Erosion Hazard Level And Design Of Soil Conservation For Flood Mitigation In The Arui Watershed, Indonesia

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Abstract.

Excessive surface runoff is often underestimated concerning flood mitigation. Indeed, flooding has become a recurring disaster in the past 20 years in Indonesia. This research aims to determine the erosion hazard level and develop conservation plans for dryland agriculture and oil palm plantations to mitigate surface runoff, thereby reducing the risk of flooding. The data collected includes hydrology, dryland agricultural areas, oil palm plantations, and topography, which are analyzed based on threats and conservation potential. Conservation plans that can be implemented include Minor Recharge Holes (MRH) in dryland agriculture and dead-end ponds Palm Dead Pond (PDP) in oil palm plantations. The research results indicate that the MRH design, with a diameter of 1-1.5 m and a depth of 1-1.5 m, still results in surface runoff exceeding 70%. Meanwhile, the PDP design, with a depth of 1-1.5 m and a size of 1-1.5 x 1-1.5 x 7-8 m, yields runoff below 50%, even during extreme rainfall (220 mm), with runoff being only 2%. A change in land use, primarily dominated by dryland agriculture and oil palm plantations, has been a significant factor in triggering flooding in the Arui watershed. In addition to MRH and PDP, five rivers can accommodate surface runoff, which is expected to contribute to long-term flood mitigation in the Arui watershed.

Keywords: *Conservation design, flood mitigation, oil palm plantations, dry land and Arui watershed.*

I. INTRODUCTION

Floods have emerged as a prominent disaster over the past two decades. The onset of a flood is invariably preceded by surface runoff and the accumulation of sedimentary material due to erosion. Erosion results in the loss of tillage layers and a decrease in the soil's capacity to absorb and retain water. According to Kusumandari and Nugroho (2015); Masnang et al. (2014) ; Steiner et al. (2023) the erosion process involves the degradation of soil aggregates, which can subsequently obstruct soil pores or be carried away by erosion, impeding water infiltration and thereby escalating runoff. The increasing incidence of surface runoff serves as an indicator of alterations in land cover, since only a negligible amount of water is absorbed into the soil. In areas still covered by forests, a substantial portion of rainwater is retained within vegetation and litter, ultimately finding its way into the soil. Conversely, excessive surface runoff in urbanized regions is a pivotal concern in flood mitigation. This is due to the profound threat posed by surface runoff (Mahmud et al. 2021b).According to RoFM (2009), the Arui watershed is one of 2,145 watersheds throughout Indonesia that need to be restored. The Arui watershed is in Manokwari district, West Papua Province based on Minister of Forestry Decree Nu. 328/Menhut-II/2009 categorized watersheds that need immediate priority treatment. According to MoLEF (2017), the Arui watershed is a watershed that must be restored, characterized by high levels of erosion, sediment that always increases from the results of monitoring and evaluation of the 2017 watershed with low values and the occurrence of floods in 2015, 2016 and 2018.

There are several watershed impacts that must be restored, including sedimentation and erosion which can disrupt the economy and community life, flooding, and landslides.and use change to non-forest is essentially a transformation of the natural landscape, involving the replacement of recharge area with impermeable surfaces (Hartanto & Rachmawati. 2017);(Marhaento et al.2018); (Endayani et al.2023). This transformation intensifies runoff and peak flow (Liu et al. 2018). Other notable impacts include the conversion, degradation, and deforestation of the Remu protected forest due to excavation activities, resulting in flooding in the city of Sorong, as well as the destruction and reduction in the area of the protected forest in Bogor, leading to landslides in 2020 (Sidiq. 2020). Additionally, the reduction of the protected forest of Wosi Rendani (PFWR) to 88.2 hectares has led to recurrent flooding (Mahmud et al. 2021a). These land use change are believed to affect the previous retention, collection, and storage of rainfall in the catchment area, causing it to shift towards runoff, consequently resulting in increased instances of flooding.In oil palm cultivation, soil conservation practices are carried out in conjunction with various methods, including the use of cover crops, terracing, planting in organized rows, and litter management, which collectively help control runoff and reduce soil erosion (Satriawan et al., 2017). As indicated by Auliyani (2020) and Triassary et al. (2021), the implementation of forest and land rehabilitation through vegetative planting and civil engineering techniques offers an effective response to managing surface runoff and decreasing sediment yield. When it comes to soil conservation in oil palm plantations, the utilization of cover crops and bund terraces has been shown to increase carbon reserves and enhance soil organic matter (Asbury & Ariyanti, 2017).

Furthermore, soil and water conservation techniques for mitigating issues like flooding, erosion, and eutrophication encompass the use of drainage ditches, horse treads, biopores, biopore bunds/terraces, midrib applications, and contour terracing, along with biological measures such as weed management and legume planting (Pradiko et al., 2014). To effectively manage weed growth and prevent erosion, soil conservation methods include the use of litter and the arrangement of fronds resulting from pruning. Mechanical approaches, on the other hand, involve the application of rorak and the construction of ditches (Jayanti & Iswahyudi, 2020).Flooding as a result of excessive surface runoff has occurred in Masni District, Manokwari Regency. The downstream watershed area in this region is dominated by oil palm plantations, and all the trees along the river border have been felled, despite their protected status. Similarly, in the Arui watershed, floods have frequently occurred due to the conversion of forests into plantations, dryland farming, and residential developments. The degradation of the Arui watershed is a matter of grave concern, given its vital role in maintaining water quality and serving as a natural buffer against floods, landslides, surface runoff, and sedimentation. Thus, it becomes imperative to assess the erosion hazard level and formulate soil conservation strategies tailored to the areas with the highest erosion hazard level. This research endeavor is of significant importance, as it not only helps ascertain the degree of erosion risk but also facilitates the development of comprehensive soil conservation plans. The ultimate aim is to bring about positive change and enhance the watershed's capacity to mitigate flooding effectively in the Arui watershed.

II. MATERIALS AND METHODS

2.1 Study area

The research location is at the BPDAS Remu Ransiki and the Unipa Fahutan Management Laboratory. The Arui watershed is geographically located at 0º 43' South Latitude – 0º 57' South Latitude and 133º 40' East Longitude – 133º 48' East Longitude (Figure 1). The materials used in the research include spatial data in the form of administrative maps, land use maps, land unit maps, and topographic maps of the Arui Watershed, rainfall data obtained through the Arui Watershed SPAS. The equipment used in the research was a soil drill, sample ring, meter, GPS, compass, knife, camera, field scales, a set of *computers* and *Microsoft Office* 2016, calculator, printer, and office stationery.

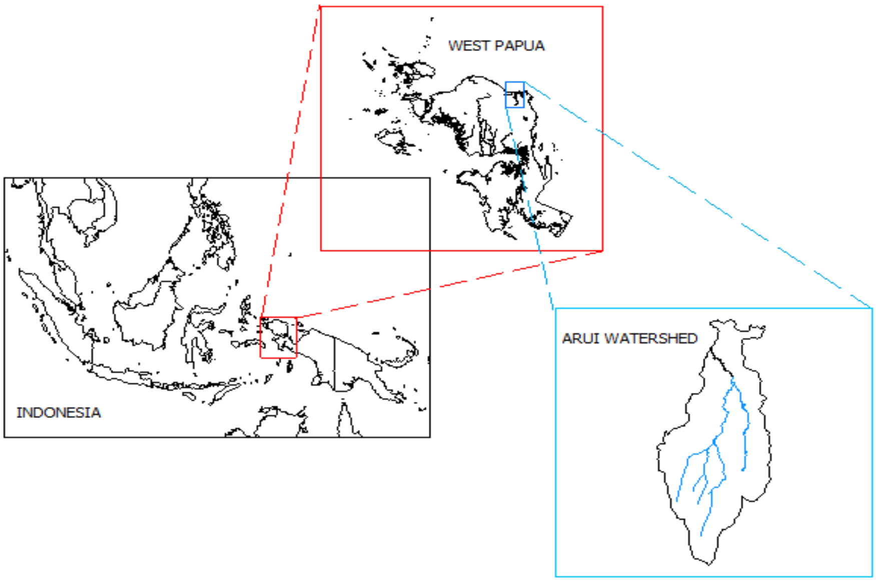


Fig 1. Research location.

2.2 Data collection

Land criteria data collection begins by dividing the Arui watershed map into land unit maps which are the result of an overlay of landform maps, soil maps, slope class maps, and potential land cover maps. The Arui Watershed land unit map is an analysis unit for calculating land parameters such as critical land, vegetation cover, and erosion index. Erosion in the Arui watershed begins with determining the physical and chemical properties of the soil, taking 5 soil samples at a depth of 0-30 cm. The soil samples observed were texture, structure, organic matter, and soil permeability. To determine the amount of erosion with predictions using the formula from the Universal Soil Loss Equation (USLE) developed by (Wischmeir and Smith,1978), namely:

$$A = R \times K \times L \times S \times CXP \qquad (1)$$

Note: A = Potential erosion (Ton ha^{-1} $year^{-1}$), R = rain erosivity factor (KJ ha^{-1}), K = soil erodibility factor (ton $K^{-1}J$), L = slope length factor (m), S = slope slope factor (%), C = plant management factor, P = soil conservation action factor. The erosion hazard level (TBE) or erosion hazard index is calculated by comparing potential erosion (A) on a land unit with the effective depth (soil solum) on that land unit (T). The T value is a standard criterion for dry land soil damage due to water erosion based on soil thickness/solum as follows:

$$TBE = \frac{A}{T} \qquad (2)$$

Note: TBE = erosion hazard level
A = actual erosion (ton ha^{-1} $year^{-1}$)
T = tolerance erosion (ton ha^{-1} $year^{-1}$)

Planning soil conservation with MRH and PDP begins with determining the TBE for each land unit in the Arui watershed. Selection of MRH and PDP based on the highest causes of erosion and changes in forest and land use, namely on plantation land and dry land agriculture. Data collection includes the area of dry land farming, the area of oil palm land, planting distance and potential rainfall on dry land farming, oil palm plantations, water stored, and the percentage of water stored. The area of oil palm land measured using Citra is as large as 4,729.81 ha and the dry land agricultural area is 2,332.06 (MoLEF, 2017). The simulation on paper measures the size of the MRH, including a diameter of 1 m, a depth of 0.5-1 m, and repeated at a diameter of 1.5 m, a depth of 0.5-1 m. while for PDP, namely: depth 1 m, width 1-1.5 m length 7 m, repeated at a depth of 1.5 m, width 1 – 1.5 m and length 7 m.

2.3 Data analysis

The volume of rainfall on land is obtained from rainfall (mm) converted to cm^3 by means of rainfall on an ombrometer mouth area. Simulation of soil conservation techniques for rainfall of 40 mm/day and rainfall of 210 mm/day and 220 mm/day (extreme) was obtained from SPAS in 2016. After obtaining the water volume, it was multiplied by the area of oil palm land (4,729.81 ha) for PDP and dry land agricultural land area of 2,332.06 ha. The stored water is obtained by multiplying the design volume, the land that can be made MRH/ PDP, and the land area.

$$\% W = (Sc - Rf) x100\% . \quad (3)$$

Note: W = Water collected

Sc = water stored in conservation techniques

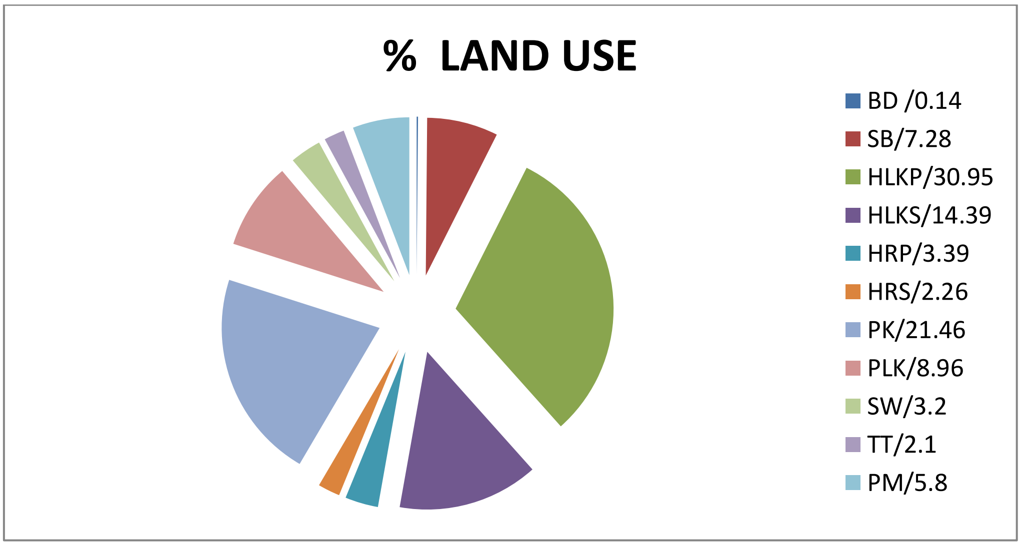
Rf = rainfall

Percent (%) of water stored using conservation techniques, the value can be positive or negative. Positive means the capacity is still remaining/excessive which allows it to be filled with water, while negative means the capacity is insufficient which will become runoff water. The scenario begins by determining the design of soil conservation techniques that can possibly be implemented. In the MRH and PDP scenarios, if the runoff is 0%, it means that it can still hold water and/ or all the water is collected, if it is more than 0%, both conservation techniques cannot hold water/the capacity has more capacity which impacts surface runoff.

III. RESULTS AND DISCUSION

3.1 Biophysics of the Arui watershed

Land use in the Arui watershed was obtained from the land use map of West Papua Province issued by BPKH XVII Manokwari. The types of land use can be divided into 11 groups (Figure 2).



Note: BA= Water Body; SB= Shrub HLKP= Primary Dry Land Forest; HR = Primary Swamp Forest; HRS = secondary swamp forest;; HLKS = secondary dry land forest; Pk = Plantation; PLK = Dry Land Farming; Sw = Rice Fields; TT = Open Land; P M = Settlement

Fig 2. Arui watershed land use

The land use in this area exhibits diverse characteristics, with primary dry land forests being the most dominant, covering 7,192.40 hectares (30.95%). Plantation land use accounts for 4,987.25 hectares (21.46%), followed by secondary dry land forests with 3,343.47 hectares (14.39%). Water bodies make up 33.30 hectares (0.14%), while the smallest land use category is mixed dry land farming, comprising 16.36 hectares (0.07%). Forests serve numerous critical purposes, including the preservation of flora and fauna, enhancing aesthetics, offering recreational opportunities, safeguarding natural resources (Paransi et al., 2021), stimulating the economic well-being of communities residing near these forests (Wahyudi et al. 2014), and maintaining water discharge patterns and stability (Mahmud et al.2022). The type of land use as forest still dominates, it is hoped that forests will continue to play a role in supporting life support systems, maintaining the durability and fertility of the soil, biodiversity is maintained and disasters are avoided.

Table 1. Land use in Arui Watershed

Slope	Morphology	Coverage Area	Wide	%
>45%	upstream	Primary Dryland Forest	3,561.91	15.37
		Secondary Dryland Forest	6.51	
0-8%	downstream	Waterbody	29.64	60.01
		Thicket	1,309.12	
		Primary Dryland Forest	356.01	
		Secondary Dryland Forest	1,625.90	
		Primary Swamp Forest	1,180.69	
		Plantation	4,688.68	
		Dryland farming	2154.92	
		Ricefield	743.27	
		Open Land	482.68	
		Transmigration	1,357.96	
15-25%	middle	Water body	3.67	24.62
		Thicket	245.11	
		Primary Dryland Forest	3,762.20	
		Secondary Dryland Forest	1,463.65	
		Primary Swamp Forest	16.11	
		Plantation	41.13	
		Dryland farming	177.14	
		Open Land	5.32	
		Total	**23,211.62**	100

Table 1 displays the biophysical characteristics of the Arui watershed are primarily defined by a flat slope, accounting for 60% of the terrain. In the downstream watershed, the landscape is marked by utilization areas with lower drainage density, some of which are prone to flooding, and agricultural vegetation dominates. In contrast, the upstream and middle watersheds are characterized by the prevalence of oil palm plantations and forests. These biophysical attributes are intricately linked to the region's capacity to respond to precipitation and can significantly impact various hydrological factors, including surface runoff, evapotranspiration, infiltration, groundwater levels, and river flow. According to Kusumandari &Nugroho (2015), the type of land use plays a crucial role in influencing soil erodibility during the erosion process.The erosion hazard level (TBE) or erosion index is calculated by comparing potential erosion (A) on a land unit with the effective depth (soil solum) on that land unit (T). The T value is a standard criterion for dry land soil damage due to water erosion based on soil thickness/solum. The erosion index values in the Arui watershed are presented in Table 2.

Table 2. Level of erosion hazard for each Land Unit

Land Units	Area (Ha)	% Wide	R	K	LS	CP	A	T	TBE
BADULP1	23.32	0.10	65.96	0.37	0.4	0	0.00	11.21	0.00
BATROP2P1	3.67	0.02	65.96	0.26	0.4	0	0.00	11.21	0.00
BATROP2P2	6.31	0.03	65.96	0.37	1.4	0	0.00	11.21	0.00
Sub-Total									0.00
BLKDULP1	2.15	0.01	65.96	0.26	0.4	0.01	0.07	11.21	0.01
BLKDULP2	181.55	0.78	65.96	0.26	1.4	0.01	0.24	11.21	0.02
BLKDYSP1	459.57	1.98	65.96	0.26	0.4	0.01	0.07	11.21	0.01
BLKDYSP2	54.16	0.23	65.96	0.26	1.4	0.01	0.24	11.21	0.02
BLKEUTP1	832.45	3.59	65.96	0.37	0.4	0.01	0.10	11.21	0.01
BLKEUTP2	0.63	0.00	65.96	0.17	1.4	0.01	0.16	11.21	0.01
BLKTROP2P1	14.94	0.06	65.96	0.37	0.4	0.01	0.10	11.21	0.01
BLKTROP2P2	8.77	0.04	65.96	0.37	1.4	0.01	0.34	11.21	0.03
Sub-Total									0.12
HLKPDYSP2	3,467.79	14.94	65.96	0.17	1.4	0.001	0.02	11.21	0.00
HLKPDYSP3	3,561.91	15.35	65.96	0.17	6.8	0.001	0.08	11.21	0.01
HLKPEUTP1	355.04	1.53	65.96	0.37	0.4	0.001	0.01	11.21	0.00
HLKPEUTP2	294.41	1.27	65.96	0.17	1.4	0.001	0.02	11.21	0.00

HLKPTROP2P1	0.97	0.00	65.96	0.37	0.4	0.001	0.01	11.21	0.00
Sub-Total									0.01
HLKSDULP1	80.27	0.35	65.96	0.37	0.4	0.1	0.98	11.21	0.09
HLKSDULP2	1,266.01	5.45	65.96	0.26	1.4	0.1	2.40	11.21	0.21
HLKSDYSP1	6.51	0.03	65.96	0.26	0.4	0.1	0.69	11.21	0.06
HLKSDYSP2	2.28	0.01	65.96	0.26	1.4	0.1	2.40	11.21	0.21
HLKSDYSP3	119.88	0.52	65.96	0.17	6.8	0.1	7.62	11.21	0.68
HLKSEUTP1	58.87	0.25	65.96	0.37	0.4	0.1	0.98	11.21	0.09
HLKSRENP2	1,469.83	6.33	65.96	0.26	1.4	0.1	2.40	11.21	0.21
HLKSTROP1P1	40.27	0.17	65.96	0.37	0.4	0.1	0.98	11.21	0.09
HLKSTROP2P1	12.66	0.05	65.96	0.26	0.4	0.1	0.69	11.21	0.06
HLKSTROP2P2	1.99	0.01	65.96	0.26	1.4	0.1	2.40	11.21	0.21
HLKSTROP3P1	37.49	0.16	65.96	0.37	0.4	0.1	0.98	11.21	0.09
Sub-Total									2.00
HRPDYSP1	23.07	0.10	65.96	0.26	0.4	0.005	0.03	11.21	0.00
HRPDYSP2	16.11	0.07	65.96	0.26	1.4	0.005	0.12	11.21	0.01
HRPEUTP1	0.78	0.00	65.96	0.37	0.4	0.005	0.05	11.21	0.00
HRPTROP1P1	748.00	3.22	65.96	0.26	0.4	0.005	0.03	11.21	0.00
HRPTROP2P1	389.48	1.68	65.96	0.26	0.4	0.005	0.03	11.21	0.00
HRPTROP3P1	19.37	0.08	65.96	0.37	0.4	0.005	0.05	11.21	0.00
Sub-Total									0.01
PKBDYSP2	41.13	0.18	65.96	0.17	1.4	0.3	4.71	11.21	0.42
PKBEUTP1	2,505.21	10.79	65.96	0.37	0.4	0.3	2.93	11.21	0.26
PKBTROP1P1	11.40	0.05	65.96	0.37	0.4	0.3	2.93	11.21	0.26
PKBTROP2P1	2,056.58	8.86	65.96	0.37	0.4	0.3	2.93	11.21	0.26
PKBTROP3P1	115.50	0.50	65.96	0.37	0.4	0.3	2.93	11.21	0.26
Sub-Total									1.46
PLKEUTP1	23.28	0.10	65.96	0.37	0.4	0.4	3.90	11.21	0.35
PLKEUTP2	113.04	0.49	65.96	0.17	1.4	0.4	6.28	11.21	0.56
PLKTROP2P1	297.23	1.28	65.96	0.37	0.4	0.4	3.90	11.21	0.35
PLKDULP1	14.97	0.06	65.96	0.26	0.4	0.4	2.74	11.21	0.24
PLKDULP2	0.69	0.00	65.96	0.26	1.4	0.4	9.60	11.21	0.86
PLKDYSP1	8.17	0.04	65.96	0.26	0.4	0.4	2.74	11.21	0.24
PLKDYSP2	1,562.32	6.73	65.96	0.26	1.4	0.4	9.60	11.21	0.86
PLKEUTP1	10.18	0.04	65.96	0.37	0.4	0.4	3.90	11.21	0.35
PLKEUTP2	121.22	0.52	65.96	0.17	1.4	0.4	6.28	11.21	0.56
PLKRENP1	29.28	0.13	65.96	0.26	0.4	0.4	2.74	11.21	0.24
PLKRENP2	129.10	0.56	65.96	0.26	1.4	0.4	9.60	11.21	0.86
PLKTROP2P1	1.49	0.01	65.96	0.37	0.4	0.4	3.90	11.21	0.35
PLKTROP2P2	21.08	0.09	65.96	0.26	1.4	0.4	9.60	11.21	0.86
Sub-Total									6.68
SWHTROP2P1	743.27	3.20	65.96	0.37	0.4	0.4	3.90	11.21	0.35
TRNSEUTP1	0.41	0.00	65.96	0.37	0.4	0	0.00	11.21	0.00
TRNSTROP2P1	131.60	0.57	65.96	0.37	0.4	0	0.00	11.21	0.00
TTDYSP2	4.90	0.02	65.96	0.17	1.4	0	0.00	11.21	0.00
TTEUTP1	351.08	1.51	65.96	0.37	0.4	0	0.00	11.21	0.00
TTEUTP2	974.72	4.20	65.96	0.17	1.4	0	0.00	11.21	0.00
TTTROP2P1	383.24	1.65	65.96	0.37	0.4	0	0.00	11.21	0.00
Total	**23,211.60**	**100.00**					**119.42**		**10.65**

Note: A = potential erosion (ton ha^{-1} $year^{-1}$); T= stands for tolerance erosion (ton ha^{-1} $year^{-1}$) R = rain erosivity factor (KJ ha^{-1});K = soil erodibility factor (ton K^{-1}J); L= slope length factor (m); S = slope slope factor (%); C = plant management factor ; P = soil conservation action factor.

The data presented in Table 2 and Figure 2 indicate that the Arui watershed consists of 58 land units, with an erosion hazard level (TBE) of 10.65, which is classified as "very high." Among the different land conversion categories, plantations and dryland agriculture are the ones experiencing the highest TBE values, with values of 1.46 and 6.68, respectively. The erosion index, as indicated, serves as the basis for formulating management policies for specific land units. Land units that have a large erosion value with a thin soil solum thickness will be more vulnerable than land units that have a thicker soil solum thickness. The priority of policy determination will of course be more focused on these areas. According to Kusumandari &Nugroho (2015) erosion cannot be left alone, because if erosion occurs in rather steep areas it can lead to greater erosion such as erosion of grooves, ditches and even landslides.

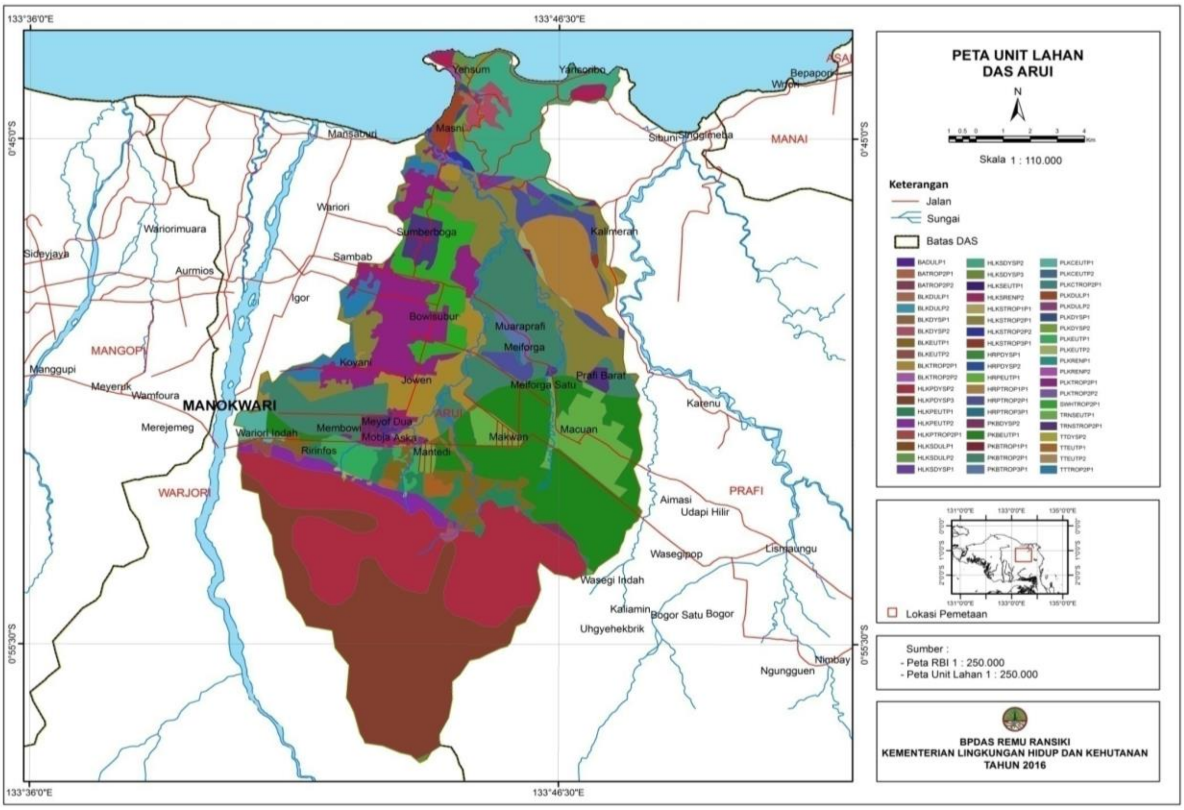


Fig 3. Map of ARUI watershed land units

3.2 Soil conservation scenario

High-intensity rainfall events often lead to surface runoff, which, in turn, contributes to the serious problem of flooding. It's worth noting that the primary culprit for these flooding events is not solely the magnitude of rainfall but also the significant changes resulting from the conversion of forested areas into non-forest functions. From an ecological perspective, these land-use conversions bring about substantial alterations in the landscape, such as land leveling, the loss of natural basins that act as water pockets, and a reduction in catchment areas. These changes entail the loss of diverse vegetation, including shrubs, bushes, undergrowth, and various tiers of trees. Moreover, transformations in the water system are evident, including the disappearance of smaller rivers that once played a crucial role in water retention. The number of basins available for water storage diminishes, and the soil's capacity to hold, retain, and absorb water decreases. Consequently, there has been a significant shift in water management patterns, with surface runoff rapidly flowing into rivers. The design of flood mitigation scenarios is of utmost importance, as it should consider both land use and ecological functions. Several land conservation plans can be implemented to ensure that development beyond forestry, such as dryland agriculture and oil palm plantations is maintained environmental sustainability, including Minor recharge holes (MRH) and Palm Dead Pond (PDP). According to Auliyani (2020), the fundamental principle of soil conservation is to preserve soil fertility and productivity to prevent their decline.

3.3 Minor Recharge Holes (MRH)

The reduction in land available for water absorption has various consequences, including the escalation of surface runoff, heightened risk of floods, increased likelihood of landslides, and a greater susceptibility to drought (Sukmawardhono & Nugroho, 2020). This problem needs to be overcome by creating an artificial infiltration system which is very important. These systems can enhance water infiltration into the soil, decelerate water runoff, thereby reducing peak discharge, and facilitate the storage of eroded soil. This approach makes it more feasible to restore soil sediments effectively. Minor recharge holes (MRH) includes the implementation of modifications

Note:  Dry land agricultural crops

 MRH measures 2 m in diameter x 1 m deep

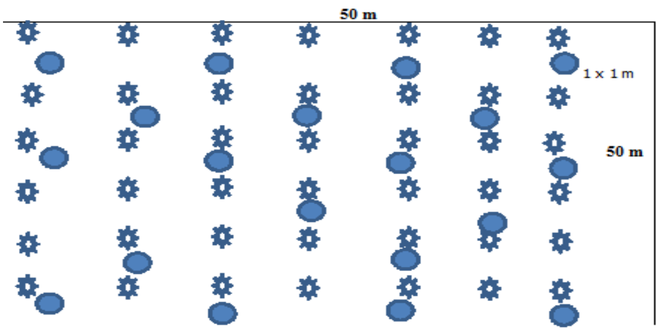


Fig 4. MRH Design

Such as creating holes and rorak, which are circular earth excavations constructed on sloped terrain. These modifications serve to store, accommodate, and enhance the absorption of surface water flow, as illustrated in Figure 4. This proactive approach can significantly contribute to better managing water resources and mitigating the impacts of land use changes on the hydrological system.Minor recharge holes (MRH) involves the creation of circular pits between long-term plants like *Nephelium Lappaceum L*, *Musa paradisiaca, and Lansium domesticum*, with dimensions typically ranging from 1 to 1.5 meters in diameter and depths of 0.5 to 1 meter. For instance, in an area of 0.25 hectares, there can be as many as 19 MRH structures, as depicted in Figure 4. In a 1-hectare area, this would translate to a total of 76 MRH structures. Given that the dry land area of the Arui watershed is 2,332.06 hectares, it is estimated that there could be a total of 177,236.56 MRH structures implemented in the area. Rorak structures are employed to enhance water absorption in the middle and upstream sections of the watershed while also slowing down the flow of water in the upstream areas, in line with the findings of Kodoatie and Sugiyanto (2002). MRH, resembling circular dug wells, are designed to collect runoff water and allow it to be slowly absorbed into the ground. Research conducted by Auliyani (2020) has indicated that, as the distance between MRH structures becomes closer, surface runoff tends to decrease, more water is collected, nutrient loss is minimized, and erosion is reduced. The simulation of the MRH design, including the amount of stored water and surface water flow, is detailed in Tables 3 and 4.

Table 3. Simulation of MRH design results with a diameter of 1 m in dry land farming

Rainfall (mm)	Amount Rainfall in palm oil (m^3)	MRH size (m^3)	Capacity in Plb (m^3)	Remaining storage water	% Water is stored	% Surface runoff
40		1.00 x 1.00	138,244.50	-794,579	14.8	85.2
		1.00 x 0.75	104,569.60	-828,254	11.2	88.8
	932,824	1.00 x 0.50	69,122.26	-863,701	7.4	92.6
		1.00 x 1.00	138,244.50	-2,660,227	4.9	95.1
		1.00 x 0.75	104,569.60	-2,693,902	3.7	96.3
120	2,798,472	1.00 x 0.5	69,122.26	-2,729,350	2.5	97.5
160		1.00 x 1.00	138,244.5	-3,593,051	3.7	96.3
		1.00 x 0.75	104,569.6	-3,626,726	2.8	97.2
	3,731,296	1.00 x 0.5	69,122.26	-3,662,173	1.8	98.2
		1.00 x 1.00	138,244.50	-4,759,081	2.8	97.2
		1.00 x 0.75	104,569.60	-4,792,756	2.1	97.9
210	4,897,326	1.00 x 0.50	69,122.26	-4,828,203	1.4	98.2

The simulations for dryland agriculture indicate that with 177,236.56 MRH units, each measuring 1x1 m, the total amount of water that can be stored in the MRH structures is approximately 138,244.5 m^3 (Table 3). Additionally, based on the results presented in Table 4, the simulation of MRH design with 1x1 meter dimensions demonstrates that for a medium rainfall of 40 mm, the water collected by the MRH structures is 14.8%, while surface runoff constitutes 85.2%. In the case of extreme rainfall amounting to 210 mm, the water collected by the MRH is significantly lower, at only 1.4%, with surface runoff making up the majority at 98.2%. Efforts to mitigate flooding often involve increasing the amount of water that infiltrates the ground, storing excess water, and reducing surface runoff. According to Mahmud et al. (2019) dams serve as reservoirs to store water during periods of excessive surface water, and this stored water can be channeled to agricultural land when needed. These strategies are critical in effectively managing and mitigating the impacts of flooding.

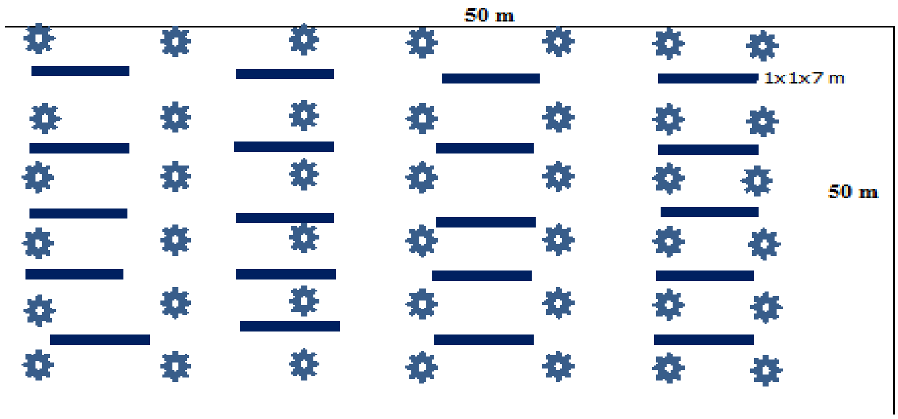
Table 4. Simulation of MRH design results with a diameter of 1.5 m in dry land farming

Rainfall (mm)	Amount Rainfall in palm oil (m^3)	MRH size (m^3)	capacity in Plb (m^3)	Remaining storage water	% Water is stored	% Surface runoff
40		1.5x 1	313,708	-619,115	33.63	66.37
		1.5x 0.75	233,952	-698,871	25.08	74.92
	932,824	1.5x 0.5	155,968	-776,855	16.72	83.28
		1.5x 1	313,708	-2,484,763	11.21	88.79
		1.5x 0.75	233,952	-2,564,519	8.36	91.64
120	2,798,472	1.5x 0.5	155,968	-2,642,503	5.57	94.43
160		1.5x 1	313,708	-3,417,587	8.41	91.59
		1.5x 0.75	233,952	-3,497,343	6.27	93.73
	3,731,296	1.5x 0.5	155,968	-3,575,327	4.18	95.82
		1.5x 1	313,708	-4,583,617	6.40	93.36
		1.5x 0.75	233,952	-4,663,373	4.78	95.22
2 10	4,897,326	1.5x 0.5	155,968	-4,741,357	3.18	96.82

The simulation results from Table 4 demonstrate that even with larger MRH designs measuring 1.5 x 1 meters, during heavy to extreme rainfall, a significant portion of the water is still directed as surface runoff. Nevertheless, these structures are expected to gradually reduce surface runoff, thereby contributing to long-term flood mitigation efforts. The effectiveness of these measures may vary depending on local conditions and specific environmental characteristics.

3.4 Palm Dead Pond (PDP)

According to Merten et al.(2016), the conversion of forests into monoculture oil palm plantations has seen significant changes in the hydrological cycle and has resulted in lower quality of water resources (Tarigan 2016; Dislich et al. 2017). Even though the large and massive conversion of functions from forests to agriculture and oil palm plantations has not been noticed, however, after a disaster occurs, we become aware of it. Soil conservation that needs to be implemented on monoculture oil palm land is PDP. PDP is a U-shaped earth excavation made to cut a slope that functions to accommodate, absorb, and store surface flow on oil palm land. PDP is a modification of rorak, earth excavation, and trenches. As according to Kodoatie & Sugiyanto (2002) the upstream and middle parts must increase the number of rorak so that water absorption increases and slows upstream surface runoff. Generally, the ditch is an excavation of around 1 m which is made long and then channeled into the river so that the water disappears quickly. PDP is made between oil palm plants with a length of 7 m, a width of 1-1.5 m, and a depth of 1-1.5 m (Fig 5).



Note:

= Palm oil plantations

= PDP measures 1m wide x 1 m deep x 7 m long

Fig 5. PDP design

Such as long excavations made in peatland planted with oil palm. In general, rorak is made with a length of 1-2 m, width 0.25 - 0.50 m and depth 0.20 - 0.30 m, or length 1 - 2 m, width 0.3 - 0.4 m and depth 0.4 - 0.5 m. More water is collected, erosion is reduced and nutrient loss is lower, thereby reducing surface flow even further if the rorak is made closer (Pratiwi & Salim. 2013). The spacing for oil palm planting is 8 x 9 m. If the size is 1x 1x 7 m with a limit of 3 m for each PDP for an area of 0.25 ha, the result is 30 PDP or 120 PDP ha^{-1} (Figure 5). Meanwhile, the area of oil palm land in the Arui watershed is 4,729.8 ha, so there will be 567,576 PDP. From the simulation on oil palm land if there are 567,576 PDP with a size of 1 x 1 x 7 m, then the water that can be stored in the PDP is 3,973,032 m^3 (Table 5).

Table 5. Simulation of 1 m depth PDP design results on oil palm plantations

Rainfall (mm)	Amount Rainfall in palm oil (m^3)	PDP size (m^3)	Water capacity at PDP (m^3)	Remaining storage water	% Water is stored	% Surface runoff
40		1x 1x 7	3,973,032	+2,081,112	100	0
	1,891,920	1x 1.25x7	4,966,290	+3,074,370	100	0
		1x 1.5x 7	5,959,548	+4,067,628	100	0
		1x 1x 7	3,973,032	-283,788	93	7
		1x 1.25x7	4,966,290	+709,470	100	0
90	4,256,820	1x 1.5x 7	5,959,548	+1,702,728	100	0
160		1x 1x 7	3,973,032	-71,703,768	53	47
	7,567,680	1x 1.25x7	4,966,290	-70,710,510	66	34
		1x 1.5x 7	5,959,548	-69,717,252	78	22
		1x 1x 7	3,973,032	-6,432,528	38	62
		1x 1.25x7	4,966,290	-5,439,270	47	53
220	10,405,560	1x 1.5x 7	5,959,548	-4,446,012	57	43

Based on Table 5, the simulation results of the PDP design with a depth of 1 m, if the rainfall is 40 mm, all the water can be accommodated, however, in very heavy rainfall between 90 mm, the capacity of the PDP measuring 1x1x 7 m and 1x1.25 x 7 m is not sufficient, so the surface flow is 7%. PDP design if the rainfall is 160 mm (very heavy) with various PDP sizes, surface runoff is still below 50%. From this design, the greater the rainfall, the greater the surface runoff. KBDS is similar to small recharge ponds (SRP) which have been implemented in cocoa plantations. According to Mahmud et al. (2021a), SRP simulation results measuring 3 x 1 x 1 m in heavy and very heavy rainfall on cocoa plantations did not occur surface runoff.The spacing for oil palm planting is between 8-9 m, in fact, there are no obstacles for heavy equipment to dig and evenly distribute the excavation results throughout the land. Simulation of PDP design with a depth of 1.5 m in oil palm plantations, shown in Table 6.

Table 6. Simulation of PDP design with a depth of 1.5 m in oil palm plantations

Rainfall (mm)	Amount of rainfall in palm oil (m^3)	PDP Size (m^3)	Water capacity at PDP (m^3)	remainder Water storage _	% Water is stored	% Surface runoff
40		1.5x 1 x8	6,810,912	+4,918,992 _	100	0
	1,891,920	1.5x 1.25x8	8,513,640	+6,621,720 _	100	0
		1.5x 1.5 x8	10,216,368	+8,324,448	100	0
		1.5x 1 x8	6,810,912	+2,554,092 _	100	0
		1.5x 1.25x8	8,513,640	+4,256,820 _	100	0
90	4,256,820	1.5x 1.5 x8	10,216,368	+5,959,548 _	100	0
160		1.5x 1 x8	6,810,912	- 756,768	90	10
	75,676,800	1.5x 1.25x8	8,513,640	+945,960 _	100	0
		1.5x 1.5 x8	10,216,368	+2,648,688 _	100	0
		1.5x 1 x8	6,810,912	- 3,594,648	65	35
		1.5x 1.25x8	8,513,640	- 1,891,920	81	19
2 20	10,405,560	1.5x 1.5 x8	10,216,368	- 189,192	98	2

The MRH and PDP conservation techniques are expected to be able to reduce surface runoff which causes flooding in the Arui watershed. The Arui watershed currently has 5 rivers that can accommodate excess surface runoff both from other open lands and runoff from conservation techniques. Thus, stakeholders such as companies and palm oil farmers must be able to make the right choice for flood mitigation. If you really want to save and prevent the Arui watershed from flooding, you should choose a PDP design measuring 1.5 x 1.5 x 7 m or longer and wider, because below 50 % of rainwater is surface flow. However, it depends on the oil palm land owner whether the depth is 1.5 m or 15 m because there are advantages and disadvantages. PDP has disadvantages for farmers and people who keep pigs, goats, cows, and other domestic animals but are released.

Fig 6. Banteran Dam has a water capacity of 21,000 m^3

As an illustration, a PDP measuring 1.5 meters in width, 1.5 meters in depth, and 8 meters in length can hold a volume of water equivalent to 10,216,368 m^3, which is comparable to 486.5 Banteran reservoirs. A Banteran Reservoir has a normal water surface depth of approximately 5 meters, a dam height of 6.1 meters, and an inundation area of 47,000 m^2 . Consequently, to manage flood control in the downstream area, which is prone to receiving floodwaters, a large dam with substantial water storage capacity would be required, as suggested by Risi et al. (2018) in their research. PDP can replace catchment areas that previously existed but have now turned into oil palm land. Because reduced catchment areas can have an impact on flooding and drought, according to Sukmawardhono & Nugroho (2020), floods, droughts, and landslides are the impact of decreasing the area of forest that functions as catchment areas.Implementation of conservation with PDP is the opposite of embung. If you build embung it cannot be used for farming, considering that everything consists of water. However, the PDP area still consists of soil between the land and plants, and ditches are made that can collect and store water. In this way, more water will be stored in the ground and only a small amount will flow over the surface of the land and then into rivers. The construction of the embung is estimated at Rp.13 billion (the cost of the Banteran embung) then 486.5 embungs will cost IDR

6,324.5 billion. Currently, it is not appropriate to build a reservoir in the Arui watershed, because farmers still rely on irrigation from the Prafi Dam to meet their water needs.PDP is expected to have many benefits including palm leaf fronds, empty palm fruit bunches, factory kitchen ash, and palm waste such as shells can be put into PDP which is expected to be decomposed within 2-3 months.

The results of decomposition and sediment deposited in PDP periodically, every 3-4 months, are returned to the area around the oil palm trees. With this PDP, sediment from surface runoff and decomposition results are not washed away but are stored in the PDP. Surface flow and small nutrient losses mean plant growth will be better because nutrient and water needs are relatively met (Auliyani. 2020). For oil palm farmers, it will reduce fertilizer costs because organic fertilizer is available from the decomposition of palm leaf midribs, shells, cakes, and empty palm fruit bunches. So far, the cut palm fronds have been scattered around the palm trees, of course, they have taken a long time to decompose. However, if it is collected and placed in the MRH, it will mix with sediment and water and will easily decompose into organic material. Some NGOs propagate the idea that oil palm cultivation is water-intensive, potentially leading to drought and water shortages. If this claim holds true, then planting oil palm in the Arui watershed area, where rainfall is abundant year-round, and water levels are consistently low, might not pose a problem. The issues related to palm oil plantations, such as permits, community empowerment, and the environmental impact, require urgent resolution. Neglecting these concerns could lead to the revocation of palm oil plantation permits. As a stern warning from the highest authority in the Republic of Indonesia, permits will be revoked for companies that fail to demonstrate commitment to the welfare of local communities and the preservation of the environment. In the beginning of 2022, the government took action by revoking the Cultivation Rights (HGU) of abandoned plantations, covering an area of 34,448 hectares. According to Alika (2022), this area includes 25,128 hectares owned by 12 legal entities, with the remaining 9,320 hectares part of the abandoned HGU belonging to 24 legal entities.

IV. CONCLUSION

The erosion hazard level in dry land agriculture is 6.68 and plantations are at 1.46. Simulation of the MRH design results in a diameter of 1–1.5 m and a depth of 0.5–1 m. If the rainfall is 40 mm (medium), then the water collected is 14.8% and surface runoff is 85.2%. Rainfall amounted to 210 mm (extreme), then the water collected was only 1.4%, and surface runoff was 98.2%. Simulation of MRH design results measuring 1.5 x 1 m: if the rainfall is 40 mm (medium), then the water capacity is 33.63% (larger capacity), and surface runoff is 66.37%. Rainfall amounted to 2 10 mm (extreme), only 6.40% of the water is stored, and surface runoff is still very large at 93.36%. The PDP design with a depth of 1–1.5 and a size of 1–1.5 x 1–1.5 x 7–8 m is dominated by runoff below 50%; even at extreme rainfall (220 mm), runoff is only 2%. Palm oil waste, such as palm leaf fronds, empty palm fruit bunches, factory kitchen ash, and shells, can be put into PDP and will decompose within 2–3 months. Soil conservation using the PDP technique, measuring 1.5 m wide x 1.5 m deep x 8 m long, is capable of holding 10.216.368 m3 of water, equivalent to 486.5 embung Banteran. Land use change, which is dominated by dry land agriculture and oil palm plantations, triggers flooding in the Arui watershed. Apart from the MRH and PDP, there are 5 rivers that can accommodate surface runoff, which is expected to be able to mitigate flooding in the Arui watershed in the long term in addition to implementing MRH and PDP.

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