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Spatial Distribution of Dryland Forest on Water Availability in Kumaligon Watershed Central Sulawesi, Indonesia

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ABSTRACT

Kumaligon Watershed in Buol Regency, Central Sulawesi Province is located in a groundwater basin with an area of 1,488.77 Ha. The region consists of karst hills and dryland forest cover with high water demand. This watershed is the main source of water for the community in fulfilling the needs of clean water, agriculture and tourism, so this research is important to do. Therefore, this study aims to determine the spatial distribution effect of dryland forest area on water availability in the Kumaligon Watershed. A spatial-meteorological method was used with an analytical approach to determine the distribution, while the Thornthwaite-Mather water balance analysis assessed the water availability. The result showed that dryland forest is concentrated in the upstream region of the karst hills with an area of 1,082.43 Ha and water availability of 4,332.34 m^3/year. By comparing the water demand in 2021, namely, 1,218.75 m^3/year, a criticality index of 0.28 was obtained, which indicates that the condition of the region was not critical. Based on these findings, the dryland forests in the region are expected to still have an adequate supply of water in the next 25 years.

1. INTRODUCTION

Forests help to protect and maintain life support systems [1, 2], such as water, where they play an important role in its absorption, storage, and provision to living organisms [3]. Furthermore, in watershed regions, their cover areas must be planned theoretically based on ecosystem management [4, 5]. At least 30% of watersheds and/or island must be used as forests with a proportional distribution [6].

Kumaligon watershed in Buol Regency, Central Sulawesi Province, has a relatively high dryland forest cover area in the karst hills. It also has a groundwater basin (GB), as well as a high water demand for domestic use, tourism activities, such as hot springs, spiritual tourism, fish ponds, and forest tours, as well as rice fields and plantations [7].

Furthermore, the watershed area contains springs with a flow rate of 25 liters/sec as well as a karst river, which makes it attractive to investors for the development of new tourist centers [8]. The springs in the karst area are unique due to the topography, gravity, and geological structures. Based on these conditions, rainwater can seep directly into their dissolving cavity, which allows the flow of water into the underground rivers [9].

The high water use in the watershed area needs to be managed properly to avoid conflict. Also, the presence of dryland forest in the karst hills and GB must be maintained proportionally. In the karst areas, air and soil moisture have the highest effect on vegetation diversity, while rainwater infiltration in the GB region can fill the free and compressed aquifers, which ensures continuous usage throughout the year [10].

Planning a proportional forest cover area in a watershed can be used as a management strategy to prevent all land-use activities, which reduces the flow index and avoid water use conflicts. Furthermore, a low index can be used as a reference in determining the forest threshold [11]. Land use planning in watershed areas must include a proportion of native forest vegetation because it plays an important role in regulating water use [12].

Forests dominated by trees are expected to ensure water availability in watershed areas. Planting trees with various management options can increase groundwater resources because they facilitate absorption. They also help to reduce surface runoff, and peak discharge, which increases vegetation density and prevents damages caused by rain intensity [13-15]. Vegetation cover in the hydrological system affects the outflow, hence, it needs to be considered in watershed management as well as its association with conservation planning [16, 17].

Taking into account the large number of land use activities in relation to water utilization in the current Kumaligon watershed karst area as previously described, it is deemed important to analyze the pattern of spatial distribution of dry forest cover in the provision of water sources.

Vegetation density in the hydrological system has a long-term effect because it influences the quality, continuity, and quantity of water discharge in an area, especially watersheds. Therefore, this study aims to determine the spatial distribution effect of dryland forest area on water availability in the Kumaligon Watershed.

Spatial analysis of the distribution of dryland forest in the karst area of the Kumaligon watershed on water availability includes a description of the analysis of potential and biophysical conditions as well as social and economic culture of the community, analysis of the availability and demand for water for the community, analysis of water criticality, analysis of spatial distribution and area of dryland forest in supplying water.

2. MATERIAL AND METHODS

2.1 Time and location

This study was carried out from July to December 2021 in the Kumaligon watershed area, Biau Sub-District, Buol Regency, Central Sulawesi Province as shown in Figure 1. July-December is only the time for research work and does not affect the results, because the local weather analyzed is from January to December in a 10 year period.

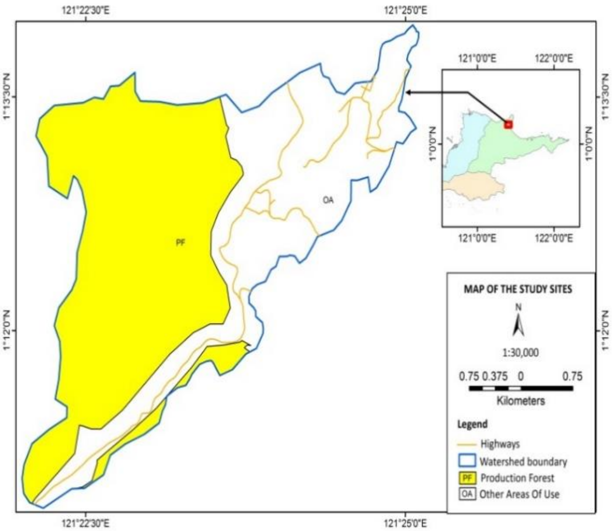

Figure 1. Map of study sites

2.2 Tools and materials

The materials used include: (a) topographic maps, road network and settlement maps from Badan Informasi Geospatial; soil, geological, rainfall zoning, slope class, spring location, and watershed area maps from BPDASHL Palu Poso; groundwater basin (GB) and provincial spatial planning maps from the Department of Public Works and Spatial Planning of Central Sulawesi Province; forest area and land cover maps from the BPKH XVI Palu. All data collected were on the same scale of 1:50,000. (b) Landsat 8 imagery and SPOT 7 2017-2021 image data from LAPAN and (c) previous relevant studies. This study used rainfall data for the last 10 years, namely 2012-2021, which were obtained from the Lalos Meteorological Station in Tolitoli.

The tools used include: (a) Global Positioning System (GPS), camera, measuring tape, tally sheet, and work map for field survey; (b) Computer, ArcGIS version 10.4.1, Microsoft office excel, Microsoft office word, printer, ink, A4 paper, stationery for data/map/image processing, and study report.

2.3 Method

This study used a descriptive approach with a spatial-meteorological method. Furthermore, the primary data were collected using field surveys and literature studies, which explored theories related to the spatial analysis of water needs and availability in watershed areas. Secondary data related to this study were also obtained from reliable sources.

2.3.1 Analysis of vegetation cover and land availability

To determine the condition of the plantation fields and cultivated plants, the vegetation cover percentage (VCP) approach was used by dividing the vegetation cover area (VCA) with the watershed region and then multiplied by 100%. In terms of activities in the study location, the land availability index (LAI) analysis was carried out to determine population pressure (PP) on the availability of forest land. The index was calculated based on the area of agricultural land (AL) with the total number of the farming family (FF) using the formula: LAI = (AL/FF) [18]. The types of land cover and vegetation, as well as area boundaries, were analyzed spatially from Landsat 8 and SPOT 7 satellite images as well as geological, watershed, and land use maps.

2.3.2 Analysis of water availability

Water availability was calculated with the meteorological water balance approach [19]. The monthly water potential estimation was carried out with data on rainfall, vegetation/land cover, air temperature, and soil physical properties to obtain the availability and deficit (mm/month). The balance shows the relationship between the inflow and outflow in the watershed area. It was also used to evaluate the availability in the region, namely total surplus and deficit.

The water balance equation assumes that all rainwater can fill groundwater, which serves as reserves in the soil, thereby meeting the evapotranspiration needs. Excess water in the soil is considered surplus when the reserve has reached the maximum limit, and it is then released in the form of runoff. Mathematically: P = Et+Gr+Ro, where P = precipitation (mm), Et = evapotranspiration (mm), Gr = change in groundwater reserves (mm), Ro = runoff discharge (mm). Changes in reserves are highly dependent on the water holding capacity (WHC), which is influenced by soil texture as well as the type of vegetation cover. Therefore, it can be used to determine the total retained moisture [20, 21].

To calculate the surplus availability, an analysis was carried out sequentially using the following formula [20, 21]:

1. The monthly average rainfall (P) (mm/month) was calculated from data for a 10-year period, namely 2012-2021.
2. Monthly potential evapotranspiration (PE) (mm/mo) was obtained from the monthly mean temperature data (30 days a standard month; 12 hours irradiation):

$$i = (T/5)^{1.514};\ I = \sum i;\ P_{ex} = 16(10T/I)^{\alpha} \tag{1}$$

$$\alpha = (675.10^{-9}.I^{3}).(77\mathrm{x}10^{-6}.I^{2})+(0{,}01792.I)+0.49239$$
$$\text{For corrected evapotranspiration: } PE = f.P_{ex} \tag{2}$$

Description: P_{ex} = uncorrected potential evapotranspiration (mm/mo); PE= corrected potential evapotranspiration (mm/month); f = correction factor (see the latitude and time correction table; for the study area, f = 1.00); T = temperature (°C); i = monthly heat index; I= total heat index in a year; α = heat index constant in a year.

3. Water Holding Capacity/WHC: WHC is the ability of the soil to hold/store water, and it was determined by overlaying the maps of land use, soil depth, and soil texture. The land use data were obtained from the interpretation of Landsat 8/SPOT 7 images, while the depth and soil texture were obtained from the analysis of land, soil, geological system maps as well as field checking. The overlay results were used to determine the total WHC using [21] on the

estimation, which was based on a combination of soil texture and vegetation.

4. The difference between rainfall and evapotranspiration (P-PE) was calculated by subtracting their monthly data value.
5. Accumulated Potential Water Loss/APWL was calculated by adding the value obtained in the negative month with that of the previous month (P-PE of the month i): (a) in dry months where P<PE, the difference was added up every month to the value (PEP) of the previous month; (b) in wet months where P>PE, APWL value = 0.
6. Soil moisture storage (ST) was calculated in the wet and dry months. (a) in wet months where P>PE, the ST in each of them was the same as WHC; (b) in dry months when P<PE, the monthly ST was calculated with the formula below:

$$ST = STo.e^{-(APLW/Sto)} \quad e = 2.718. \tag{3}$$

7. Change in soil moisture storage (ΔST) was calculated by subtracting ST in the current month from the value obtained in the previous month.
8. Actual evapotranspiration (EA): (a) in wet months when P>PE, EA = PE; (b) in dry months when P<PE, EA = P – ΔST.
9. Moisture surplus (S)(mm/bln) was calculated using the formula:

$$S = (P\text{-}PE)\text{-}\Delta ST \tag{4}$$

When ST=STo, S = P- PE, and when ST<STo, S = (P - PE) – ΔST.

10. Moisture deficit (D)(mm/bln) was calculated by subtracting EA from PE or finding the difference between the current month and the previous month (P<PE).

$$D = (PE – EA) \tag{5}$$

11. Runoff (Ro): Runoffs are obtained from moisture surplus (S), where it is assumed that 75% of the water in the area is moisture surplus, while the remaining 25% flows out as runoff in the following month. In karst geomorphological formations, the 25% that flows out is obtained from the total rainfall [22, 23].

2.3.3 Analysis of water demand

To calculate the water demand, standards and formulas are used based on SNI 196728.1-2002 [24]:

1. Domestic water demand (WD) with a standard consumption of 100 liters/capita/day was calculated using the formula below:

$$WD = 365 \text{ days} \times (q_{(r)}/1.000 \times P_{(r)}) \tag{6}$$

Description: $q_{(r)}$ = water consumption per capita (ltr/capita/day); $P_{(r)}$ = population (people); WD =domestic water consumption (m^3/year).

2. Water for agricultural irrigation (WAI)

$$WAI = A \times (Wc/1.000) \times T_n \times (3.600 \times 24) \tag{7}$$

Description: WAI = water consumption for irrigation (m^3/year), A = rice field area (ha), $Wc_)$ = water consumption for irrigation (ltr/sec/ha), T_n = total irrigation days (120 days/season). The amount of water used for agricultural irrigation was 1ltr/sec/ha, which is in line with SNI 19-6828.1-2002.

2.3.4 Analysis of water criticality

Water Criticality Index (WCI) is the ratio between water availability (WA) and water demand (WB) based on the formula below [20]:

$$WCI = (WB/WA) \times 100\% \tag{8}$$

The availability (Q, m^3/year) was calculated by multiplying the runoff (Ro, m/year) by the total area of the watershed (L, m^2). The Ro was obtained from the steady flow rate by multiplying the runoff coefficient of 25% in the karst areas by the yearly moisture surplus (S, m/year).

2.3.5 Analysis of spatial distribution and forest area

Analysis of dryland forest distribution patterns' effect on water availability in the Kumaligon watershed was carried out by overlaying maps, satellite images, and supporting data with the Arc-GIS software version 10.4.1. The biophysical factors and space utilization activities by the occupants were also considered during the process. Biophysical factors consist of land cover (vegetated and not vegetated), geology, topography, elevation, and GB, while the spatial activities include land use, regional infrastructure, and tourist centers.

Furthermore, the analysis of forest area and water availability in watershed was performed using the modified formula from the Minister of Public Works Regulation Number 5 of 2008 on the guidelines for the provision and use of green open spaces in urban regions [24]. Furthermore, the area used was determined by considering the water holding capacity, as illustrated in the formula below:

$$LH_{(to\text{-}i)} = (Ka\ (1+r\text{-}c)^t – DWC - Pa)/z \tag{9}$$

Description: $LH_{(to-i)}$ = forest area needed to meet water needs; Ka = current total demand (m^3/year); r = increase rate of water usage (population growth); c = correction factor (population decline); t = year; DWC = the supply capacity of drinking water company (m^3/year); Pa = current potential availability (m^3/year), which was calculated by multiplying the steady flow rate with the total area; z = water holding capacity of forest (m^3/ha/year), which was obtained from the WHC calculation of forest soil texture.

3. RESULTS AND DISCUSSION

3.1 Potential and condition of Kumaligon watershed

Geographically, Kumaligon Watershed is in the coordinate of 121°22'1,15"-121°25'3,18"E and 1°10'55,26"-1°13'58,58"N, and based on administrative classification, it is located in Kumaligon, Leok I, and Leok II Villages, Biau Sub-District, Buol Regency, Central Sulawesi Province with an area of 1,488.77 Ha.

The natural resources in the area include (a) the karst hill ecosystem, (b) Buol groundwater basin (GB) of 435 km^2, (c) the surface river flow below and above, (d) springs, (e) natural forests, such as dryland and mangrove. The Buol GB was validated based on the regulation of the Indonesia Minister of Energy and Mineral Resources Number 2 of 2017, which classified basins as hydrogeological areas with the ability to fill, drain, and release groundwater. The springs at 121°24'10"E- 1°13' 09"N have a flow rate of 25 ltr/sec, and their water quality is in a good condition, namely no smell, clear, an average temperature of 25°C, neutral (pH 7), and contain 13.31 dissolved oxygen [7].

Kumaligon watershed is located at an altitude of 0-500 m ASL, and it has wet to very wet weather conditions. Based on climate data from the Lalos Meteorological Station in 2012-2021, the area has an annual rainfall of 2,026.95 mm/year with an average of 202.70 mm/month as well as 216 rainy days/year and 18 rainy days/month. It has a rainfall intensity of 9.38 mm/rainy day with a total of 10 wet and 2 humid months. The average monthly air temperature is 27.09°C along with 82.95% humidity, 5.50 knots wind speed, 62.81% irradiation, and 1,010.46Mb air pressure. Topographically, the area has karst hills with a flat-slightly steep slope class, and the soil type includes the Mediterranean red-yellow (alfisol) and rendzina (mollisol). The parent rock is in the form of limestone, and is dominated by coral with a few alluvium-coastal deposits in the mangrove region [24].

Based on the Central Sulawesi Province Forest Area Map/Map of land cover/use (Figure 2) in 2021, the watershed has a permanent production forest area (PFA) of 871.67 ha (58.55%) and other land use areas of 617.10ha (41.45%). Furthermore, 68.83% of the area is dominated by dry land forest and mangroves, while 20.51% was used for agricultural purposes. A total of 5.27% serve as tourist centers, such as natural baths, while the remaining 5.39% consist of residential areas, roads, and bushes (Table 1).

In Table 1, 92.51% of the watershed area was used for forests, coconut plantations, mixed farming of timber and annual crops, tourist areas, and natural hot springs. This condition shows that the permanent vegetated land cover is still classified as 'very good', hence, it is expected to contribute positively to the water system in terms of quality, quantity, and continuity. This is in line with the work done by Mello et al. [25] that forest cover plays an important role in maintaining the condition and quality of the water in an area.

Table 1. Land cover/use

Land Cover/Use	Area (Ha)	%
Primary Dryland Forest	801.57	53.84
Secondary Dryland Forest	210.76	14.16
Mangrove forest	12.35	0.83
Settlement	8.22	0.55
Natural Hotsprings	1.35	0.09
Al-Hijrah spiritual tourism area and fishing pond	7.05	0.47
Nature Tourism Area of KPH Pogogul	70.10	4.71
Highways and farm roads	3.76	0.25
Rice fields	6.48	0.44
Coconut plantation	29.31	1.97
Dryland farm	23.38	1.57
Mixed plantation	246.04	16.53
Shrubs	68.40	4.59
Total	1,488.77	100.00

Based on classification by BPDAS Palu Poso in 2014, the watershed must be maintained. It has a low performance value with a flow regime coefficient (FRC) of 6 (low), an annual flow coefficient (AFC) of 0.11 (very low), sediment load value (SLV) of 2.74 (very low), flood events with a frequency of 1 time in 2 years (medium), as well as a water use index (WUI) of 0.23 (very low). A low FRC indicates that there is a relative balance between the maximum (Q_{max}) and minimum (Q_{min}) flow rates, while very low values show that there is a balance between the annual flow (Q_{mm}) and yearly rainfall intensity (P_{mm}). Furthermore, very low SLV indicated that the watershed is in a good condition, medium category of flood events shows that the river has a relatively high carrying capacity. Very low WUI implies that only a small amount of water in the watershed are below their potential, hence, they can still be used to overcome annual droughts. Based on the flow rate calculation, the watershed has Q_{max} of 31.41 m^3/sec, as well as Q_{min} and Q_{mean} of 5.24 m^3/sec and 26.18 m^3/sec, respectively.

Biau Sub-District is the capital of Buol Regency as well as the main user of water from the Kumaligon watershed. It has a total population of 29,709 people, a 5.47% growth rate between 2010-2019, and a population density of 136.40 people/km^2. The majority of the occupants in the area are farmers, fishermen, civil servants, TNI/Polri, traders, construction workers, ojek drivers, and retirees [26]. In 2021, a total of 1,093 people are carrying out farming activities in 3 villages around the watershed, namely Kumaligon, Leok I and Leok II. By comparing the current agricultural land area of 373.61 Ha with the number of farmers, the population pressure on forest land is 0.34, which was classified in the very low category.

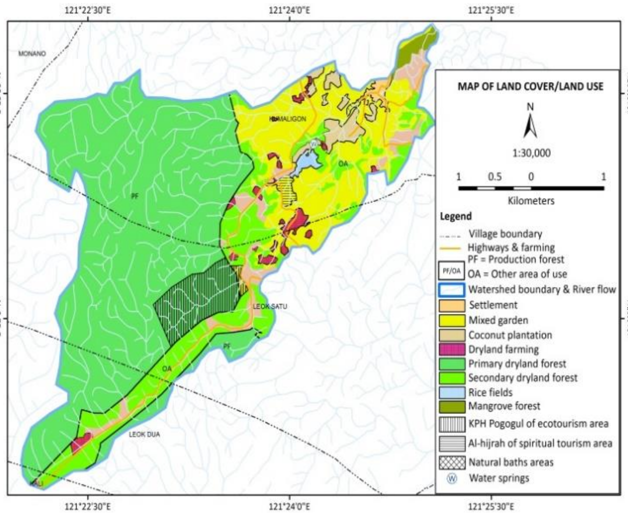

Figure 2. Map of land cover/ use

3.2 Water demand and availability

The main users of water in the Kumaligon watershed area include: (a) the residents of the Biau Sub-District, and their usage is managed by the Buol Regency Drinking Water Company, (b) rice field irrigation, (c) hot springs, Al-Hijrah spiritual tourism, fish ponds, and KPH Pogogul nature tourism.

A total water demand of 1,218,75 m^3/year was obtained and it consists of (a) domestic needs of 1,084.38 m^3/year (88.97%) and (b) agricultural irrigation for 2 harvests/year of 134,369 m^3/year (11.03%). The demand analysis was carried out using the needs of Biau Sub-District occupants and then analyzed based on a population of 29,709 people with 100 liters/capita/day. Meanwhile, agricultural irrigation usage was calculated based on the existing rice field area of 6.48 Ha.

The use of water for natural attractions in the Kumaligon watershed area was not analyzed specifically because rivers are the major source. The seasonal cropping on dryland was also not calculated because farmers only plant during the rainy season. The natural attractions, rice fields as well as fish ponds only rely on the surface flow entering the river from springs during the dry season. However, the amount of water in the river increases depending on the amount of runoff available.

Based on meteorological water balance analysis using the Thornthwaite-Mather method, a moisture surplus of 1,164mm/year was recorded in the Kumaligon watershed area. This result was obtained by calculating the annual rainfall (P) of 2,026.95 mm/year, 862.95mm/year annual potential evapotranspiration, and water holding capacity (WHC) of 306.77 mm/month or 3,681.23 mm/year. Table 2 shows the WHC in the area based on land unit/cover.

Table 2. WHC based on land unit/cover area in the Kumaligon watershed area

Land Unit	Area (Ha)	Area (%)	Sto	STox % area	WHC (mm)
l-Hlk	1,082.43	72.71	350	25,447.21	254.47
gp-Hm	12.35	0.83	300	248.86	2.49
l-Pk	282.40	18.97	200	3,793.74	37.94
gp-Sw	6.48	0.44	75	32.64	0.33
l-Pm	13.33	0.90	0	0.00	0.00
l-SB	68.40	4.59	200	918.88	9.19
l-Pt	23.38	1.57	150	235.56	2.36
Total	1,488.77	100		30,676.90	306.77

STo in Table 2 refers to the estimation of WHC value based on the combination of soil texture and land cover vegetation using the Thornthwaite & Mather method. Furthermore, values of 254.47, 2.49, 37.94, 0.33, 0.00 9.19, and 2.36mm/month were obtained from l-Hlk (clay-dryland forest), gp-Hm (groove sand-mangrove forest), l-Pk (clay-mixed plantation), gp-Sw (sand-paddy rice fields/secondary crop plantation), l-Pm (clay-settlement), l-SB (clay-bush), and l-Pt (clay-dry land agriculture with maize, legumes), respectively. Based on the annual rainfall (P) and potential evapotranspiration (PE), the difference in P-PE was 1,164 mm/year. Figure 3 shows the water holding capacity map of the Kumaligon watershed.

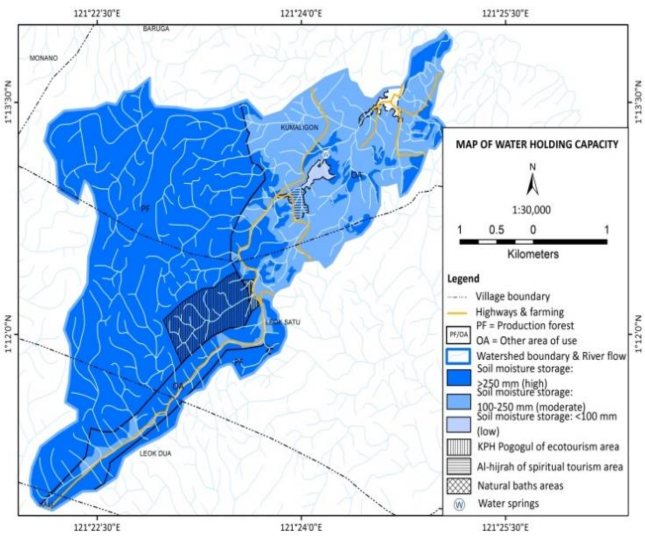

Figure 3. Map of water holding capacity

In the last 10 years, namely 2012-2021, the Kumaligon watershed area did not have dry months (10 wet months and 2 humid months), hence, the Accumulated Potential Water Loss (APWL) = 0, EA value = PE, WHC equals soil moisture storage (ST), ΔST = 0, and water deficit (D) = 0. Based on these conditions, the moisture surplus was calculated as S = (P-PE). The result showed that STo = ST of 306.77 mm/month, which indicates that the area can store and bind water, including the dominant Mediterranean red-yellow soil (alfisol) with clay texture and natural forest cover. Alfisol soils with loamy textures have a high storage capacity, but forest areas store more rainfall below the surface [27, 28].

Graphically, Figure 4 shows the monthly average rainfall (P), potential evapotranspiration, and moisture surplus (S) between 2012 and 2021.

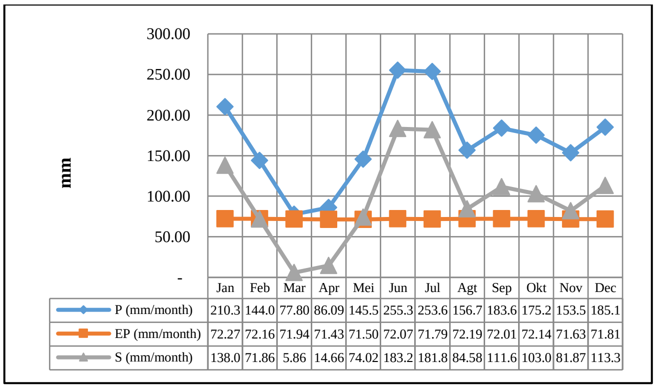

Figure 4. Graph of Rainfall (P), Evapotranspiration (EP), and Moisture Surplus (S)

Figure 4 shows that the humid months include March and April, while the wet months consist of January, February, May, June, July, August, September, October, November, and December. This condition shows that the lowest moisture surplus was obtained in March and April.

Water availability in the Kumaligon watershed area based on steady flow rate was calculated by multiplying the moisture surplus with a runoff of 25%. A rate of 291 mm/year was obtained from the calculation, which indicates that the area can provide a total of 4,332.34 m^3/year. By comparing the availability and demand in 2021, namely 1,218.75 m^3/year, a criticality index of 0.28 was recorded, which indicates that the conditions are not yet critical. This shows that the area still has an availability of 3,113.59 m^3/year, or 71.87% of unutilized water. However, it is important to carry out collective management between various parties. This is consistent with the statement of Vörösmarty et al. [28] that water security can be achieved by preserving protected areas as a source of water as well as involving stakeholders in watersheds.

3.3 Spatial distribution and area of dryland forest on water availability

The spatial distribution of dryland forest in the Kumaligon watershed area was dominant in the upstream area of the karst hill ecosystem. Based on the need for forest area using formula (9), only 857.57 ha are currently utilized in 2021 with water needs of 1,218.75 m^3/year, hence, the region still has a dryland forest surplus of 224.86 ha. In 2021, the total vegetation cover was 1,082.43 ha, or 73% of the watershed. The forest cover consists of the natural tourism center of KPH Pogogul, which has an area of 70.10 Ha.

By considering the total water demand factor of 1,218.75 m^3/year, 3,752.78 m^3/year drinking water company (DWC) water supply capacity, 4,332.34 m^3/year potential soil water availability, and 30,536.66 m^3/year water holding capacity, so government policy is needed to reduce the rate of population growth.

The spatial distribution pattern of dryland forest in the Kumaligon water has a strategic role in regulating water management. These conditions help the area beneath the shed to maintain the quantity and continuity of water flow. Furthermore, karst hills play an essential role in regulating hydrological systems, because forests can easily grow on rock outcrops [29-31].

Figure 5 shows the spatial distribution of dryland forest on water availability in the Kumaligon watershed area.

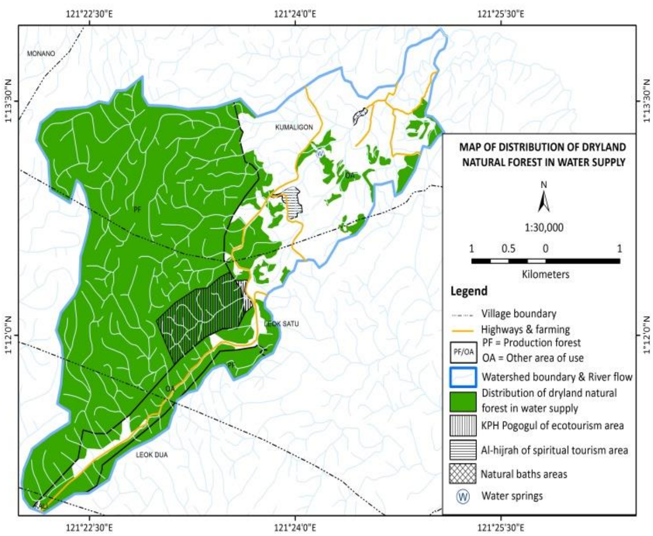

Figure 5. Spatial distribution of dryland forest on water availability

Based on the forest projection for the next 25 years as well as the increase in the Buol Biau Sub-District population, especially water users from the Kumaligon watershed, the existing forest cover area still has a surplus water supply with a demand of 2,303,993 m^3/year, as shown in Table 3.

Projection graph on the carrying capacity of the forest cover area for 25 years can be seen in Figure 6.

Figure 6 shows that the forest cover area is still in surplus for the next 25 years. Based on the results of simple linear regression, the model obtained a formula, namely Y = -7.5174 X + 227.88 with an R^2 value of 0.9944, where Y = carrying capacity of forest cover area (Ha), and X = five-year period. The regression model reveals that the carrying capacity of the forest cover area to water availability is expected to decrease linearly every five years for the next twenty-five years. However, the region still has a surplus of supply during this period.

Based on the projected results of the carrying capacity of dryland forests which will decrease in the provision of water sources for the community in the next 25 years as a result of the high rate of population growth with an average of 0.55% per year in the Kumaligon watershed area, efforts are needed to maintain and increase the area of forest cover forest.

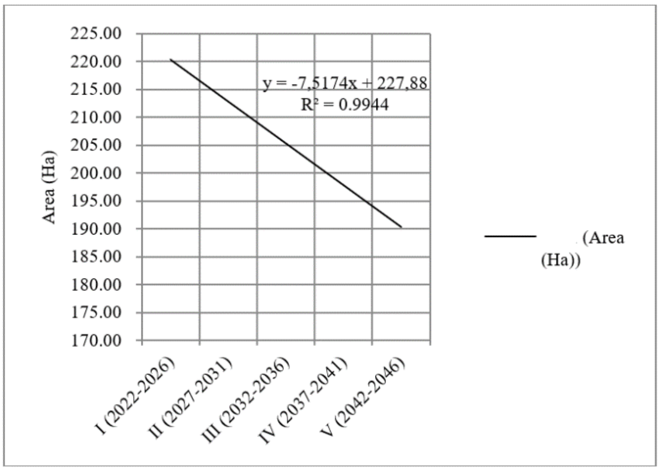

Figure 6. Projection graph of the carrying capacity of the forest cover area for 25 years

These results also indicate that there is a hydrological response to forest cover, and this is expected to change along with their area. This is in line with the opinion of Zhang et al. [32] on spatial scale, where changes in the cover affect response as well as the high rate of surface runoff.

The existence of natural forests must be maintained in terms of their total area and distribution because they help to sustain the supply and fulfillment of water needs as well as support tourism activities on the long term. This is suitable with the work done by Dibaba et al. [33] that a more comprehensive and integrated watershed management policy is needed to ensure balance in the ecosystem as well as to manage risks.

Based on the projection of the carrying capacity, a deficit of 4.88 hectares is expected to occur between 2072 and 2096 due to the high rate of population growth in Biau Sub-District and Buol Regency capital with an average of 0.55% per year or 2.74% per five years as well as a 0.16% correction factor. Therefore, in this period, it is necessary to increase the forest area through mixed plantation forests, which helps to improve water conservation in karst areas.

Meanwhile, efforts to increase the area of forest cover can be done through planting mixed forests which can help increase water conservation in karst areas. To minimize the effect of decreased water supply in the downstream watershed area, the plantation forest cover needs to be regulated proportionally [11, 34-37].

Table 3. Projection of the carrying capacity of the forest cover area for 25 years

Period	Water Demand (m^3/year)	Dryland Forest Area (Ha)	Utilized Forest (Ha)	Surplus Forest (Ha)	%
2022-2026	1,384,290.73	1,082.43	862.99	219.44	20.27
2027-2031	1,572,319.44	1,082.43	869.15	213.28	19.70
2032-2036	1,785,888.16	1,082.43	876.15	206.28	19.06
2037-2041	2,028,466.00	1,082.43	884.09	198.34	18.32
2042-2046	2,303,993.27	1,082.43	893.11	189.32	17.49
and 2072-2096	8,234,096.31	1,082.43	1,087.31	(4.88)	(0.45)

4. CONCLUSION

The spatial distribution of dryland forest is concentrated in the karst hill ecosystem of Kumaligon Watershed upstream, with an area and water availability of 1,082.43 ha and 4,332.34 m^3/year, respectively. By comparing the water demand in 2021, namely, 1,218.75 m^3/year, a criticality index of 0.28 was obtained, which indicates that the area is not in a critical condition. Until the end of 2021, the dryland forest still has a surplus of 224.86 hectares, which shows that 857.57 hectares have been utilized to meet various types of water needs. In the next 25 years, the existing cover area is expected to still have a surplus of water supply. However, from 2072-2096, a deficit of 4.88 hectares will likely occur.

To ensure water availability on the long term, the distribution pattern and area of dryland forest need to be maintained. Based on the condition of Kumaligon Watershed, it is important to conduct a study related to the regulation of spatial use to prevent water usage conflicts.

This research is limited to an initial study in the form of a spatial analysis of the distribution of dryland forest cover in predicting the availability of water for the community, so there is still a need for pilot research on each type of land cover (vegetation) related to water storage/supply capacity. In addition, it is also important to carry out studies related to spatial use regulations to prevent conflicts of use and water pollution.

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