in 2013 on mixed dryland agriculture was 11.93 tons ha⁻¹ year⁻¹. With reference to the results, the potential for erosion that occurs in mixed dryland agricultural areas is around 20,307.25 tons year⁻¹. If land use is not carried out optimally, it is possible that the erosion occurs will be greater and threaten the sustainability of the surrounding environment.

The development of private forests on Lombok Island provides new opportunities to improve land and forests conditions and community income. Based on data from the Ministry of Forestry [8], until 2012 there were 1,041 ha of private forest, or 32.67% of the total private forest that has been...
developed in the province of West Nusa Tenggara (NTB). The impact of private forest development in NTB has not been widely studied, especially those related to environmental aspects. This study aims to determine the environmental impact of private forest development in Central Lombok, especially those related to runoff and erosion.

2. Methods

This study used watershed area to measure runoff and erosion in private forest location. This research was carried out in Setiling and Sepakek private forests, Central Lombok Regency, which referred to the results of previous study [7], part of Babak watershed area. Hydrological modelling using Soil and Water Analysis Tools (SWAT) developed by Dr. Jeff Arnold of the USDA Agricultural Research Services in the 1990s [9] was used in this study. This model is a continuous model for watershed that operates on a daily basis and is designed to predict the effects of management on water, sediment, and agricultural chemistry in watersheds that do not have a measurement tool.

This study used series data from 2008-2014 to determine trends in runoff and soil erosion. Data used as input in the SWAT analysis included daily rainfall data, daily temperature, daily solar irradiation, soil properties, land use maps, soil maps, and slope maps. The analytical tool used was ArcSWAT 2012, an open source software. In SWAT, the estimating of runoff was used SCS Curve number method, a function of the soil’s permeability, land use and antecedent soil water condition; while the estimation of soil erosion was computing with MUSLE (Modified Universal Soil Lost Equation) method [9].

3. Results and Discussion

3.1. Management of private forests in Central Lombok

Sepakek village is located in Pringgarata sub-district. Setiling Village is located in the North Batukliang sub-district, Central Lombok Regency. Those villages have intermediate extensive community forest, which is around 221.2 ha in Sepakek and 110.8 ha in Setiling. [7] stated that there are three common planting patterns employed by private forest farmers, namely planting patterns with one type of woody plants (pattern A), planting patterns with various types of woody plants (pattern B) and planting patterns with mixed types of woody plants and MPTS (pattern C). Pattern B is the most profitable for farmers’ income (table 1), so that the farmers tend to prefer this pattern.

| Table 1. Comparison of the average income of private forest farmers on various planting patterns [7] |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Private forest                  | Average income year$^1$ha$^{-1}$* (IDR)  |
|---------------------------------|---------------------------------|---------------------------------|
| Sepakek                        | A: 1.143.519, B: 24.520.420, C: 28.955.957 |
| Setiling                       | A: - , B: 9.796.513, C: 8.817.384 |
| Total                          | A: 11.333.160, B: 47.857.423, C: 44.863.657 |

Remark: *Assuming timber harvesting is done at 6 years old, A: planting with one type of wood, B: planting with a type of wood mixture, C: planting with a mixture of wood species and MPTS

The type of plant is fast-growing which is in great demand because it has a fairly high price in the market such as *Paraserianthes falcatoria*, *Swietenia mahagoni*, *Pterospermum javanicum*, *Gmelina arborea* Robx, and *Duabanga moluccana*. In general, private forest farmers do not carry out intensive plant maintenance. Planting is done with a tight spacing (1x1m, 2x3m, 3x3m) without fertilization and thinning so that the growth is poor (growing dwarf, bent stem). Some studies suggest that pruning and thinning can improve the quality of crop products [10, 11], however, in some types of plants such as *Paraserianthes falcatoria*, 3-5 years old does not affect the growth of the diameter so that farmers did not thin or prune their plants [12].
3.2. Runoff and erosion in private forests in Sepakek and Setiling

Private forest development in Central Lombok has succeeded in changing land cover from rare to denser vegetation. Some studies stated that changes in land architecture such as changes in vegetation density will change local hydrological conditions [13,14, 15]. The change of hydrological conditions also occurred in Central Lombok’s private forest. SWAT model analysis showed that runoff that occurred in 2008-2014 in two private forest locations, Setiling (a) and Sepakek (b), was fluctuated with slightly different patterns (figure 1). Runoff that occurred in private forests in Setiling was ranging from 0.2 to 1.3 mm while in the Sepakek was higher, from 0.56 to 6.01 mm. There were similar patterns of runoff in the two private forests, decreased in year 1 and 2 and increased in the third year. In Setiling private forests, runoff increased in the 5th year and slowly declined until the 7th year. As for private forests in Sepakek, the pattern of runoff slowly increased again from the 4th to 6th year and returned to decline in the 7th year.

![Figure 1. Runoff in Setiling private forests (a) and Sepakek (b)](image)

Runoff is strongly influenced by local biophysical conditions such as rainfall [16], vegetation type and land cover [16, 17] and soil types [13, 18]. In general, the soil properties in both private forest locations are almost the same, which has a rather rough texture with a fairly high sand content (>60%). According to [13, 18], this will affect soil permeability. Soils with high sand content will absorb water faster so the potential of runoff is smaller. However, this did not occur at the study site. The results showed that the average permeability in Setiling was lower (1.98 cm hour⁻¹) than in Sepakek (6.01 cm hour⁻¹) but the runoff in Sepakek was higher than Setiling, so it was suspected that there were other factors that influenced the amount of runoff at the study site.

Vegetation and land cover have the role of runoff dampers by turning them into infiltration [19]. Based on the results of searches conducted on private forest owners, the condition of vegetation and land cover in the surrounding area both in terms of age and type of plants were dominated by Paraserianthes falcataria and Swietenia mahagoni. Since the land conditions and land cover that are almost the same, the possible factors that cause the differences in runoff fluctuations was the difference rate of rainfall. Rainfall in 2010 was the highest value, it was 2,975.15 mm (figure 2). This is in line with the opinion of previous studies [13, 16, 20], who stated that rainfall affects runoff. When associated with rainfall at the study site, the runoff at Setiling is only around 0.02-0.05% of the total rain that occurred, while at Sepakek is 0.08-0.2% of the total rainfall that occurred. This value is so small that it is thought to not produce significant erosion.
As with runoff, erosion that occurred in 2008-2014 also fluctuated (figure 3). The average erosion that occurred in Setiling private forests ranged from 0.01-0.12 tons ha\(^{-1}\) while in the Sepakek was higher; it is 1.19-10.04 tons ha\(^{-1}\). Both of them are categorized in the very low erosion [18]. In both private forest locations, there was different erosion patterns, from year 1st to 5th in Setiling tended to increase and subsequently to decline in the 7th year, whereas in Sepakek the increasing was only until the third year, declining in the fifth year and increasing in the 6th year. When related to rainfall patterns, erosion patterns at Setiling are closer to fluctuations in the rain patterns in the study site (Figure 2). It means that rainfall affects soil erosion as state by [20]. Differences in rainfall patterns from erosion such as in Sepakek are thought to be caused by other factors such as differences in vegetation density as mentioned by [20]. However, this study does not analyze vegetation density so it cannot be known with certainty the cause of differences in rainfall patterns with erosion that occurs.

![Figure 2. Annual rainfall at the study site.](image)

![Figure 3. Erosion rate in Setiling private forests (a) and Sepakek (b)](image)

[19] stated that the factors that influenced erosion include rainfall, soil, slopes, and land management. Both private forest locations have the same rainfall and slope. Influential soil factors are soil erodibility which, among others, is influenced by texture, structure, permeability and organic matter. The results of the analysis showed that soil erodibility in the two locations was slightly different, in Setiling is 0.52 while in Sepakek was 0.31. It means that Setiling has higher erosion sensitivity than Sepakek so that with the same rainfall and slope factors, the chance of erosion will be greater.

Based on Table 1, the pattern of private forest management in the two locations is slightly different, in Setiling was the form of mixed planting (patterns B and C) while in Sepakek were monoculture (pattern A) and mixed (patterns B and C). It can be concluded that the planting pattern does not affecting erosion rate, but contributed to decreasing value tendency compared to the mixed pattern solely. However, it is still necessary to do a deeper study so that the planting pattern can provide a more real picture of its effect on erosion in private forests.
4. Conclusion
Despite fluctuated, it can generally be concluded that runoff and erosion patterns that occurred in 2008-2014 followed a polynomial pattern. They were increasing at the beginning and decreasing at the end of the observation so that it could be said that the maturity of private forests would reduce runoff and erosion. With more diverse planting patterns, runoff and erosion will decrease from year to year. Thus, private forests development needs to be done to improve environmental quality.

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