Study on Blue-Green Space

Annex A of the Pre-Feasibility Study for the GCF SAP Funding Proposal for Project *"Building Flood Resilient Community through Adaptive Livelihood and Runoff Management in Petanglong Area of Central Java Province of Indonesia (BRAVE)"*

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Executive summary

Due to changing land and climate conditions, the Kupang and Sengkarang watersheds, located in Pekalongan City, Pekalongan Regency, and Batang Regency in Central Java, are vulnerable to the impacts of climate change. Consequently, the downstream and coastal areas of these two watersheds, which are situated in Pekalongan City and parts of Pekalongan Regency, frequently experience flooding during the rainy season. This flooding is caused by rainfall and runoff from upstream areas, and tidal flooding from the sea.

To reduce the impacts of flooding, various mitigation efforts are necessary, such as building flood-resilient communities and managing runoff from upstream areas. Blue-green spaces—part of nature-based water management that includes water retention, redistribution, regulation, and recycling—aim to control runoff in midstream areas to reduce flooding intensity in downstream areas.

A funding proposal to the GCF aims to demonstrate the potential of blue-green spaces (together with other expected resilience solution) in the project: “Building Flood Resilient Community through Adaptive Livelihood and Runoff Management in Petanglong Area of Central Java Province of Indonesia (BRAVE)”.

This study is an annex to the Feasibility Study prepared by OPM on behalf of Kemitraan, providing more in-depth analysis of the technical aspects relating to preparing and establishing a blue-green space. It looks into how to identify and select suitable sites for the blue green space, as well as the design of blue-green spaces, to take into account both hydrological factors to optimally retain runoff and socio-economic factors to provide additional benefits to surrounding communities. Furthermore, the study shows how the preparation and establishment of blue-green spaces requires the involvement and support of various stakeholders, particularly the communities around the establishment sites and the district government.

This study assesses several key points: (a) the multifunctional blue-green space concept and approach, (b) potential blue-green space designs based on site suitability (topography, land cover, and local stakeholder acceptance), (c) other socio-economic benefits based on blue-green space design recommendations, and (d) potential challenges and barriers in developing blue-green space. This study also details the stages of preparation, construction, management, monitoring, and evaluation of blue-green space, ensuring its existence can provide environmental, social, and economic benefits.

This study identified 12 indicative locations at the village level based on hydrological assessments and recommendations from city, regency, and sub-district governments. It also provides four landscape designs that offer various functions, in line with government input. However, these 12 locations and four designs still require permits from the village and surrounding community, as well as local inspections and mapping to ensure the hydrological and landscape designs can be implemented and function optimally. Additionally, this study outlines detailed activities to support the implementation and development process

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List of abbreviations

Bappeda	Badan Perencana Daerah (Regional Planning Agency
BBWS	Balai Besar Wilayah Sungai (River Basin Agency/Office)
BPBD	Badan Penaggulangan Bencana Daerah (Regional Disaster Management Agency)
BPDAS	Badan Pengelola Daerah Aliran Sungai (Watershed Management Agency/office)
DEM	Digital Elevation Model
DLH	Dinas Lingkungan Hidup (Environmental Office)
PU	Dinas Pekerjaan Umum (Public Work Office)
Pusdataru	Dinas Pekerjaan Umum, Sumber Daya Air dan Penataan Ruang (Public work, water resource and spatial planning agency)
OPM	Oxford Policy Management

1 Introduction

1.1 Climate and Hydrological Risk

Kupang watershed has an average annual rainfall of 3000 mm with wet months occurring in December, January and February (Mercy Corps Indonesia, 2022). The Schmidt-Ferguson climate classification categorizes the Kupang watershed into an area with a wet to very wet climate. Population and economic growth have the potential to influence future climate conditions in the Kupang watershed. Several studies carried out climate change projections in the Kupang watershed to see the risks of climate change on the social, economic and environmental conditions of the community, business sectors and other stakeholders (Gradiyanto et al., 2024; Mercy Corps Indonesia, 2024).

Climate parameters that are often used to see climate change are rainfall and temperature. Two widely used future climate change scenarios are SSP245 and SSP585, which consider socioeconomic components (e.g. population growth, economy, urbanization, etc.). The SSP245 scenario applies to countries targeting sustainable growth and the SSP585 scenario is the worst-case scenario with fossil-fueled economic growth (Haleem, Kashif; Khan, Afed Ullah; Khan, Jehanzeb; Ghanim, Abdulnoor A.J.; Al-Areeq, 2023). Future climate change from SSP245 and SSP585 shows changes in rainfall and temperature in the Central Java Province (Gradiyanto et al., 2024). In both scenarios, the changes in monthly rainfall in the period 2030-2049 (2040s) are not quite significant, however in the SSP585 with fossil fuel-based economic growth shows that there is an increase in monthly rainfall between January and February and a decrease in rainfall in October-November in the period 2050-2069 (2060s). Related to temperature changes, the SSP585 scenario also has the potential for a temperature increase of 1°C higher than the SSP285 scenario. Both changes in rainfall and temperature will affect the future hydrological conditions in the Kupang Watershed.

The results of this climate scenario prediction also align with the long-term climate projection in the Brief Report Hazard, Vulnerability and Risk Assessments of Kupang Watershed (Mercy Corps Indonesia, 2024). The report states that the Kupang Watershed will have wetter climate conditions with more frequent extreme rain events in the future. They also analyzed the rising sea tides that will continue to increase every year.

1.2 Objective, Output and Methodology

The blue-green space pre-feasibility study provides a preliminary assessment of the potential for blue-green space development in the Kupang and Sengkarang watersheds. This study aims to assess several key points:

Stakeholder understanding of hydrological issues (especially flooding) and blue-green space concept

Blue-green space design based on site suitability (topography, land cover, and local stakeholder acceptance).

Challenges and barriers of the blue-green space establishment

Other socio-economic benefits are based on blue-green space design recommendations.

This study uses spatial analysis, field observation, FGD, and interview approaches. Spatial analysis is used to determine the scope and characteristics of the study area at the watershed and sub-watershed levels. Field observation is used to determine and verify actual field conditions that cannot be obtained from spatial data due to the scale being too broad. FGD and interviews are used to determine stakeholders' perceptions regarding the problems of the Kupang and Sengkarang watersheds and the concept of blue-green space. These FGDs and interviews involve several government institutions at the national level (BBWS Pemali-Juawana and BPDAS Pemali-Jratun), the provincial level (Pusdataru), responsible for managing the Kupang and Sengkarang watersheds, the district level (Bappeda, DLH, PU, BPBD), and representatives from the sub-districts.

1.3 Multifunctional Blue-Green Space Concept

1.3.1 General concept of blue-green space

Blue-green space is part of nature-based water management and a technical intervention that includes water retention, redistribution, regulation and recycling (van Noordwijk et al., 2019). Flooding (and potentially future drought) that occurs in the Kupang Watershed is related to temporal changes in the amount of water as a result of ecosystem degradation and climate change. The terminology of 'space' itself refers to the appreciation of space that provides greater emotional value to human well-being, such as comfort, security, peace, health, etc. (Dobson, 2021). This emotional value for human well-being lies not only in blue-green space to overcome flooding but is also expected to create other ecosystem services such as biodiversity, natural beauty, food supply, etc. (Dai & Tan, 2024). Despite the benefits gained from the existence of blue-green space, there are complex challenges from the development efforts because it requires cooperation between various institutions and stakeholders (van Noordwijk et al., 2019).

Differences in understanding and levels of ecological knowledge between stakeholders create knowledge gaps. Stakeholders can establish cooperation by sharing each other's interests and need to overcome the knowledge gap (Kumar et al., 2020). To design a multifunction blue-green space that all stakeholders accept, a comprehensive assessment of hydrological function by integrating three different ecological knowledge: Local Ecological Knowledge (LEK), Public Ecological Knowledge (PEK) and Modellers/Researcher Ecological Knowledge (MEK) (Jeanes et al., 2006).

1.3.2 Blue-green space concept according to Indonesian policy

Blue-green space is indirectly stipulated in Regulation of the Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency No. 14 of 2022 concerning the Provision and Utilization of Open Green Space. This regulation states that the provision and utilization of the open green space serves: a) ecological functions, (b) water absorption, (c) economical benefits, (d) Social-cultural value, (e) aesthetic, and (f) disaster management. Furthermore, this regulation also states that every region is required to have green open space covering at least 30% of their area, consisting of 20% public open green space and 10% private open green space. This green open space can be developed through the provision of non-green space and blue space.

Specifically, the regulation states that blue spaces must meet the following criteria: (a) a body of water or aquatic space, (b) provide water supply, (c) have a retention function in the form of collecting and absorbing rainwater in an area, (d) have a detention function in the form of temporarily storing rainwater in an area and/or (e) provide groundwater storage and flood control. The regulation also states that blue spaces can be in the form of: (1) lakes, (2) reservoirs, (3) rivers, (4) embung, (5) situ, (6) springs, (7) biopores (biopori), (8) infiltration wells. (9) bioswales, (10) rain gardens, (11) retention and detention ponds, and (12) artificial swamp or constructed wetlands. This regulation demonstrates that the development of blue-green spaces in Indonesia already has a legal umbrella, defined by its criteria and forms, as outlined in these regulations. Because it includes green and blue infrastructure, planning and implementation of blue-green space development requires coordination with several government institutions, such as the Environmental Agency as the manager of green open spaces and conservation activities, the Public Works and Spatial Planning Agency which helps with space allocation and drainage arrangements, and Regional Planning Agency (Bappeda) which helps with planning at the district/city level.

1.3.3 Impact of blue-green space on hydrological conditions

For flood risk reduction, blue-green space affects the water cycle from the patch (farmer's plot) to the landscape level. Green space management is carried out through land cover management to slow down runoff from rain and tide events. Tree-based land cover (e.g. agroforestry, mixed garden) management in the upstream and downstream areas is useful for increasing infiltration and reducing runoff that causes flooding. Field measurements conducted by Brawijaya University (Suprayogo et al., 2020) show that the more trees on the land, the more rainwater is infiltrated. The tree canopies temporarily holds rainwater and the tree roots make the soil more porous.. Blue space management is carried out by managing water bodies such as rivers, drainage and irrigation channels, including opening and closing water gates. People can clean rivers, drainage channels and irrigation channels from sediment and garbage to ensure optimal water storage capacity. They also need to ensure that the condition of the water gates in the drainage channels to prevent flooding from upstream and the entry of high tides continues to function properly.

1.3.4 Multifunctional blue-green space

Apart from the primary function of Blue-green space in this project to reduce the impact and risk of flooding, Blue-green space is also expected to provide other benefits for stakeholders, especially to local communities. Some other potential benefits of Blue-green space are environmental benefits, social and health benefits and economical benefits. Environmental benefits including maintaining water quality, increasing fresh water supply, and carbon sequestration. Social and health benefits include recreational opportunities, improved mental wellbeing, community gathering spaces, and increased physical activity. Economic benefits can include increased property values, reduced infrastructure costs (through natural flood management), and potential tourism revenue.

A study conducted by Brawijaya University showed that the presence of soil cover in the form of vegetation and litter reduces soil erosion, thereby reducing sedimentation in rivers. Reduced erosion causes fertile topsoil to be maintained so that farmers do not need to use excessive fertilizer. Reduced erosion and excessive use of fertilizer contribute to maintaining water quality. Settlement areas that implement integration mechanisms between rain harvesting from rooftops and integrate it with small ponds can provide alternative sources of freshwater so that people can reduce groundwater utilization. This rain harvesting mechanism and small ponds is also useful in reducing and slowing down runoff during the rainy season, thereby reducing the risk of flooding.

Management of protected areas such as riverbanks with productive and economically valuable vegetation can protect the environment and provide additional income for the community. This income can come from fruit harvesting, ecotourism and carbon credit mechanisms. Planting vegetation that are habitat for predators of agricultural pests is also useful for maintaining the biodiversity function (Aminah et al., 2021). The presence of these predators can contribute to reducing excessive use of pesticides, thereby reducing production costs and maintaining water quality.

2 Study Area

2.1 Kupang and Sengkarang Watershed

The Kupang and Sengkarang watersheds are two adjacent watersheds in Central Java. Therefore, these two watersheds share similar topography and environmental, social, and economic challenges. The Kupang Watershed (180.10 km²) has a main river, 55.29 km long, that flows into the Java Sea. The Kupang Watershed covers three administrative areas: Pekalongan City, Pekalongan District, and Batang District. Among the three administrative areas, 55.3% of the Kupang Watershed area is in Pekalongan District (Table 1). The Sengkarang watershed (315.48 km^2) also flows into the Java Sea. Ninety five percent of the Sengkarang watershed area is in Pekalongan Regency, and the rest is in Pekalongan City (Table 2). Pekalongan City is the downstream area of these two watersheds, so it is vulnerable to various hydrological problems, especially flooding. Because the upstream and midstream of these two watersheds are in Pekalongan Regency and Batang Regency, solving the flood problem in Pekalongan City requires collaboration from these three regions.

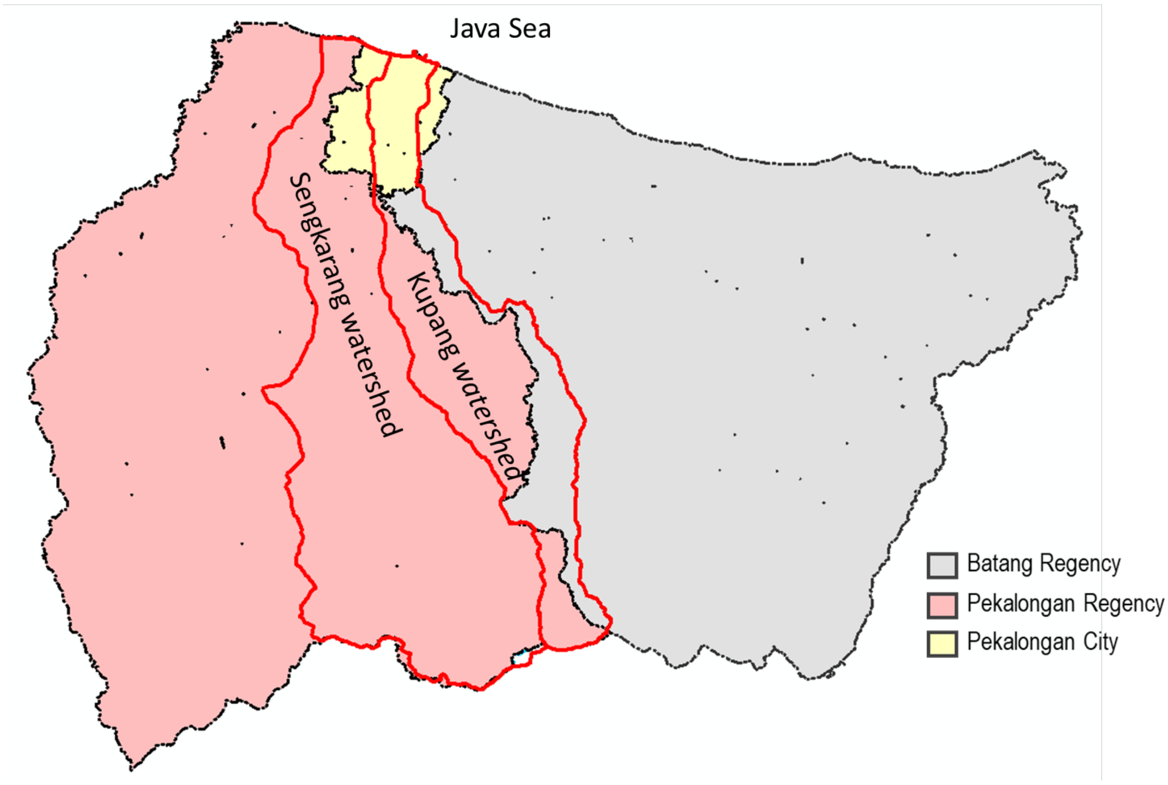

Figure 1 Location of the Kupang Watershed and the Sengkarang Watershed in Pekalongan City, Pekalongan Regency and Batang Regency

Table 1 Area of Kupang Watershed (Sudianto et al., 2023)

Regency/City	Sub-District	Area km^2	Area (%)
Pekalongan city	North Pekalongan	8.754	4.83
	South Pekalongan	7.558	4.17
	East Pekalongan	8.323	4.60
	West Pekalongan	3.076	1.70
	Total	**27.711**	**15.30**
Pekalongan District	Buaran	3.901	2.15
	Kedungwuni	6.507	3.59
	Karangdadap	20.268	11.19
	Talun	44.821	24.75
	Doro	9.802	5.41
	Petungkriyono	14.879	8.22
	Total	**100.178**	**55.31**
Batang District	Warungasem	10.982	6.06
	Wonotunggal	31.68	17.49
	Bandar	7.828	4.32
	Blako	2.685	1.48
	Wanayasa	0.044	0.02
	Total	**53.219**	**29.39**
Total Area of Kupang Watershed		**181.108**	**100.00**

Table 2 Area of Sengkarang Watershed (source: spatial analysis)

Regency/City	Sub-District	Area km 2	Area (%)
Pekalongan Regency	Bojong	2.63	0.83
	Buaran	8.35	2.65
	Doro	70.14	22.23
	Karanganyar	27.48	8.71
	Karangdadap	3.30	1.05
	Kedungwuni	23.53	7.46
	Lebakbarang	58.36	18.50
	Paninggaran	0.12	0.04
	Petungkriyono	65.35	20.72
	Talun	4.98	1.58
	Tirto	20.46	6.49

Regency/City	Sub-District	Area km 2	Area (%)
	Wiradesa	2.85	0.90
	Wonokerto	2.22	0.70
	Wonopringgo	9.23	2.92
	Total	299.00	94.78
Pekalongan City	Pekalongan Barat	8.16	2.59
	Pekalongan Selatan	3.73	1.18
	Pekalongan Utara	4.59	1.45
	Total	16.48	5.22
Total Sengkarang Watershed		315.48	100.00

2.1. Indicative Area of Blue-Green Space

The study identified indicative areas and locations for blue-green space development through spatial analysis, field observations, interviews, and discussions. The indicative areas are at the sub-district level, which were identified based on elevation data using spatial analysis to determine catchments, sub-catchments, and water flow directions. The field observations verified the indicative areas based on their actual conditions, taking into account the condition and depth of riverbanks, drainage channels, and groundwater levels. Discussions and interviews with the government sharpened the indicative area into several indicative locations at the village level based on land ownership status and their contribution to runoff.

Some criteria for indicative area and location of blue-green space are: (1) still having ground space or the ability to infiltrate water and reduce runoff, (2) the slope relatively flat to reduce water movement, and (3) a water collection area. Areas with a groundwater depth of more than 1 m during the dry season (when it is not raining) have the potential to infiltrate water. These areas typically experience light or no flooding. The water level can be observed through wells, drainage channels (whether semi-built or without concrete casting), or rivers. The water collection area is located where the tributaries meet based on spatial analysis. The flat location can be identified through elevation and ground checks. In the flat area, the water movement in the open channels (drainage) tends to be slow. Nine potential sub-districts may meet criteria based on the spatial analysis in the Kupang and Sengkarang Watershed, namely: (a) South Pekalongan, (b) Tirto, (c) Buaran, (d) Karangdadap, (e) Kedungwuni, (f) Wonopringgo, (g) Doro, (h) Talun, and (i) Warungasem. The field observations were carried out in these nine sub-districts to verify the indicative sub-districts, ensuring that these criteria were also met in the field.

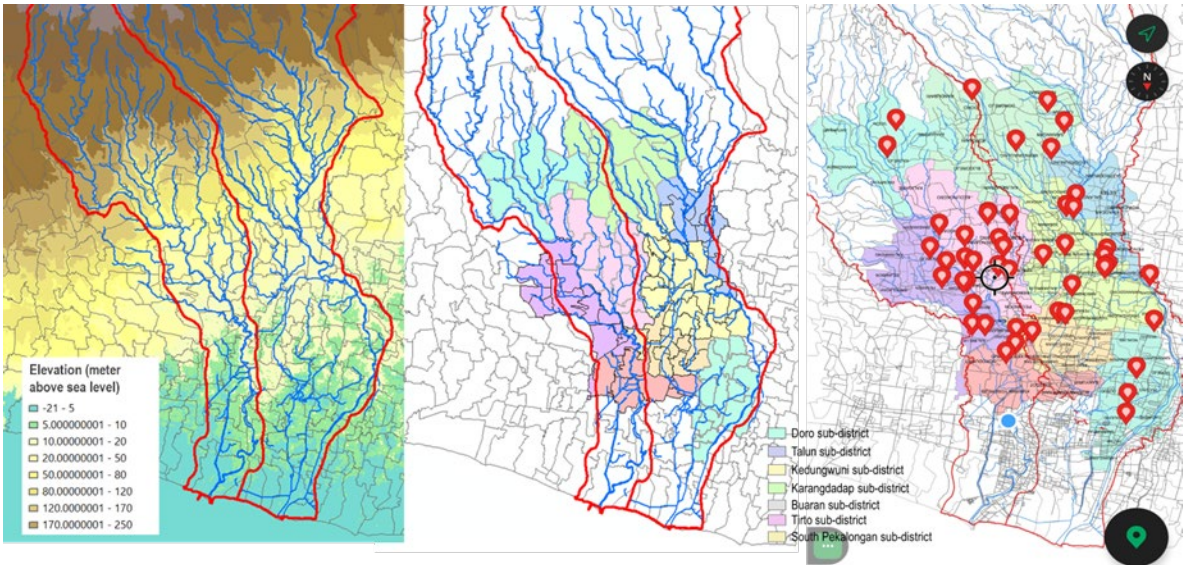

Figure 2 Elevation of potential areas between 10-50 m above sea level (Left), potential sub-district based on elevation level (middle) and ground checked location (right)

The field observation showed only four sub-districts meet all of these criteria: (a) Karangdadap, (b) Kedungwuni, (c) Warungasem, and (d) Wonopringgo, and only a few areas in South Pekalongan, Buaran, and Tirto meet the criteria. Talun and Doro sub-districts have hilly landscapes and are dominated by mixed dry agriculture land cover (Fig. 3). With such land cover that is mixed between crops and trees, the Talun and Doro sub-districts have naturally produced ecosystem services for carbon storage, biodiversity, and water management without turning it into a blue-green space. Some areas in South Pekalongan already have high water levels. Buaran District is not crossed by rivers, but it relies heavily on irrigation channels for rice cultivation. The blue-green space in Buaran sub-district may function more as a water storage though rain harvesting than runoff controller. Tirto sub-district has a relatively small catchment area due to its elongated shape along the Sengkarang River. However, the South Pekalongan, Tirto, and Buaran sub-districts are also beneficiaries of the blue-green spaces related to flooding and water scarcity.

Figure 3 Mixed dry agriculture in Doro and Talun sub-districts

Figure 4 Groundwater levels in Tirto sub-district during ground checks

In summary, the results of spatial analysis and field observations indicate that the indicative area (10,058 ha) for developing blue-green space for flood control should be in the sub-districts of Karangdadap, Kedungwuni, Warungasem, Wonopringgo, and some areas of South Pekalongan, Buaran and Tirto (Fig. 5). **All areas in Pekalongan City, as well as Buaran and Tirto sub-districts of Pekalongan Regency, are beneficiaries of blue-green space in relation to flood control (Fig 5**). Hydrological analysis and discussions with the government at the city, regency and sub-district levels narrowed down some indicative locations at the village level for the blue-green space development (Fig. 6 and Table 3). Hydrological analysis identified the villages based on elevation relative to the surrounding river and the presence of tributaries. Governments identified the location based on its proximity to the river and the open green space development plan. However, other villages within the indicative area still have the potential for blue-green space development because they are generally located in the water catchment areas from the upstream and midstream of the Kupang and Sengkarang watersheds. Because blue-green space can be built at the community level, collective action on a large number of blue-green space allows for more retained runoff. Building small blue-green spaces as a collective action provide Blue-green space can still be developed by regulating the inlet and outlet channels to and from the nearest drainage channels/rivers.

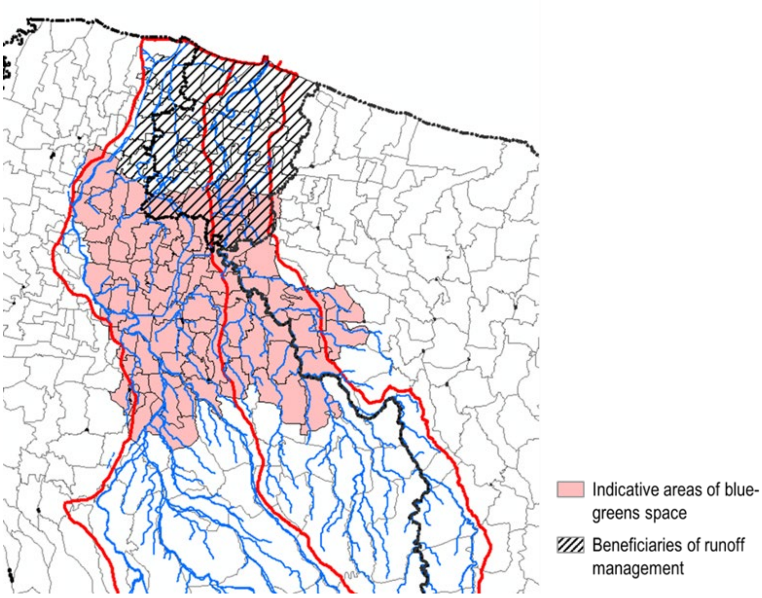

Figure 5 Providers and beneficiaries areas of blue-green space

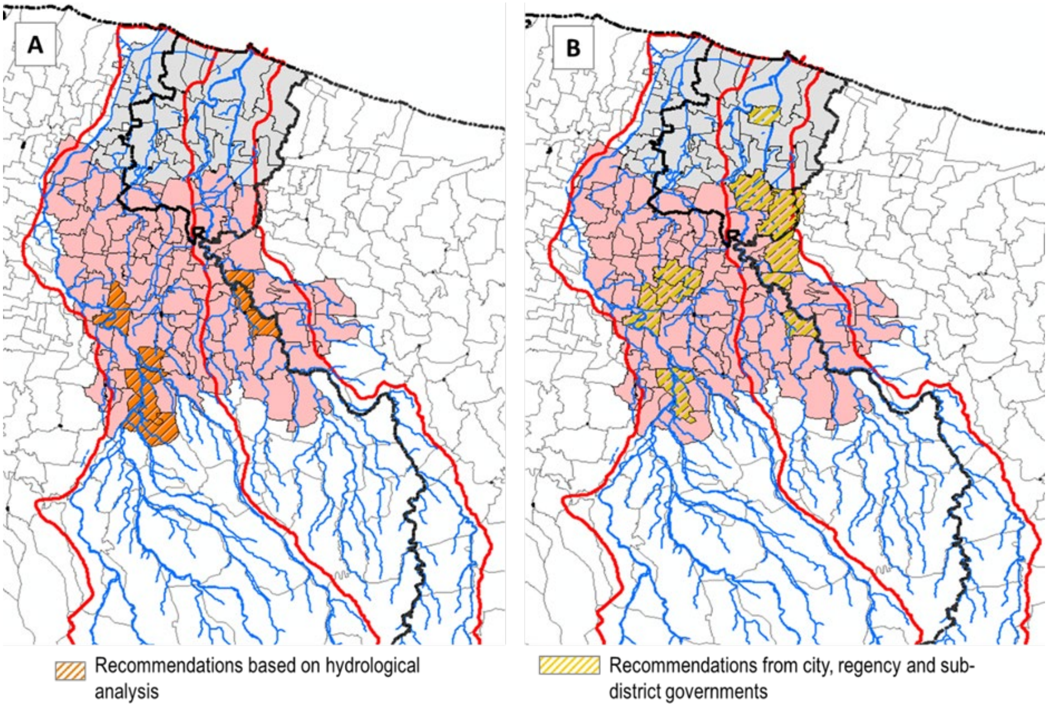

Figure 6 Villages for blue-green space development based on spatial and hydrological analysis (A) and discussion with governments (B)

Table 3 Indicative villages within the indicative area of blue-green space

Sub-district	No	Villages	Recommendations		Tenurial status	Remark	Priority	Landscape design (Section 3.4.2)
			Hydro-logical analysis	Govern-ments				
Wonopringgo, Pekalongan regency	1	LEGOK-GUNUNG	✓		Government assets	Need to check the Detailed Spatial Planning document to see if there is any government asset land that has not been utilized in that village		Design 1,2,3
	2	GALANG-PENGAMPON	✓	✓	Bengkok land	Need permission from village authority	P1	Design 1,2,3
Kedungwuni, Pekalongan regency	3	KEDUNG-WUNI BARAT	✓	✓	Bengkok land		P1	Design 1,2,3
	4	PAKISPUTIH	✓		Government assets	Need to check the Detailed Spatial Planning document to see if there is any government asset land that has not been utilized in that village		Design 1,2,3

Sub-district	No	Villages	Recommendations		Tenurial status	Remark	Priority	Landscape design (Section 3.4.2)
			Hydro-logical analysis	Govern-ments				
	5	Pekajangan		✓	Bengkok land	Need permission from village authority		Design 1,2,3
	6	AMBO-KEMBANG		✓	Bengkok land			Design 1,2,3
Karangdadap	7	Pangkah	✓		Government assets	Need to check the Detailed Spatial Planning document to see if there is any government asset land that has not been utilized in that village		Design 1,2,3
	8	Kalilembu	✓	✓	Bengkok land	Need permission from village authority	P1	Design 1,2,3
Warungasem	9	MASIN	✓	✓	Bengkok land		P1	Design 1,2,3
	10	Kalibeluk		✓	Village square	Need permission from village authority and ground checks regarding the surrounding drainage		Design 3

Sub-district	No	Villages	Recommendations		Tenurial status	Remark	Priority	Landscape design (Section 3.4.2)
			Hydro-logical analysis	Govern-ments				
						network for inlet-outlet arrangements		
South Pekalongan	11	Kuripan Yosorejo		✓	Tahura	Need permission from the city government and the design needs to be integrated with the Tahura spatial planning. Ground checks regarding the surrounding drainage network for inlet-outlet arrangements.		Design 1
	12	Sokoduwe t		✓	City government asset	The land is currently leased to the community for rice cultivation. The blue-green space design can accommodate rice management, allowing water to be used to irrigate the rice fields when needed.		Design 4

Regarding the design and development process, the government recommends that the location and design of blue-green spaces consider socio-cultural aspects. In addition to considering topography and inlet-outlet networks, site selection should include areas with minimal economic loss. During the development process, community involvement should be considered regarding the function and types of vegetation to build a sense of ownership. After construction, management operations need to involve community groups to ensure the sustainability of ecological and socio-economic functions.

2.2. Landscape and Hydrological Characteristics

2.1.1 Elevation

Based on elevation analysis from DEM data, the Kupang and Sengkarang watersheds have elevations of up to 2,600 meters above sea level, with the lowest points located in coastal areas below sea level. Pekalongan City and Tirto District in Pekalongan Regency, as flood-affected areas, have elevations below 10 meters above sea level. The indicative area for blue-green space development has elevations ranging from 10 to 60. Areas above 60 mdpl, such as Talun and Doro districts, have hilly topography, which makes runoffs and still have a lot of movement above the ground surface.

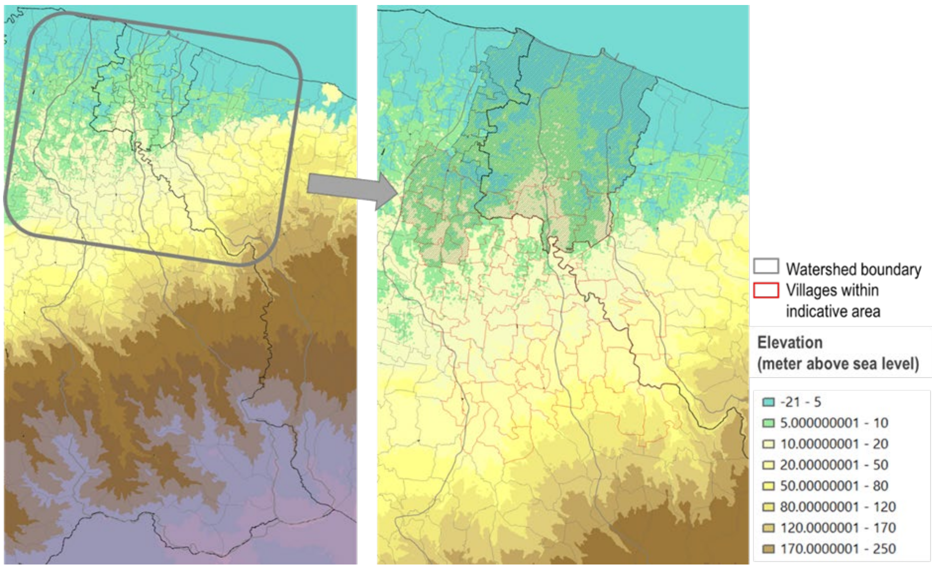

Figure 7 Elevation of Sengkarang and Kupang Watersheds

2.1.2 Land use and cover

Based on the results of the 2019 land cover analysis (Table 4 and Fig 8), rice fields dominate the Kupang Watershed and secondary forests dominate the Sengkarang Watershed. Forests, mixed gardens and settlements are the land cover that dominate the Kupang Watershed after rice fields. Rice fields, production forests, settlements and mixed gardens are the land cover that dominate the Sengkarang Watershed after secondary forests. This condition indicates that the Sengkarang Watershed has a higher proportion of tree-based land cover (forest, production forest, and mixed gardens) compared to the Kupang Watershed. In addition, the Sengkarang Watershed has a smaller percentage of built-up areas (including settlements and fishponds) and productive agriculture (such as rice fields and drylands) compared to the Kupang Watershed. This situation indicates that the Sengkarang Watershed offers better hydrological functions than the Kupang Watershed.

Land cover in the indicative area (10,058 ha) is dominated by rice fields (55.3%) and settlements (37.4%), and the rest is dryland agriculture (Figure 8). Based on field observations, some of the rice fields are rain-fed, while others receive irrigation from local irrigation systems. Vegetation in rain-fed rice fields is sometimes combined or rotated with dryland agriculture.

Table 4 Land cover 2019 of Kupang and Sengkarang Watershed

Land cover 2019	Kupang Watershed		Sengkarang Watershed	
	Ha	%	Ha	%
Secondary dryland forest	2,250.3	13.6	10,374.6	32.8
Production forest	1,229.4	7.4	4,769.2	15.1
Plantation	806.0	4.9	1,181.4	3.7
Dryland agriculture	900.1	5.5	975.4	3.1
Mixed dryland agriculture	3,292.3	19.9	3,656.2	11.6
Ricefield	5,089.0	30.8	5,660.4	17.9
Fishpond	175.9	1.1	415.0	1.3
Shrub	28.5	0.2	73.6	0.2
Cleared/opened land	10.3	0.1	37.9	0.1
Settlement	2,730.7	16.5	4,491.2	14.2
Total	16,512.5	100.0	31,634.8	100.0

2.1.3 Water balance analysis

The following water balance analysis uses a simple hydrological model based on the Thornthwaite and Mather water balance model (Hendrayana H., et.al, 2011). This hydrological model relies on general equations to calculate the main components of the water balance: potential evapotranspiration, actual evapotranspiration, storage (rainwater not used for evapotranspiration), and surface runoff (remaining rainwater that cannot be stored in the soil). Tables 1 and 2 are water balance analyses of the Kupang Watershed using 2011 rainfall data and 2008 land cover data (Table 3) based on the Water Balance Analysis Report in the Kupang and Sengkarang Watersheds (Purnama, I.L.S., et al, 2012).

Table 5 Water balance of the Kupang Watershed

Water balance components	Precipi-tation (P, mm)	Potential Evapo-transpiration (PE, mm)	P-PE (mm)	Storage (mm)	Actual Evapotrans-piration (AE, mm)	Runoff (mm)	Runoff (%)
Jan	569	155	414	414	155	247.5	43%
Feb	669	124	545	545	124	396.3	59%
Mar	322	152	170	170	152	283.5	88%
Apr	240	158	82	82	158	182.7	76%
May	206	164	42	42	164	112.5	55%
Jun	91	150	-59	0	142	56.3	62%
Jul	49	143	-94	0	104	28.1	57%
Aug	42	151	-109	0	80	14.1	34%
Sep	43	161	-118	0	67	7	16%
Oct	98	177	-79	0	107	3.5	4%
Nov	233	175	58	0	175	1.8	1%
Dec	321	161	160	160	161	80.9	25%
Total	2883	1871	1012	1413	1589	1414.2	
Max	669	177	545	545	175	396.3	88%
Min	42	124	-118	0	67	1.8	1%
Average	240.25	155.9167	84.33333	117.75	132.4167	117.85	43%

Table 6 Water balance of the Sengkarang Watershed

Water balance components	Precipi-tation (P, mm)	Potential Evapo-transpiration (PE, mm)	P-PE (mm)	Storage (mm)	Actual Evapotrans-piration (AE, mm)	Runoff (mm)	Runoff (%)
Jan	577	124	453	453	124	349.1	61%
Feb	755	101	654	654	101	501.3	66%
Mar	457	123	334	334	123	417.9	91%
Apr	346	127	219	219	127	318.5	92%
May	291	131	160	160	131	239.1	82%
Jun	140	121	19	19	121	129.3	92%
Jul	89	116	-27	0	114	64.6	73%
Aug	65	120	-55	0	108	32.3	50%
Sep	70	129	-59	0	106	16.2	23%
Oct	187	142	45	45	142	8.1	4%
Nov	398	140	258	258	140	133.1	33%
Dec	487	130	357	357	130	245	50%
Total	3862	1504	2358	2499	1467	2454.5	
Max	755	142	654	654	142	501.3	92%
Min	65	101	-59	0	101	8.1	4%
Average	321.8333	125.3333	196.5	208.25	122.25	204.5417	60%

Table 7 Land use 2008 in the Kupang and Sengkarang watersheds used in the Water Balance Analysis Report of the Kupang and Sengkarang Watersheds.

Land use	Kupang watershed		Sengkarang Watershed	
	Ha	%	Ha	%
Forest	2093.33	11.6%	8416.56	27.5%
Swamp forest	2.72	0.0%		0.0%
Mixed garden	3718.77	20.6%	5647.2	18.4%
Waterbody	249.86	1.4%	429.87	1.4%
Shrub	1275.37	7.1%	2700.58	8.8%
Ponds	58.96	0.3%	247.82	0.8%
Built in area	23.96	0.1%	15.75	0.1%
Settlement	3537.34	19.6%	4212.47	13.8%
Grassland	90.64	0.5%	97.64	0.3%
Swamp	8.31	0.0%		0.0%
Irrigated ricefield	6252.8	34.7%	6860.25	22.4%
Rainfed ricefield	16.75	0.1%	193.78	0.6%
Agriculture	692.09	3.8%	1807.98	5.9%
Total	**18020.9**	**100.0%**	**30629.9**	**100.0%**

Table 8 Land cover 2019 of Kupang and Sengkarang Watershed (Pre-FS Blue-Green space study)

Land cover 2019	Kupang Watershed		Sengkarang Watershed	
	Ha	%	Ha	%
Secondary dryland forest	2,250.3	13.6	10,374.6	32.8
Production forest	1,229.4	7.4	4,769.2	15.1
Plantation	806.0	4.9	1,181.4	3.7
Dryland agriculture	900.1	5.5	975.4	3.1
Mixed dryland agriculture	3,292.3	19.9	3,656.2	11.6
Ricefield	5,089.0	30.8	5,660.4	17.9
Fishpond	175.9	1.1	415.0	1.3
Shrub	28.5	0.2	73.6	0.2
Cleared/opened land	10.3	0.1	37.9	0.1
Settlement	2,730.7	16.5	4,491.2	14.2
Total	16,512.5	100.0	31,634.8	100.0

The relevance of hydrological modeling results to current conditions and the effectiveness of blue-green space

The water balance analysis used in the Water Balance Analysis Report of the Kupang and Sengkarang Watershed uses land cover (Table 3) with a composition percentage similar to the 2019 conditions (Table 4) dominated by rice fields, forests, and mixed gardens (mixed dryland agriculture and settlement). Therefore, a rough analysis at the watershed level estimates that approximately 40-60% of rainfall is converted into runoff. With an average annual rainfall of 3000 mm and a runoff coefficient of 50% (average between 40-60%), the Kupang and Sengkarang watersheds produce a runoff of 1500 mm. However, this runoff calculation is carried out at the watershed level and most of the runoff will flow into the river and does not directly flow into the blue-green space in the middle and downstream areas. Microtopography, routing time, and routing distance of runoff from upstream to downstream areas provide delay time and buffer for peak runoff events. In addition, conservation activities in upstream areas that focus on enriching tree stands and canopy strata can increase infiltration, thereby reducing runoff production from those areas. In the midstream areas, efforts to control water runoff in the river require reservoirs or dams with proper construction.

By design, blue-green spaces are not intended to control runoff in rivers, but rather to collect and retain the runoff before it reaches the river. The effectiveness of a blue-green space is calculated based on its capacity to store water, as determined by its design. For example, a blue-green space of 1 ha with 50% of hollowed area to store water during rain and a depth of 0.5 m has a water-storage capacity of 25,000 m3 (10,000 m2 x 50% x 0.5 m). If in one year there are 150 days with above-average rainfall that make the blue-green space optimal, then the blue-green space retains 3.75 million m^3 of water per year.

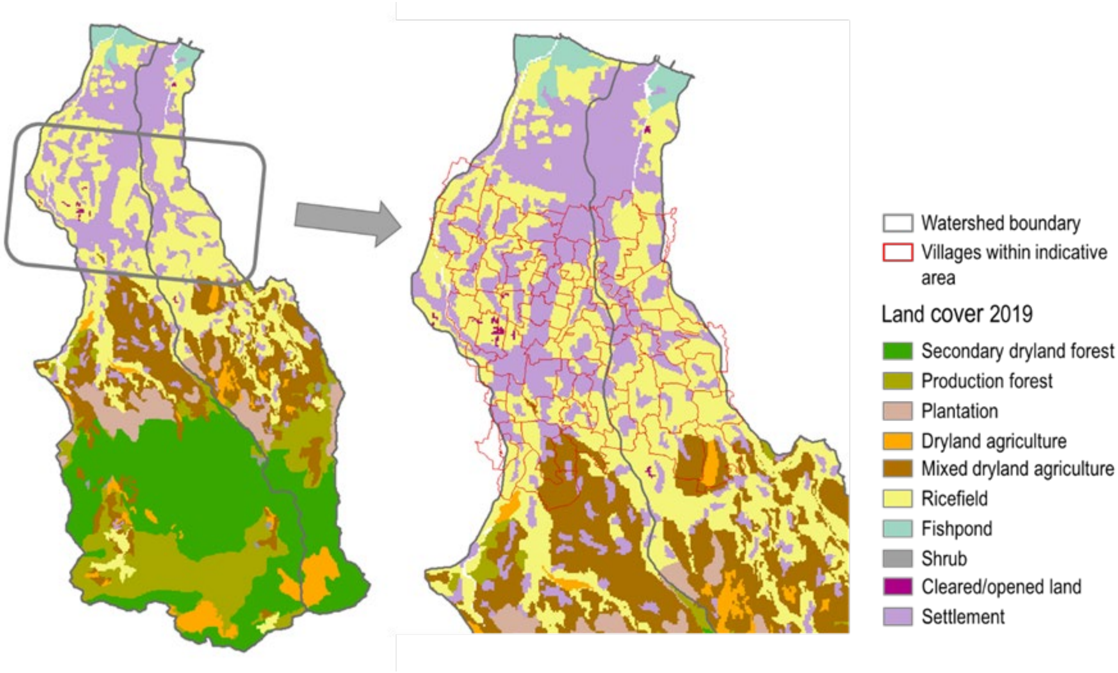

Figure 8 Land cover 2019 of Kupang Watershed and Sengkarang Watershed (Source)

2.3. Socio-Ecological Issues

The Kupang and Sengkarang watersheds have relatively flat topography in the downstream area, slightly steep in the midstream and steep to very steep in the upstream. This condition makes the upstream and midstream areas have a high risk of erosion, which affects sedimentation in the downstream areas. Sedimentation in the downstream area decreases the water bodies storage capacity for rain floods from the upstream and tidal floods from the sea. The higher the sedimentation, the smaller the water storage capacity in the downstream area so that flooding can occur when the water accumulation exceeds its storage capacity. According to BNPB (2020) and Brief Report Hazard, Vulnerability, and Risk Assessment of Kupang Watershed (Mercy Corps Indonesia, 2024), the flood event that often faced by Pekalongan City and Pekalongan District, was caused by increased runoff from upstream to downstream and tides from the sea. The areas most affected by the flood were lowland areas, especially downstream from the Kupang and Sengkarang watersheds.

The recharge area in the upstream relies solely on forested areas and mixed gardens that still retain trees: the less tree cover, the more runoff generated during rain events. Based on land cover, midstream areas are dominated by settlement and agricultural land (rice fields and dryland agriculture), which have low water infiltration capacity. According to the Laporan Akhir Pra Kajian Kelayakan dan Analisa Penentuan Lokasi Waduk (Mercy Corps Indonesia, 2022) and information from Kepala Bapperida Kota Pekalongan, the downstream and coastal areas are also experiencing a decrease in groundwater levels due to excessive groundwater extraction. This groundwater extraction accelerates land subsidence, causing parts of the coastal area to become submerged below sea level. From all these situations, many factors contribute to flooding in the Kupang and Sengkarang watersheds, including socio-economic conditions of the community, infrastructure, land cover, topography, high rainfall, sea tides, and climate change. These causes do not stand alone but all are related, creating complex causal effects.

3 Blue-Green Space Development Preparation

On 26 May 2025, MCI conducted discussion with Batang Local Development Planning Agency focused on exploring GCF opportunities and the relevance of Blue-Green Space (BGS) interventions within the broader climate resilience context. This was followed by a session on 16 June 2025, which highlighted best practices in resilient livelihood model and their potential application and further development in Batang. Together, these engagements provide a foundation for aligning BGS and resilient livelihood approaches with GCF priorities while ensuring their relevance and scalability in the Batang context. The objective of blue-green space design is to determine the definitive location of the blue-green space. The decision to determine the definitive location is based on physical factors of the location, permits and support from the surrounding community for the blue-green space development process.

3.1. Stages of Blue-Green Space Preparation

There are two phases of blue-green space design, namely: (1) physical and hydrological mapping and inspection of indicative locations and (2) socio-economical discussion and consultation. The objective of location determination phase is to change the status of the prospective location from indicative to definitive based on an assessment of the physical feasibility and acceptance by the community. Once a location's status changes from indicative to definitive, it signifies that the location is physically and hydrologically feasible to become a blue-green space, and the surrounding community supports its development. To ensure the sustainable management of the blue-green space after construction, the project needs to secure a letter of approvalwith the landowner and/or potential blue-green space manager. The MoU should include a management strategy and a post-construction operational budget. The next step is to design a blue-green space according to physical and hydrological characteristics of the area. To fulfill its socio-economic function, the design also needs to incorporate the opinions of the community from various groups (gender, age, and disability). Figure 9 shows the design preparation stages of the blue-green space.

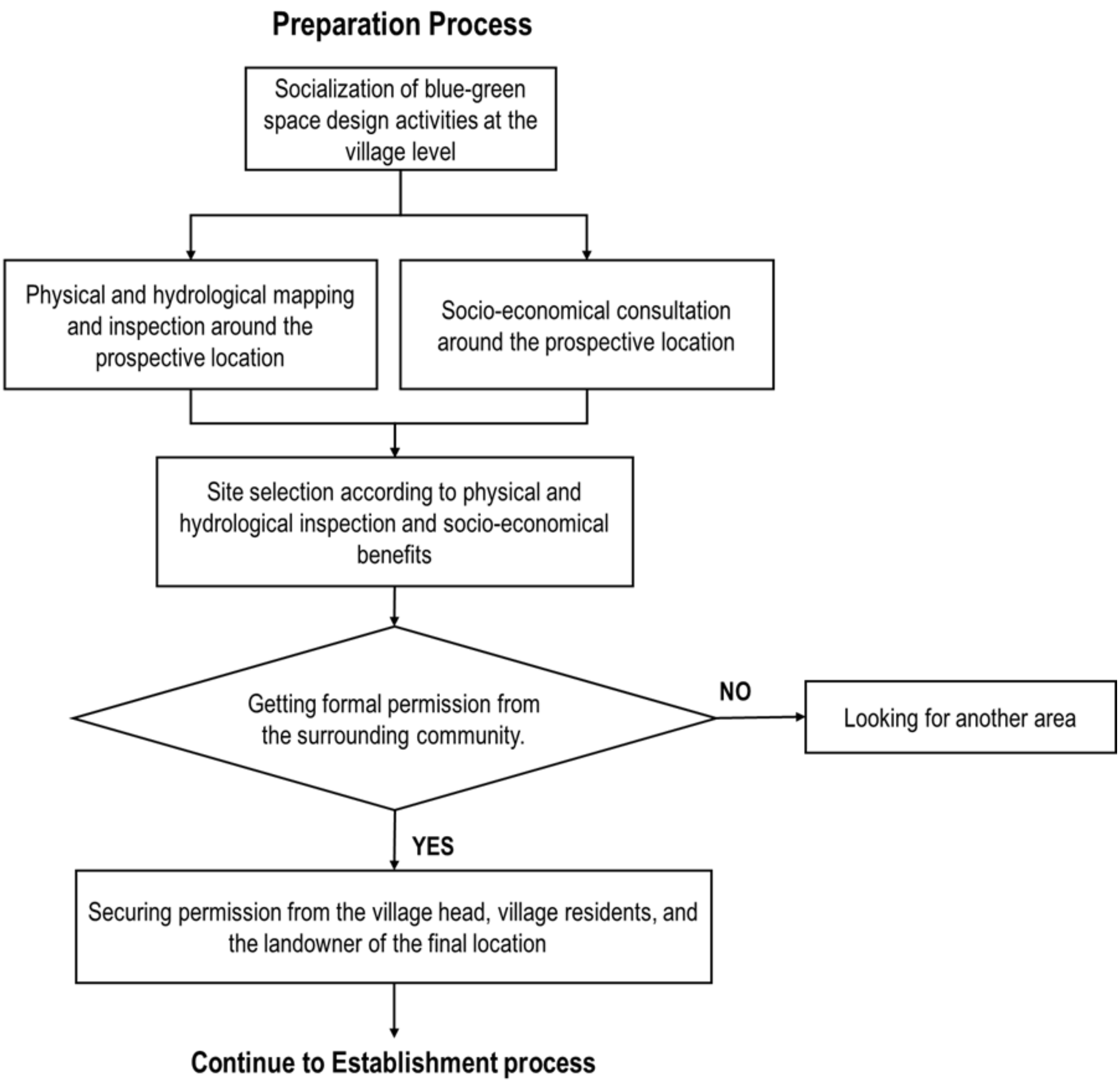

Figure 9 Stages of blue-green space design process

3.2. Physical and hydrological mapping and inspection of the indicative location

The physical condition assessment of the indicative blue-green space location aims to ensure that the site is suitable for the construction of a blue-green space, both physically and hydrologically. This assessment is carried out by considering the depth of groundwater in and around the location, and the distance to several essential objects. The components of the physical condition assessment can be seen in Table 5. These assessments are conducted through mapping and field inspections at the site level and measurements of the area's elevation and contour.

Table 9 Components of physical and hydrological assessment

No	Assessment components	Description	Criteria and indicators

1	Area of the indicative area.	To identify the area dedicated to blue-green space	Area (m^2)
2	Condition of the drainage network around the area	To see whether there is drainage around the location and what its condition is, especially the drainage that will later be connected to the outlet of blue-green space.	The quality and quantity of the drainage network (e.g., physical conditions, local management arrangement, cleanliness, etc.)
3	Catchment area of the indicative location	To identify the area where water flows to the indicative area	Area (m^2)
4	Groundwater in and around the area (radius 0-100 m)	The groundwater level assessment is used to determine whether there is still room for infiltration or not. The higher the groundwater level in an area, the more saturated the location. The establishment of blue-green space becomes difficult and does not function properly when the groundwater level is less than 1 m during the dry season.	Average of Groundwater depth in and around the indicative location.
5	Groundwater level in the lowland area (radius 100- 500 m)		Average of Groundwater depth in the lowland of the indicative location.
6	Elevation up to a radius of 1000 m	Seeing whether the surrounding area tends to be flat or somewhat steep. This affects the amount and speed of runoff accumulation from higher areas.	Flatness of the area of 1000 m
7	Land cover in and around the area	Land use/cover around the blue-green space will affect the design of the risks monitoring system and the contingency plan.	Percentage land cover and land use type (productive and not-productive types) in and around the indicative area.
8	Distance to settlement	To calculate impacts and establishment costs. If the location of blue-green space is far from the settlement area, it may offer fewer social benefits. However, if they are too close, risk monitoring systems and contingency plans become essential components of this blue-green space.	Distance (m)
9	Distance to community land		Distance (m)
10	Distance to river		Distance (m)

11	Distance from indicative location to the flooded areas	To identify the flooded location in and around indicative locations based on information from the surrounding community. Together with topographic/elevation details, this information helps determine the blue area within the green-blue space and its inlet-outlet.	Distance (m)
12	Beneficiaries area	To identify lowland areas that benefit from reduced water runoff, which prevents flooding by retaining it through blue-green spaces.	Area (m^2)
13	Lower areas that may be affected by the water release from the blue-green space	To identify the impacted areas of the water release from the blue-green space.	Impacted area (m^2)
14	Gray infrastructure requirement	To identify the potential for gray infrastructure for blue-green space establishment.	Percentage and type of potential gray infrastructure.

3.3. Socio-economical consultation and discussion of the indicative location

The assessment of the socio-economic conditions of the prospective blue-green space location aims to determine the acceptance of the blue-green space by the surrounding community, identify potential problems that may arise as a result of the blue-green space according to local perception, and find an acceptable design of the blue-green space. This assessment can be carried out through socialization activities and/or discussions with the community around the location. Table 6 shows the components of the socio-economic assessment of the prospective location.

Table 10 Components of socio-economical assessment

No	Assessment components	Description	Criteria and indicators
1	The benefits expected by the community from this blue-green space, including different socio-economic groups (gender, age, disability)	To dete rmine the socio-economic functions expected by society.	Socio-economical properties (e.g., productive areas protected from flooding, number of public areas protected from flooding population, etc.)

2	Potential problems felt by the surrounding community.	To understand their concerns regarding the existence of blue-green space. They may allow the establishment of blue-green space if we can demonstrate the solutions to those concerns.	Result of risk analysis
3	Acceptance of the blue-green space by the surrounding community	To get community permission for blue-green space establishment	Acceptance by communities
4	Post-construction management strategy	To identify who will manage and where the management budget will come from.	The existence of a post-construction management strategy
5	Willingness of community representatives to be involved in the blue-green space design process	To ensure that they also benefit from the blue-green space, not only the communities affected by the flood.	The existence of a person or group appointed by the village (by Village leader degree) who is dedicated to being actively involved in BGS planning.
6	Expected design by the local community	To encourage their involvement in the design and development process	The existence of expected design by the local community.
7	Accessibility and safety of blue-greens space	To identify accessibility of blue-green space for public and its safety considerations	Safety and accessibility of the blue-green space.
8	Construction cost estimation	To identify the budget required to build blue-green space at that location	Budget (IDR)

3.4. Site Selection

After conducting identification, physical and hydrological mapping, and inspection (Table 9), and Socio-Economic consultation with involved stakeholders (Table 10), location selection can be done using score analysis and weighting of each assessment component. The score value can be developed based on variations in survey results from several potential blue-green space areas. The area with the total highest score is the priority area for blue-green space development. Based on Figure 9, the follow-up for the priority area is to obtain formal written permission from the surrounding community and landowners for the development of Blue-green space, as a basis for drafting the MoU.

Table 10a. Example of scoring for each assessment of criteria and indicator that can be used for site selection.

No	Prioritisation criteria	Criteria & indicators	Description
1	Maximising the area of the blue green space	Area (m^2)	The plot size is recommended to be a minimum of 2,500 m^2, and unlikely to be over 15,000 m^2.
2	Maximising area served by blue green space and number of beneficiaries	Area (km^2) No of beneficiaries	The area served is recommended to be at least 1 km^2 with priority given to larger catchments, although typically not exceeding 5 km^2.
3	Predominantly flat terrain within a 1000 m radius	Flatness of the area of 1000 m (%)	Slope preferably does not exceed 12%, with preference for flatter terrain. The exact value to be confirmed during design phase.
4	Condition of the drainage network around the area	The presence of drainage around the location	The area should be served by an existing drainage network.
		Cleanliness of drainage	Preference is given to areas with well-maintained and clean drainage systems.
5	Groundwater in and around the area (radius 0-100 m), and groundwater in the lowland/lower area	Average of groundwater depth (during the rainy season) (cm)	Areas with greater groundwater depth are preferred, with recommended minimum assumed depth of 50 cm.
6	Land use/cover in and around area	Land use in the targeted area	The blue-green space is assumed to be located on underutilized land (e.g., shrubland or unmanaged areas).
7	Proximity to settlement	Distance (km)	The space is recommended to be situated no more than 5 km from

			settlements, with priority given to nearer locations.
8	Acceptance of the blue-green space by the surrounding community	permission	The blue green space must require permission from the surrounding community.

A set of exclusion criteria will be followed to ensure that activities related to the blue-green space component of this project are aligned with GCF investment criteria and GCF ESS Category C. Sites will be excluded from consideration if they meet any of the following conditions:

- **Drainage:** Absence of an existing drainage system.
- **Land Use:** Land currently under productive use (e.g., agriculture or active economic use). Land that will result in the reduction or displacement of existing productive land for local farmers or communities.
- **Permissions:** Lack of necessary permits or stakeholder approvals for development, particularly by residents of the surrounding settlements.
- **Community health:** Presence of contamination posing risks to community health and safety.
- **Land tenure:** Unclear, disputed, or insecure land ownership or tenure status.
- **Management arrangements:** Absence of a management plan endorsed by the relevant working group.
- **Financial viability:** Absence of a budget plan that adequately covers operational and management costs and does not demonstrate potential for economic returns or income generation.

3.5. Blue-Green Space Designs

3.4.1. Physical and hydrological design of blue-green space

The hydrological and physical design of the land must accommodate water sources, inlets and outlets, and the location/form of puddles. The water source for a blue-green space can come from rainwater alone or rainwater combined with nearby drainage. If the blue-green space receives water from nearby drainage, the quality of the drainage water entering the blue-green space must be considered. The cleanliness of the blue-green space will be disturbed if the water entering is from household waste drainage. The inlet and outlet can affect water circulation within the blue-green space. The infiltration wells using recycle materials such as pressed plastic, can be built to accelerate water infiltration into the ground. However, the construction, design, and materials used for infiltration wells require a technical civil engineering study to determine the feasibility of constructing infiltration wells at that location. The inundation location affects the water capacity to be retained by the blue-green space and the desired landscape design.

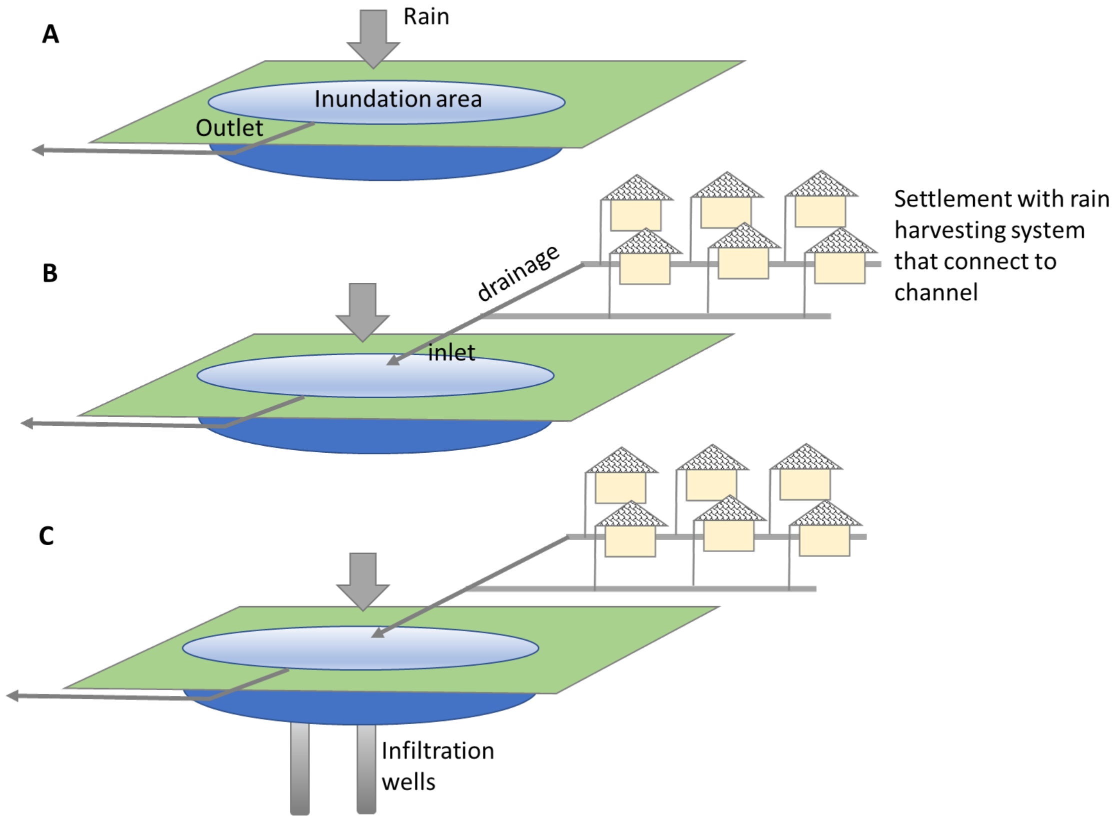

Figure 10 Physical and hydrological design of blue-green space

Basic blue green space with only rainwater as the source of water (A), blue-green space with additional water source from the nearby drainage (B), blue-green space with infiltration wells to accelerate the infiltration rate (C)

3.4.2. Landscape design

There are several landscape design recommendations from blue green space based on location, benefits and type of land cover (Table 7).

Table 11 Landscape designs of blue-green space

No	Design	Descriptions	Co-benefits
1	Design 1	Blue-green space is built as a city/regency/sub-district/village park.	Public health and recreation physical activity opportunities and improved fitness Mental health benefits from nature access Community gathering spaces for social interaction

No	Design	Descriptions	Co-benefits
			Economic benefits from fruit trees can be used for the blue-green space operational. Carbon credit and biodiversity credit Micro-climate regulators and pollution control
2	Design 2	Blue-green spaces combine gardens and productive land. Agricultural crops can be planted on ridges (guludan) to prevent them from being submerged during rain.	People can enjoy the beauty of nature Economic Income Generation - Direct revenue from agricultural sales combined with reduced infrastructure costs for flood control Food Security and Local Access - Provides fresh, locally grown food while reducing dependency on external food sources Community Resilience - Builds social cohesion through shared food production while creating climate adaptation capacity for extreme weather events
3	Design 3	Blue-green space is built in the village square	Community Social Hub Creates a central gathering place that strengthens social connections, supports local events and markets, and provides safe recreational space for all ages. Health and Wellbeing Improvements Provides accessible green space for physical activity and relaxation, improves air quality, reduces urban heat effects, and offers mental health benefits through nature contact. Climate and Environmental Resilience Enhances biodiversity through habitat creation, sequesters carbon, improves local microclimate conditions, and demonstrates sustainable practices for the broader community.
4	Design 4	Blue-green space is built in areas with rice fields or agricultural gardens.	Biodiversity Conservation and Ecosystem Services Creates habitat corridors for beneficial insects, birds, and aquatic species that provide natural pest control, pollination services, and maintain ecological balance supporting agricultural systems. Climate Regulation and Carbon Sequestration Wetland areas and diverse vegetation capture and store significant amounts of carbon while moderating local temperatures and humidity, creating more favorable microclimates for crop growth. Diversified Income Streams and Food Security Enables integrated farming systems combining traditional crops with aquaculture, agroforestry, eco-tourism, and sustainable harvesting of wetland products, providing multiple revenue

No	Design	Descriptions	Co-benefits
			sources and reducing economic risk for farming communities.

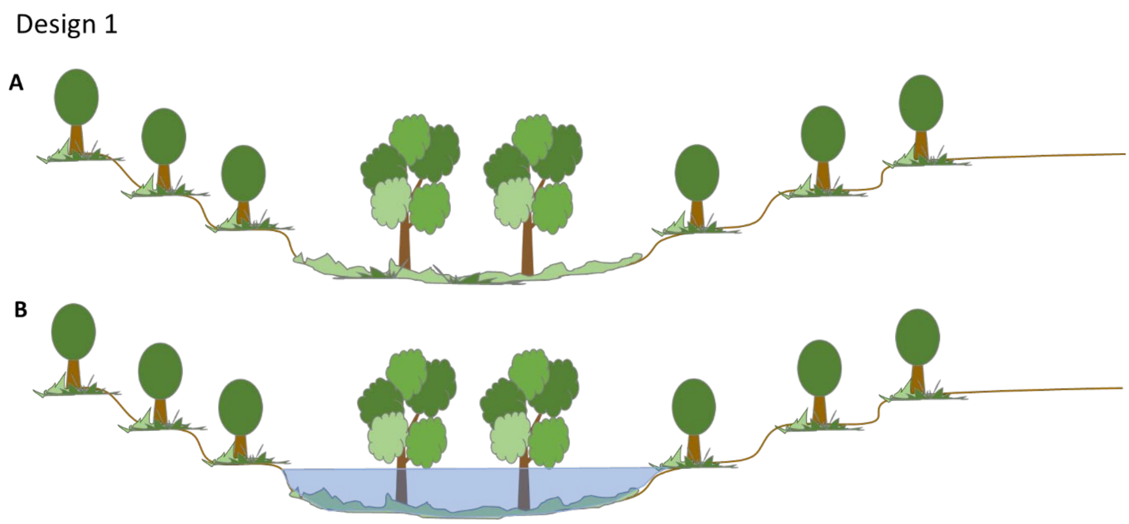

Figure 11 Design option 1: condition of blue-green space during the dry season (A), condition of blue-green space during the rainy season with water inundation as temporary water storage (B)

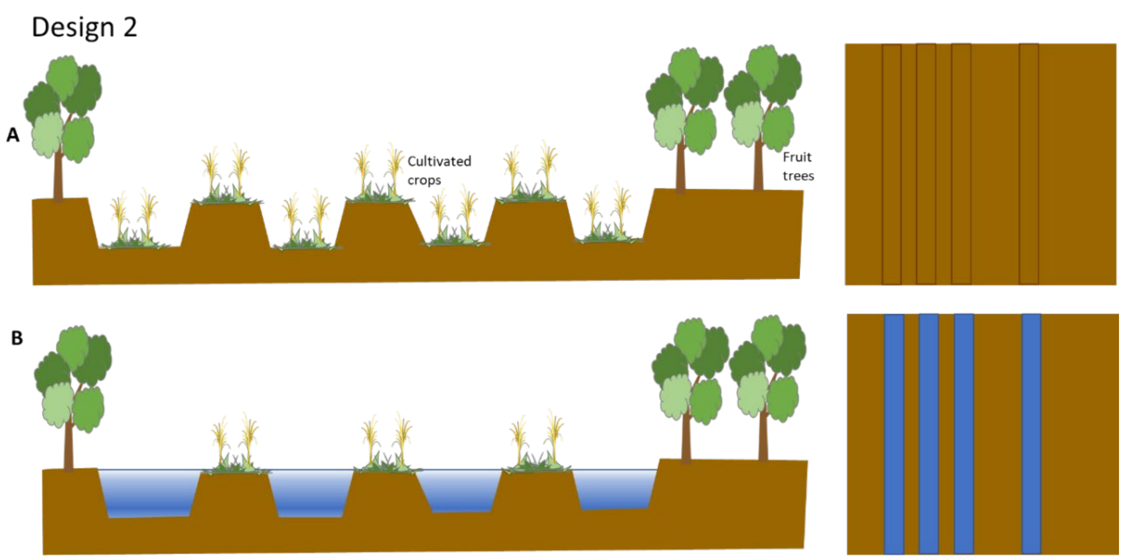

Figure 12 Design option 2: Blue-space is located between the ridges so that people can still plant vegetables or other agricultural crops in higher places, (A) during the dry season, (B) during the rainy season.

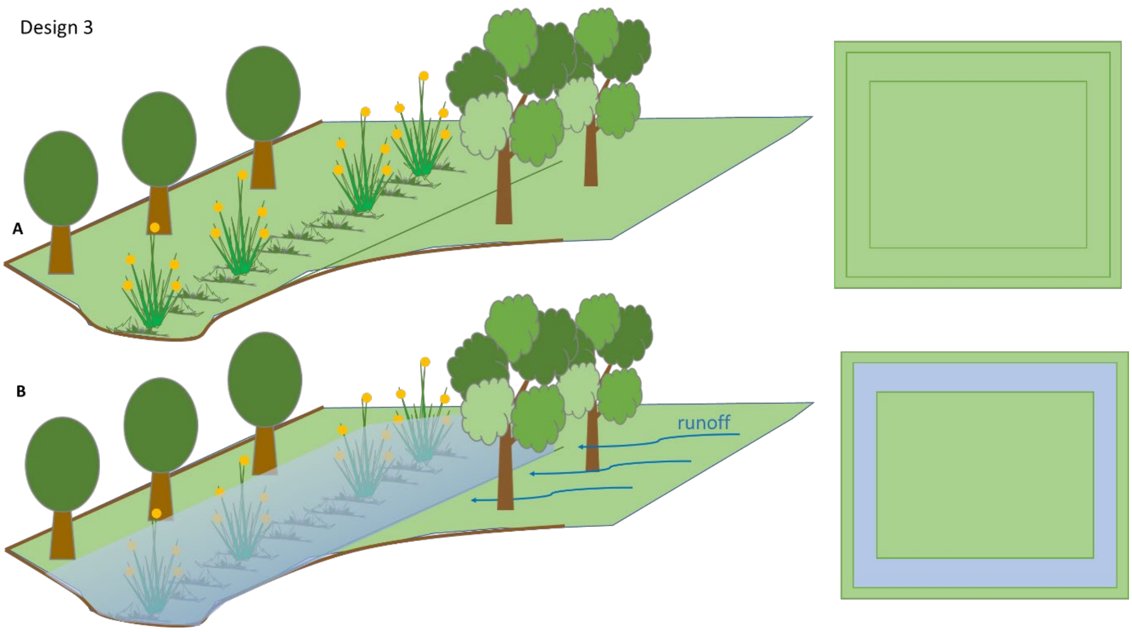

Figure 13 Design option 3: blue space is located around the area so that people can use the central area as a field or other public area, (A) during dry season, (B) during rainy season

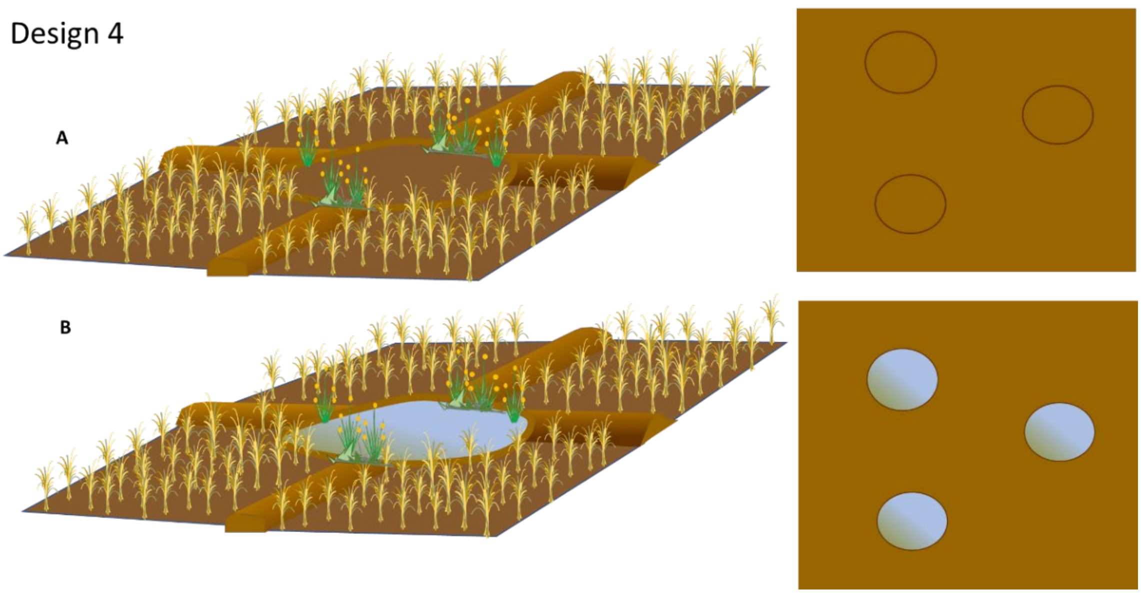

Figure 14 Design option 4: Blue spaces are spread out in the middle of the rice fields, farmers can use these areas to temporarily store water, (A) during the dry season, (B) during the rainy season.

4 Blue-Green Space Establishment

4.1. Stages of Establishment Process

The establishment begins by forming a working group consisting of core members involved in the preparation process and representatives from the city/regency government, villages, and communities. Beyond the establishment of working groups and public consultations, four components need to be prepared during the establishment process are: (1) Provide physical and hydrological design of blue-green space based on the results of physical and hydrological characteristic assessments, (2) Provide landscape design based on the results of socio-economic characteristics assessments, (3) Provide a risk monitoring and communication systems and procedures for blue-green space and its surrounding areas and (4) Provide a contingency plan for blue-green space and its surrounding areas. Each component requires an active involvement, coordination and communication from various parties, and regular working group meetings are key to the progress of blue-green space establishment process. Prior to the implementation of the establishment, the working group presents the overall design of the blue-green space to the wider public through public consultation, especially to the lower areas that may be affected during water release.

Before providing a more detailed description of each component in the next subsection, Table 8 shows a summary of the actor requirements and outputs of each component.

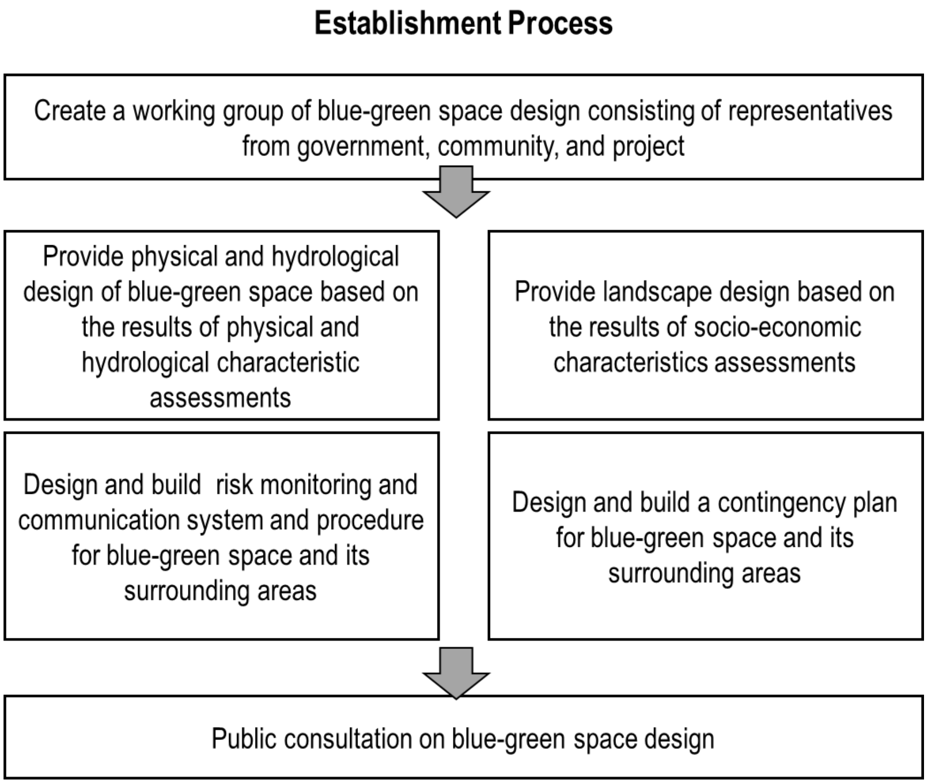

Figure 15 Stages of blue-green space establishment process

Table 12 Output and actors of each establishment process.

No	Activity	Outputs	Key actors	Support actors
1	Provide physical and hydrological design of blue-green space	Location and area of water 'hollow' (cerukan, cekungan) Inlet and outlet Water source Safety infrastructures	Government, local community (optional)	Water engineering, especially water drainage
2	Provide landscape design	Landscape design Vegetation types Zoning	Local communities Government	Architecture landscaper
3	Develop monitoring and communication system and procedure of blue-green space risks	Risk monitoring systems and procedures for locations around and below blue-green space Communication systems and procedures for surrounding areas Communication system and procedures for the lower areas	Governments (regency/city, sub district and village)	Water engineering or hydrologist
4	Develop flood contingency plan and integrate it with the regional document	Flood c ontingency plan at the sub-district level Integration with the regional flood contingency plan		-

4.2. Physical and hydrological design of blue-green space based on the results of physical and hydrological characteristic assessments

The physical and hydrological design is to optimize the hydrological functions of the blue-green space. For example, blue-green spaces for flood control are expected to store and retain runoff as much as possible, giving the lower area time to distribute the water to the sea. Therefore, physical and hydrological design are crucial for fulfilling the primary function of blue-green spaces. Table 9 shows the key components that are input into the physical and hydrological design.

Table 13 Key components in determining physical and hydrological design

No	Key components	Description
1	Detail contour of the location	The shape is depicted using the contours of the location to determine whether there are natural depressions or hollows in the area. If so, the inundation area can be

No	Key components	Description
		focused on that location. If not then the design should create the inundation location.
2	Amount and type of water sources and inlet	The water sources expected to fill the basin: only rainwater or rainwater and runoff from the location above.
3	Amount and type of water outlet	To prevent flooding/overflows that could cause disasters in surrounding areas, it is necessary to establish one or more outlets to regulate water levels in the blue-green space. These outlets must be equipped with water gates to regulate water levels in the inundated area (Figure 16).
4	Maximum capacity of water storage	This capacity can be determined by considering the carrying capacity of the location in relation to the water pressure stored in the area.
5	Potential integration with other water resource management infrastructure: example of infiltration wells (optional)	The water infrastructure can enhance the function of blue-green spaces. For example, the presence of infiltration wells has the potential to increase water storage capacity by accelerating the infiltration process. However, the construction of this infrastructure requires site feasibility testing, to determine the appropriate infrastructure design.
6	Distance to nearest channel (optional)	To include blue-green space in the landscape hydrology system so that it can have a wider impact.

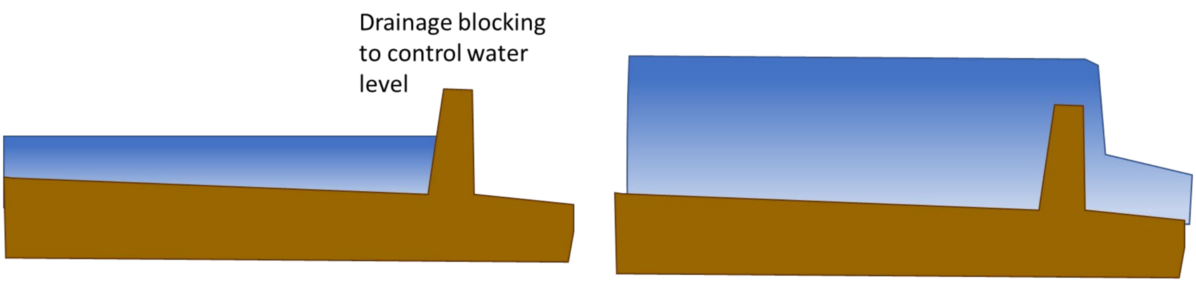

Figure 16 Drainage blocking at the outlet to control the water level in the blue-green space. The blocking can be replaced with a water gate, but both options require management and maintenance.

4.3. Landscape design based on the results of socio-economic characteristics assessments

Landscape design selection focuses on the socio-economic value of the blue-green space as desired by the surrounding community. If the community expects the blue-green space to be a family recreation area, sports venue, etc., in that case the landscape design can focus on beauty, family safety, and the provision of sports facilities. If the community expects the blue-green space to provide additional economic benefits, the landscape design can focus on the enabling conditions for economically valuable plants. Landscape design requires input and active involvement from the surrounding community to ensure it meets their desires. Several key components in determining landscape design can be seen in Table 10.

Table 14 Key components in determining landscape design

No	Key components	Description
1	Identify other functions of blue-green space according to the surrounding community	To determine the socio-economic functions expected by society.
2	Determine and agree on the proportion of built-up areas, green areas and blue areas	To bridge the gap between hydrological functions and socio-economic functions, as well as other policies related to public spaces.
3	Determine the types of vegetation for the blue-green space	The types of vegetation to be planted or cultivated within a blue-green space influence the landscape design. Some factors that need to be considered when selecting plant types include: a) Are they water-resistant? b) what water level can be accepted by vegetation? c) What is the maximum duration of waterlogging for plants to survive? If the plants selected require minimal waterlogging (e.g., agricultural crops), the landscape design can be designed using ridges (bahasa: guludan).

4.4. Monitoring and communication system and procedure of blue-green space risks

Because this blue-green space is intended to serve as a temporary water reservoir, it will store large amounts of surface water during the rainy season. The blue-green space risk monitoring system aims to reduce the risk of short-term water movement into and/or out of the blue-green space. If the blue-green space design includes a water source from the upper areas that is connected through a nearby drainage channel, local rainfall events in the upper area may affect the water level in the blue-green space, even if no rainfall occurs in that area. Conversely, when the blue-green space exceeds its capacity and water needs to be released, the lower area has the potential to receive water from this blue-green space. Therefore, monitoring and communication systems and procedures of blue-green space risks need to include the surrounding area. Table 11 shows the key components of monitoring and communication of blue-green space risks.

Table 15 Key components of the monitoring and communication of blue-green space risks

No	Key components	Description
1	Monitoring and reporting water levels in the blue-green space a) Time scale of reporting b) Method c) Who announce it d) Who should know it	Monitoring and reporting of water levels in blue-green spaces aims to predict the possibility of overflow when incoming water exceeds capacity. This can impact the surrounding areas, especially the lower areas.
2	Procedure for releasing water in the blue-green space: a) Methods b) Procedures c) Who announce it d) Who should know it	This release procedure is to prevent a sudden rise in water level in the lower area, which may endanger the community who work around the drainage channel as the outlet of the blue-green space.
3	Regular socialization, trainings and drills on monitoring and communication of blue-green space risks	This training and drill involved the management team, the community around and in the area below the blue-green space.

4.5. Sub-district Level Flood Contingency plan

According to National Disaster Management Agency Regulation Number 2 of 2023 concerning the Preparation of Disaster Contingency Plans, each region is required to develop a disaster contingency plan based on regional conditions and the type of disaster. As part of a regency or city area, Blue-Green Space has the potential for disaster emergencies that may affect surrounding areas, such as flooding due to overflowing water, land fires, land sinking, etc. Therefore, a contingency plan for various potential disasters must be developed and integrated with the regional contingency plan. The BNPB regulation states that contingency plans are prepared in a participatory manner by parties involved in disaster management. Referring to the contingency plan preparation guidelines (BNPB, 2011), there are several key components in a contingency plan document (Table 12). To facilitate integration with the regional contingency document, the contents of the contingency plan need to be adapted to the existing format, and it should be developed at sub-district level where the blue-green space will be established.

Table 16 Key components of the flood contingency plan

No	Components	Description
1	Type and level of hazard	For each type of disaster, the hazard value is calculated using the potential impact value and probability of occurrence.
2	Determination of events	Risk determination/assessment is carried out according to mutual agreement
3	Scenario development	Scenarios are developed through a combination of: time of incident (morning, afternoon, evening), duration of incident, intensity, level of loss
4	Determination of policies and strategies	Provide direction and strategies for each institution in the form of policies and guidelines.
5	Sectoral planning	Details of activities that must be carried out by each institution/party during an emergency response situation
6	Synchronization and harmonization	Synchronization and harmonization of Institutional activities in the context of emergency response so that each institution knows their duties and responsibilities.
7	Formalization	The flood contingency plan should be submitted to the BPBD to be integrated with the regional contingency plan for each disaster.
8	Trainings, simulation or drills	To test the accuracy of contingency plans.
9	Data update	Updating the flood contingency plan should be done before the regional contingency plan so that it can be integrated with the latest document.

5 Blue-Green Space Management, Monitoring and Evaluation

5.1. Stages of Management, Monitoring and Evaluation

Blue-green space management begins with the formation of a management team consisting of members of the establishment group and parties who have the authority and capacity to manage blue-green space, such as representatives from the environmental office (DLH), public works (PU), other relevant local agencies, sub-districts, villages etc. The first task of this group is to prepare a management, monitoring, and evaluation guide that they will use in carrying out their duties. The management guideline must include blue-green space action plan and operational budget, as well as accommodate and integrate with the previously established contingency plans. This guide must be agreed upon by the involved parties (such as representatives of regency/city, sub-district, village and impacted villages), legalized by the relevant authorities, and disseminated to the public. Once all guidelines, action plans and operational budgets are in place, the project can hand over the blue-green space to the management team. Next, management, monitoring and evaluation activities are inseparable in order to achieve the objectives of the blue-green space establishment.

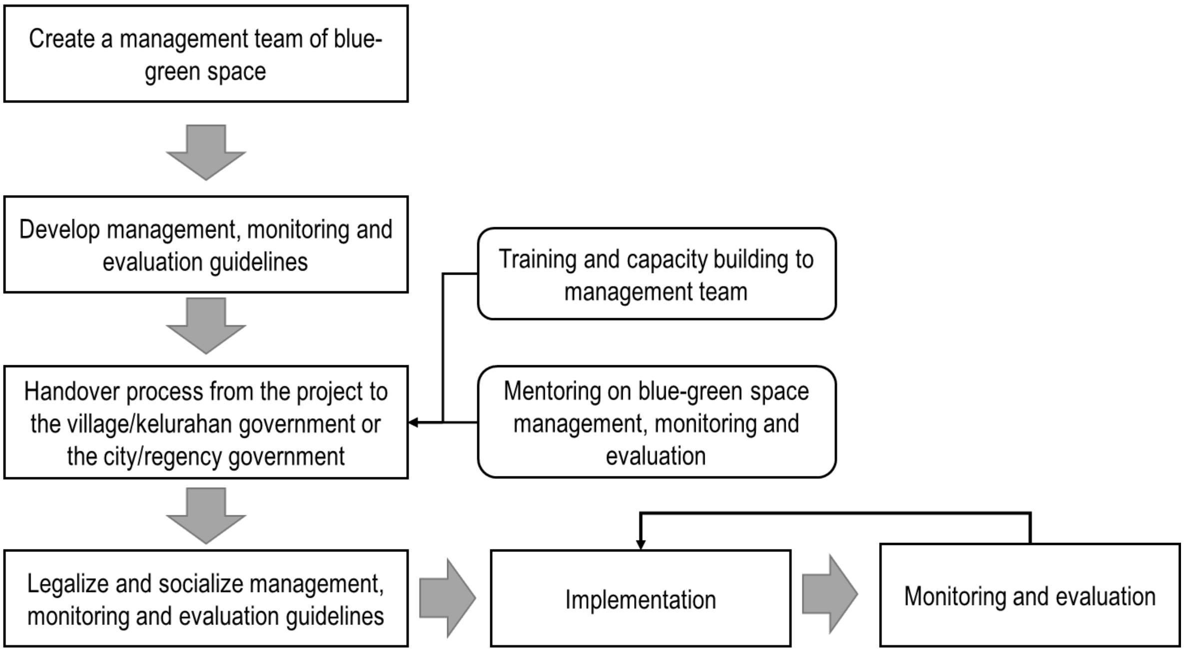

Figure 17 Stages of management, monitoring and evaluation of blue-green space.

The blue-green space handover process (Figure 17) includes training and capacity building of the management team covering hydrological and physical management, landscape (and vegetation) management, socio-economic component management (such as public activities, economic activities, etc.), safety and emergency situations, and technical monitoring and evaluation. After the formal handover, mentoring the team is still necessary to address various issues that arise when managing blue-green space, especially unexpected issues. The mentoring period can be reduced as the management team develops their decision-making and problem-solving skills while carrying out their duties.

5.2. Key Components in Blue-Green Space Management, Monitoring and Evaluation

The objectives of blue-green space management activities are: (1) ensuring that blue-green space produces environmental and socio-economic functions as expected and (2) preventing disasters as a result of the existence of blue-green space. The three key activities in managing blue-green space are: (1) water resource management, (2) vegetation management and (3) mud management (Table 13). In addition, there is another supporting activity required by the agreed design, such as socio-economic activities. The management team (Section 5.1) is responsible for managing the key and supporting activities. Socio-economic activities are to build relational value between surrounding communities and space by providing social, cultural and economic value. The management, monitoring and evaluation of these socio-economic activities should be integrated into the overall management, monitoring and evaluation guidelines of the blue-green space.

Table 17 Key activities of blue-green space management

No	Key components	Description
1	Water management	Water management ensures hydrological function as a temporary water storage facility is functioning properly. Furthermore, the water management also ensure that the blue-green space's presence does not cause problems in the surrounding area. Management activity is carried out maintaining the inlet and outlet conditions. Management schedule: before and after the rainy season, or as agreed upon. Management objects: Inlet and outlet are clean of trash and debris.
2	Vegetation management	Vegetation management ensures the socio-cultural function of blue-green spaces is maintained. Management activity is carried out based on plant type Management schedule: depends on plant type. Management objects: plant or vegetation
3	Mud management	As a temporary water catchment area, the incoming water that flow into the blue-green space also carries mud from upper area erosion. This mud will settle within the blue-

No	Key components	Description
		green space. The mud will reduce the water storage capacity of the blue space and reduce the infiltration rate. Management activity is carried out by removing the mud and returning it to a non-flooded area. Management schedule: before and after the rainy season Management object: mud layers after inundation event

The purpose of monitoring and evaluating blue-green spaces is to gather information on their condition and assess their impact. These monitoring activities also serve as input into risk monitoring and communication systems and contingency plans. Some parameters that require routine monitoring include water levels and vegetation conditions (Table 14).

Table 18 Key activities of blue-green space monitoring and evaluation

No	Key components	Description
1	Water level before, in and after the blue-green space, including inlet and outlet conditions	Water level monitoring is carried out by periodically recording the water levels in several locations: above the blue-green space, within the blue-green space, and below the blue-green space. Monitoring schedule: Periodic, following established early warning system procedures when a disaster occurs. Monitoring indicators: Water levels in channels and in flooded areas
2	Vegetation	Monitoring the condition of existing vegetation, especially for trees. Vegetation monitoring data can also be used to assess biodiversity and carbon condition. Monitoring schedule: Periodic, as agreed. Monitoring indicators: Number and species of trees.

6 Challenges and Gaps of Blue Green Space

Table 19 Challenges and gaps

No	Challenges	Potential Solution
1	Land tenure or ownership in the context of providing land for blue-green space	According to the regulation of the Minister of Agrarian Affairs and Spatial Planning or Head of the National Land Agency no. 14 of 2022 concerning the Provision and Utilization of Green Open Spaces, Article 10: The provision of green open space may be subject to incentives in an effort to realize quality open green open space, that may be provided by: the Central Government to district/city governments; district/city governments to other district/city governments; the Central Government and/or district/city governments to the community. The incentives referred to: utilization of abandoned land that has been designated in accordance with statutory provisions; cooperation in the utilization of land sourced from land banks in accordance with statutory provisions;
2	Village and community acceptance of green open spaces	Integrating blue-green space as a village achievement, such as include some or all activities/components of blue-green space in 'Program Kampung Iklim' (Proklim) activities. (https://kemenlh.go.id/contents/16/Program-Kampung-Iklim-Proklim). Example: rain harvesting, village reservoir (embung) infiltration wells. To increase public acceptance: City/district governments collaborate with sub-district and village governments regarding Blue-green space socialization strategies.
3	Specific government regulations concern blue-green space. Current regulations concern Open Green Space	Consult with the legal department regarding the interpretation of the Open Blue Space within the Green Open Space to determine whether it can be considered a reference for the Blue-Green Space. Issue of a (Mayor/Regent) decree for the Working Group on the Design and Development of Green Open Spaces

No	Challenges	Potential Solution
	(Ruang Terbuka Hijau), where Open Blue Space (Ruang Terbuka Biru) is part of Open Green Space.	For long-term and scaling-Up strategy: A Regent's Regulation or Mayor's Regulation on the Development and Management of Blue-Green Spaces based on Open Green Spaces and Open Blue-Space regulation to strengthen the policy and facilitate the allocation of government funding.
4	Budget	Mixed budgets from various stakeholders according to their authorities Connecting with other environmental economic instruments, such as CSR companies and ecosystem service incentives
5	Wastewater or drainage overflow that enters the blue-green space.	Blue-green space inlet management by providing a control tank to filter waste or garbage before entering the blue-green space

References

Aminah, S. N., Nasruddin, A., Annisaa, N. W., Abdullah, T., & Fatahuddin. (2021). The presence of refugia and population of insect pest in rice field. *IOP Conference Series: Earth and Environmental Science*, *807*(2). https://doi.org/10.1088/1755-1315/807/2/022093

Dai, W., & Tan, Y. (2024). Study on Multi-Scenario Rain-Flood Disturbance Simulation and Resilient Blue-Green Space Optimization in the Pearl River Delta. *Buildings*, *14*(12). https://doi.org/10.3390/buildings14123797

Dobson, J. (2021). Wellbeing and blue-green space in post-pandemic cities: Drivers, debates and departures. *Geography Compass*, *15*(10), 0–22. https://doi.org/10.1111/gec3.12593

Gradiyanto, F., Parmantoro, P. N., & Suharyanto. (2024). Impact of climate change on Kupang River flow and hydrological extremes in Greater Pekalongan, Indonesia. *Water Science and Engineering*, *18*(1), 69–77. https://doi.org/10.1016/j.wse.2024.03.005

Haleem, Kashif; Khan, Afed Ullah; Khan, Jehanzeb; Ghanim, Abdulnoor A.J.; Al-Areeq, A. M. (2023). Evaluating Future Streamflow Patterns under SSP245 Scenarios: Insights from CMIP6. *Sustainability*, *15*(22). https://doi.org/https://doi.org/10.3390/su152216117

Hendrayana, H., Widyastuti, M., Riyanto, I.A., Nuha, A., Widasmara, M.Y., Ismayuni, N. and Rachmi, I.N., 2021, October. Thornthwaite and Mather water balance method in Indonesian Tropical Area. In *IOP Conference Series: Earth and Environmental Science* (Vol. 851, No. 1, p. 012011). IOP Publishing. (https://iopscience.iop.org/article/10.1088/1755-1315/851/1/012011/pdf)

Jeanes, K., van Noordwijk, M., Joshi, L., Widayati, A., Leimona, F., & Leimona, B. (2006). *Rapid Hydrological Appraisal in the context of environmental service rewards*. World Agroforestry.

Kumar, P., Avtar, R., Dasgupta, R., Johnson, B. A., Mukherjee, A., Ahsan, M. N., Nguyen, D. C. H., Nguyen, H. Q., Shaw, R., & Mishra, B. K. (2020). Socio-hydrology: A key approach for adaptation to water scarcity and achieving human well-being in large riverine islands. *Progress in Disaster Science*, *8*, 100134. https://doi.org/10.1016/j.pdisas.2020.100134

Mercy Corps Indonesia. (2024). Brief Report Hazard, Vulnerability and Risk Assessments of Kupang Watershed. In *Mercy Corps Indonesia*. https://doi.org/10.29117/ansaq.2024.0195

Mercy Corps Indonesia, ; Diponegoro University. (2022). *Laporan Akhir Pra Kajian Kelayakan Dan Analisa Penentuan Lokasi Waduk Untuk Mendukung Operasionalisasi Spam Regional Petanglong Untuk Pelayanan Ke Wilayah Pekalongan Raya*.

Purnama, I.L.s., Trijuni, S., Hanafi, F., Aulia, T., and Razali, R., 2012, Analisis Neraca Air di DAS Kupang dan Sengkarang, Fakultas Geografi Universitas Gadjah Mada, Yogyakarta.

Suprayogo, D., van Noordwijk, M., Hairiah, K., Meilasari, N., Rabbani, A. L., Ishaq, R. M., & Widianto, W. (2020). Infiltration-Friendly Agroforestry Land Uses on. *Land*, *9*.

van Noordwijk, M., Bargues-Tobella, A., Muthuri, C., Gebrekirstos, A., Maimbo, M., Leimona, B., Bayala, J., Xing, M., Lasco, R., Xu, J., & Ong, C. K. (2019). Trees as part of nature-based water management. In M. Van Noordwijk (Ed.), *Sustainable Development through Trees on Farms: Agroforestry in Its Fifth Decade.* (pp. 299–327). World Agroforestry (ICRAF) Southeast Asia Regional Program.