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Article

Location's Suitability for Small Reservoirs at Bodri–Kuto Watershed Based on Spatial Monthly SPI

Authors

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* Correspondence:

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Abstract: Despite efforts for to develop and conserve water resources development and conservations, almost every year during the dry season, some areas in Central Java pProvince in Indonesia are still experience aing lack of water, especially at in rural villages. Theose areas require supply for water supply via water trucks as well asand/or portable pumps to obtain water from rivers and groundwater reduction in agricultural plantation. At the moment, theThe Central Java government committed to realise implementing a program of involving the construction of ng 1000 small reservoirs until the yearby 2020 to overcome water shortages. However, the land availability for the technically ideal sites are mostly belongs to privately owned, which requires lengthy and costly land acquisition. To avoid the uncertainty in of land acquisition, some of the site for small reservoirss' construction are were placed at on the state-owned land, which does did not require land acquisition. The shift from technically ideal sites to available state-owned land for the construction of small reservoirs raise the issue onput into question the suitability location suitability of those reservoirs. This paperIn this study, we evaluateds the suitability of the location for of small reservoirs at in the Bodri–Kuto Watershed using the monthly standardized precipitation index (SPI). index. It We useds rainfall records of 25 stations in the watershed from the year 2000 to 2016 and. The analysis was performed foranalyzed yearly and monthly rainfall data. From The yearly analysis it shows that the dry conditions (SPI < −0.5) in the year from 2005 to 2009 spread toaffected more than half of rainfall stations (>50%), while whereas the rainfall stations that experienced more dry years were included Kedung Wungu, Babadan, Bojong, Ketapang, Sekopek, and Podowaras (more than 9 years out of 17 years). From The monthly SPI, it shows that during month July, August, and September, all of the rainfall stations were experienceing moderately dry or worse conditions (SPI < −0.50). Using 25 rainfall stations, we determined the spatial spread of dry conditions is determined using this three monthly SPI values from (July, August, and September). Overlay between of the spatial spread of dry conditions versus with the location of small reservoirs can be used to evaluate the suitability of the small reservoir locations. It shows that there is 1We found that 1 (=3%) location is very suitable, 7 (=21%) locations are suitable, 24 (=73%) locations are moderately suitable, and 1 (=3%) location is less suitable. It showsThe findings indicate that spatial distribution of SPI can be used as an additional criterionа to for evaluatinge the suitability of small reservoirs' locations should it needs to depart from technically ideal locations be unavailable.

Keywords: SPI indice; drought indexice; Bodri–Kuto wWatershed; location's suitability

1. Introduction

Since the issuance of water resources law No. 7/2004 as modified by the law No. 17/2019 in Indonesia, the development of water resources in Indonesia has been very intense, covering including

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efforts ~~for~~ to conserve and develop water resources ~~conservation~~, ~~water resources development,~~ implementing programs for ~~alleviating~~ mitigating water-related disasters and a~~,~~ water resources information system, and encouraging stakeholders' participation in water resources development.

In Central Java p~~P~~rovince, ~~there are~~ two watersheds are managed by the provincial g~~G~~overnment~~, i.e.,~~ : Bodri-Kuto and Pemali-Comal ~~watersheds~~. However, ~~there are still some cases of~~ water deficiency still occurs in the areas, especially during dry season. Since 2015, some regenci~~es~~y in Central Java ~~Province~~ experienced ~~some~~ drought problems, lack of clean water supply, and lack of irrigation water. Some emergency actions were undertaken, such as supplying clean water by deploying water trucks and ~~operating~~ using portable pumps to pump water from rivers or ground water for irrigation. ~~Additionally, some~~Some artificial rainfall efforts ~~had~~ were also ~~been practised~~ implemented with less success~~es~~. Kendal Regency, one of regencies in the Bodri-Kuto w~~W~~atershed, was declared by the Provincial Disaster Mitigation Agency as ~~a region which~~ experiencing a~~ed~~ drought emergency in ~~the year~~ 2015, 2017, and 2019.

One effort ~~to overcome the dry condition~~ of~~,~~ the provincial government to overcome the dry condition ~~has~~ was the commitment~~ted~~ to developing 1000 small reservoirs throughout the province. In the Bodri-Kuto watershed, there are 33 small reservoirs (10 already operating~~ed~~ and other 23 are ~~on going~~undergoing design and construction). Small reservoirs are reservoirs ~~which~~ with ~~have~~ storage <1 million m^3, or height <15 m, or crest~~'s~~ ~~lentgh~~length <500 m.

~~In its~~During implementation, the construction ~~did not run~~progressed poorly primarily ~~well~~ due ~~primarily~~ to delays in land acquisition. Land ~~acqusition~~acquisition has ~~been~~ historically delayed many projects [1]. This land acquisition is causing major delays in the construction of some public infrastructure~~s construction~~. The ~~research on the~~ factors causing delay in land acquisition ~~such as [2] who~~can be grouped into four~~4~~ principal factors~~, i.e.,~~: political interference~~,~~ high cost of land transactions~~,~~ weak planning institutions~~,~~ and rehabilitation issues with extensive legal delays [2].

To avoid the uncertainty ~~in~~ of land acquisition, some ~~sites for the~~ small reservoirs ~~construction are moved to~~were instead constructed on the closest state-owned land, which ~~therefore does not require~~avoided the lengthy land acquisition process. The shift from technically ideal sites to available state-owned land for the construction of small reservoirs ~~raise the issue on~~put into question the ~~suitability~~ location suitability of th~~e~~ose reservoirs.

~~The~~ Study of the impact of these location~~s'~~ changes ~~to the location suitability~~ of small reservoirs ~~at~~ in the Bodri-Kuto watershed ~~has been studied by [3] which shows small~~indicated their low suitability [3]. ~~It reveals~~ Hhowever, ~~that~~ the ~~study~~ authors used the~~s~~ average of each month's rainfall data ~~data~~ as reference for its respective month's standardized precipitation index (SPI) calculation. ~~Additionally, it~~They used the drought vulnerability criterion~~a~~, which is defined as joint ~~occurences~~occurrences of dry spells in consecutive months for evaluating the location~~'s~~ suitability. The use of the mean of each month's rainfall ~~data will result in the~~indicates the SPI ~~in~~ with ~~regard~~ respect to ~~its respective~~ each month's deviation only. As a ~~consquence~~consequence, the same dry spell in one month ~~gives~~ differently ~~meaning of~~impacts the dryness in ~~an~~other months, which must be avoided. Secondly, the use of drought vulnerability, which combines the joint ~~occurences~~occurrences of frequenci~~es~~y of dry and very dry spells in consecutive~~s~~ months, ~~will~~ changes the probability of drought condition ~~to be different from the~~so that it does not reflect actual ~~real~~ field conditions.

~~This paper~~In this study, we evaluate~~d~~s the suitability of ~~of~~ locations for small reservoirs at Bodri-Kuto w~~W~~atershed using the monthly SPI ~~index described in~~ [4]. ~~For~~ To calculate monthly SPI~~'s calculation~~, ~~it~~ we used the~~s~~ average of monthly rainfall. ~~Additionally, it~~We use~~d~~s the envelope spatial dryness condition to justify the location suitability.

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2. Materials and Methods

2.1. Location

The location of the study ~~is~~ was ~~in~~ the Bodri-Kuto w~~W~~atershed in Central Java p~~P~~rovince, which ~~cover~~ includes regencies of Kendal, Semarang, Batang, and Temanggung, ~~such~~ as shown in Figure 1. ~~The figure~~Figure 1 shows ~~areal~~ the area of the Bodri-Kuto w~~W~~atershed ~~superimposed with~~ indicating the ~~loctions~~locations ~~of~~ with ~~constructed~~ small reservoirs, ~~on-going~~ reservoirs under~~s~~ construction ~~during~~ in 2017, rainfall stations, and areas supplied with emergency water ~~supply~~ by water truck~~,~~ and pumped irrigation.

Figure 1. Bodri-Kuto w~~W~~atershed in Central Java p~~P~~rovince and ~~its~~ locations of small reservoirs~~locations~~.

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2.2. Data

~~The study uses~~We used secondary data ~~of~~ of 17 years (2000–2016) of rainfall records from 25 stations in the catchment obtained from the Water Resources Agency in Central Java ~~Province;~~, location of emergency water supply and irrigation ~~collected~~ obtained from the Kendal Disaster Management Agency~~;~~, and location of small reservoirs ~~constructed~~completed, ~~on going~~under construction~~,~~ and planned collected from the Water Resources Agency in Central Java Province, ~~and from~~the Agricultural Department~~,~~ and the Forestry Department. Other data ~~are~~ included information on the ~~occurences~~occurrences of drought in the field obtained from governmental offices, villages, and newspapers.

2.3. *Analysis*

The nature of drought ~~phenomena~~ is complex and any drought index should realistically ~~able to account for~~consider ~~the condition of~~ climatological factors such as rainfall, temperature, air humidity, wind~~s~~, ~~as well as th~~ande soil conditions. The selection o~~f~~n the drought index for an analysis is ~~very~~ dependent ~~to~~ on the specific region, available information (data base), and the objective of the analysis [6]. Author et al. ~~Ref.~~ [7] ~~had~~ comprehensively reviewed some drought indices, ~~which~~ address~~ing~~~~ed~~ the principles of the methods along with their limitations and strengths. Author et al. ~~It is further identified by~~ [8] reported that ~~actually there is~~ no singular ~~one particular specific~~ index ~~which~~ can portray~~ait~~ drought conditions for all of ~~whole~~ space and time. Droughts are multidimensional in nature, manifested ~~at~~ on different temporal scales, and cannot be fully characterized using a single indicator [9].

The use of SPI [10] has been ~~very~~ popular, ~~due~~ primarily due to its less complicated formulation and requiring~~es~~ only rainfall time series, ~~and yet,~~and is capable of characterizing both temporal and spatial climatological drought conditions ~~both temporal and spatial wise~~ [11].

Author et al. ~~Ref.~~ [12] applied~~s~~ three drought indices: SPI, precipitation index percent of normal (PIPN), and agricultural rainfall index (ARI) using database~~s~~ from 1990 to 1961 ~~at the~~in N~~n~~ortheast ~~of~~ Iran. The future drought conditions in the Kashafrood basin, Iran, due to climate change result~~ing~~~~ed~~ from low and high greenhouse gas emission scenarios (SRES B2 and A2, respectively), were ~~predited~~predicted using all ~~of those~~ three indices. ~~It was demonstrated that all of the~~All indices indicated higher drought frequency as a result ~~from~~ of climate change under both scenarios. ~~It~~The findings support~~s~~ that even the simple SPI ~~indice~~ can ~~perform~~ provide equally good results ~~compare~~compare with ~~to~~ the more detail indices (PIPN and ARI).

Author et al. ~~Ref.~~ [13] studied the use of contemporaneous autoregressive moving average (CARMA) time series analysis to model the SPI at a time scale of 12 months (SPI-12) ~~at~~ in the north-west mountainous region in Jordan. ~~It~~ They used a rainfall data-base recorded from five rainfall stations from 1983 to 2013 (30 years ~~length~~). ~~In the study, it is~~The results demonstrated that ~~the~~ CARMA (1,1) can model the SPI ~~12~~ in ~~at~~ the region and that the cross-correlation structures between the stations were well preserved.

Author et al. ~~Ref.~~ [14] ~~have~~ applied the ~~used of~~ normalized monthly precipitation and ~~standardized precipitation index (~~SPI~~)~~ to study the influence of El ~~Nino~~ Niño events using rainfall data based ~~from~~ on 1950–2010 in Indonesia. ~~It~~ They ~~showed~~ found that the influence of El ~~Nino~~ Niño events is better represented by use of SPI. ~~Furthermore, the~~The use of temporal and spatial SPI ~~on~~ in more regions and seasons affected by El ~~Nino~~ Niño can ~~better~~ more accurately reflect ~~result in~~ drought outlook.

Author et al. ~~Ref.~~ [4] applied SPI to analy~~z~~se the influence of climatic variability to the seasonal rainfall pattern ~~at~~ in South-western ~~of~~ Congo. ~~It shows~~They found that the frequency of occurrence of dry periods in successive years is relatively low, although 25 years over the last 50 years have experienced droughts.

Recently, Author et al. ~~ref.~~ [3] used SPI to evaluate the correlation between drought area and the location of small reservoir~~s~~ construction in the Bodri-Kuto watershed In Indonesia. ~~It showed low~~The reported the low suitability ~~between~~ of the location~~s~~ of small reservoir~~s~~ ~~construction and~~given the drought condition~~s~~. However, Author et al. ~~ref.~~ [3] used SPI defined as the standardized deviation from it~~'~~s respective month~~s~~ [3]. This ~~will result~~use of ~~in the~~ SPI ~~value in regard to~~only indicates ~~its respective~~each month's deviation ~~only~~, resulting in different dry spell ~~meaning~~ definitions in different months ~~although~~ despite having equal SPI values. Secondly, ~~it~~ they applied drought ~~severety~~severity criteria based on ~~simultenously~~simultaneous drought frequencies of dry and very dry spells in consecutive months. ~~The use of this~~This joint drought ~~severety~~severity definition ~~will change the~~means the probability of drought conditions ~~which~~ may ~~differ from real~~not reflect field condition~~s~~.

The SPI ~~index~~ in this ~~paper is~~study was calculated both ~~for~~ yearly and m~~M~~onthly ~~SPI~~. For yearly SPI, ~~it~~ we use~~d the~~~~s~~ mean of yearly rainfall data as the reference~~, while,~~ for monthly SPI, ~~it~~ we used~~s~~ the mean of monthly ~~r~~reainfall data as the reference applicable throughout the months. In principle,

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the index calculates the standardized of rainfall. When it the SPI less than the average, the index is negative. The larger the negative value, shows the higher itlarger the deviationes (smaller than) from its average or reference value, therefore, indicating a more severe drought index. The SPI formula used is as follows [3,15,16]:

$$\text{SPI} = \frac{X_i - \overline{X}}{\sigma}$$

where:

X_i is = rainfall (mm) at time period i,

$\overline{X}$ is = average rainfall (mm), and

σ is the = standard deviation (mm).

Based on the SPI calculated above, the drought condition can bewas classified as shown in Table 1.

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Table 1. Classification based on SPI value [4].

Value of SPI	Condition
−0.49 to −0.49	~~normal~~Normal
−0.50 to −−0.99	~~moderately~~ Moderately dry
−1.00 to −−1.49	~~dry~~Dry
−1.50 to −−1.99	V~~v~~ery dry
<−2.00	~~Extreem~~Extreme dry

~~source: [4].~~

The analysis performed in this ~~paper~~ study ~~is briefly explained~~was as follows:~~.~~

~~1.~~ (1) SPI c~~C~~alculation:

The SPI ~~analysis is performed~~was analyzed for ~~at~~ 17 years of rainfall records (2000–2016) from 25 rainfall stations in the watershed. Before the SPI a~~A~~nalysis, the ~~the~~ missing data ~~has been~~were filled with inversed square distance values (Fisher et al., 1987) and the data ~~has been~~ were ~~chekced~~checked for ~~its~~ consistency ~~by~~ usinge ~~of~~ the double mass curve ~~and~~ with correction~~ed~~ (Wilson, 1983).

~~2.~~ (2) The ~~period of~~ dry months ~~are~~ were also cross checked using Oldeman's method (Parvin and Saleh, 2013). ~~It~~We confirmed that ~~month of~~ July to September are the driest months.

~~3.~~ (3) Spatial i~~I~~nterpolation ~~is~~ was performed based on the SPI at 25 rainfall stations. The spatial interpolation throughout the watershed ~~is~~ was performed using multi-dimension inverse distance weighting (IDW) in ~~the~~ ArcMap (company, city, state abbrv. if USA, country) to obtain the spatial distribution of SPI [17]. Other approaches to define spatial distribution ~~is~~ include using principle component analysis for clustering homogenous regions based on SPI [18].

~~4.~~ (4) Drought classification and mapping: ~~.~~

Based on the spatial SPI, ~~the spatial classification on~~ drought conditions ~~is performed~~were spatially classified based on Tshiabukole (2016), as shown in Table 1.

~~5.~~ (5) ~~Severety~~Severity o~~f~~n d~~D~~rought ~~condition:~~.

The ~~severety~~severity of drought ~~condition~~ is based on monthly SPI. The longer the dry condition (as indicated by SPI ~~index~~), ~~will result in~~the more severe the ~~condition~~drought. Severe drought conditions ~~is~~ are experienced when the location is continuously ~~in~~ dry condition for three months. The criteria for ~~severety on~~ drought severity are ~~is~~ shown in Table 2.

~~6.~~ (6) Location~~'s~~ s~~S~~uitability: ~~.~~

The suitability of reservoir locations based on the SPI ~~index is~~was obtained from overlying spatial mapping of drought classification with locations of small reservoirs (constructed or planned).

Table 2. Drought ~~d~~D~~D~~uration, ~~severety~~severity, and location suitability.

No.	Duration *	Drought ~~Severety~~Severity	Suitability
1	3 months	Very High	Very Suitable
2	2 months	High	Suitable
3	1 months	Moderate	Moderately Suitable
4	-	Low	Less Suitable

* Monthly SPI < −0.50 (moderately dry or worse).

3. Results

3.1. Yearly SPI

The yearly SPI ~~is~~ was used to identify ~~which~~ the ~~years are in the~~ driest ~~periods~~years. ~~It is identified~~which was achieved by counting the number of rainfall stations whose records showed dry conditions. Figure 2 shows the number of rainfall stations (out of 25 ~~stations~~) ~~which~~ that experienced moderately dry or worse conditions (SPI < −0.50) ~~in~~ every year. In ~~the year~~ 2000, for example, ~~there~~

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~~were 4~~four stations experienced moderately dry condition, three~~3~~ ~~stations~~ experienced dry condition, and two~~2~~ ~~stations~~ experienced very dry condition. In total, ~~there were 9~~nine stations (out of 25 ~~stations~~) ~~which~~ experienced moderately dry or worse conditions in ~~the year~~ 2000. ~~From this figure, it can be seen~~Figure 2 shows that the driest years were observed in ~~the year~~ 2005, 2006, 2007, 2009, 2012, and 2015, where more than 10 rainfall stations simultaneously experienced moderately dry or worse conditions (SPI < −0.50).

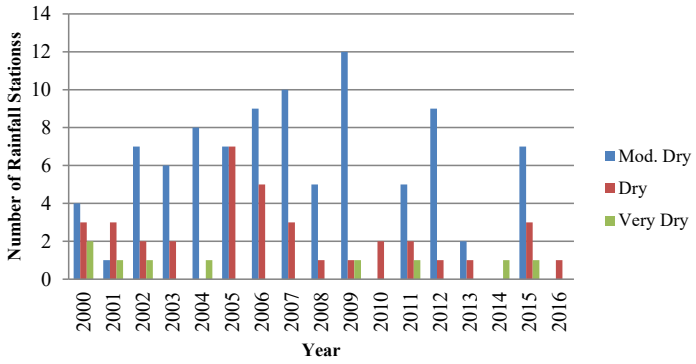

Figure 2. Number of rainfall stations experiencing moderately dry or worse conditions.

Figure 3 shows the frequency ~~of a station in the~~of ~~condition of~~ moderately dry or worse conditions at the various stations. The worst rainfall record~~s~~ ~~is~~ was observed at ~~in~~ Podowaras station, ~~s where it has~~which experienced nine~~9~~ years of dry conditions and eight~~8~~ years of very dry conditions out of the 17 years of records (2000–2016). ~~The Podowaras records always shows dry and very dry conditions throughout the period.~~ Other ~~rainfall~~rainfall records showing moderately dry or worse ~~are~~ conditions included: Kedung Wungu (13 years), Babadan (9 years), Bojong (12 years), Ketapang (10 years), and Sekopek (10 years)~~, Podowaras (17 years).~~.

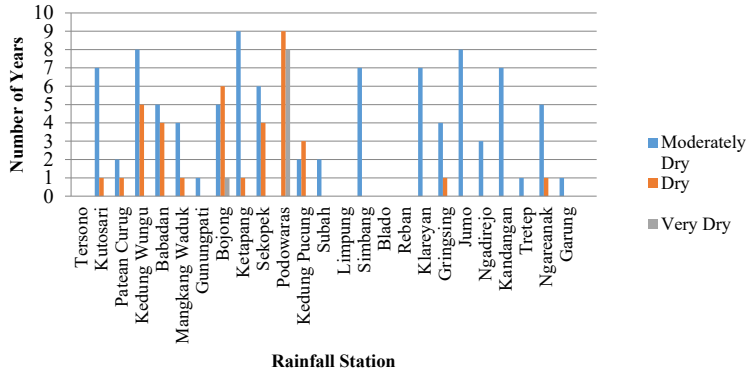

Figure 3. Rainfall stations experiencing moderately dry or worse conditions.

3.2. *Monthly SPI*

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The result of monthly SPI for all 25 rainfall stations is shown in Table 3. ~~In~~ On average, the moderately dry months ~~are in~~were June to ~~Octobre~~October, ~~where their~~with SPI values ~~are~~ below

−0.5 (moderately dry or worse). In this analysis, ~~it~~ we used~~s~~ the driest three months~~, i.e., the month of~~: July, August, and September.

Table 3. Monthly SPI at 25 rainfall stations.

No.	Rainfall Station	Monthly SPI											
		Januar y	Februar y	Marc h	Apri l	May	June	July	Augus t	~~September~~Septembe r	Octobe r	Novembe r	Decembe r
1	Tersono	1.82	2.87	0.83	0.70	−0.22	−0.55	**−0.76**	**−1.06**	**−1.00**	−0.57	0.19	1.41
2	Kutosari	1.18	1.30	−0.32	−0.33	−0.45	−0.71	**−0.91**	**−1.10**	**−0.96**	−0.80	−0.03	0.27
3	Patean Curug	1.08	1.05	0.81	0.40	−0.12	−0.58	**−0.79**	**−1.06**	**−0.94**	−0.40	0.43	0.72
4	Kedung Wungu	0.81	0.75	−0.18	−0.24	−0.46	−0.72	**−0.88**	**−1.20**	**−1.10**	−0.90	−0.54	−0.05
5	Babadan	0.76	1.06	−0.14	−0.44	−0.42	−0.77	**−1.01**	**−1.16**	**−0.96**	−0.75	−0.36	0.11
6	Mangkang Waduk	1.34	1.30	0.23	0.14	−0.21	−0.55	**−0.75**	**−1.12**	**−0.89**	−0.60	−0.01	0.32
7	Gunungpati	1.66	1.04	1.00	0.55	−0.20	−0.69	**−0.97**	**−1.10**	**−0.81**	−0.43	0.74	0.88
8	Bojong	0.70	0.50	−0.29	−0.30	−0.59	−0.80	**−1.01**	**−1.16**	**−0.95**	−0.83	−0.51	0.11
9	Ketapang	1.10	1.13	−0.22	−0.40	−0.62	−0.68	**−1.03**	**−1.15**	**−0.93**	−0.60	−0.25	0.14
10	Sekopek	0.87	0.86	−0.17	−0.27	−0.53	−0.71	**−0.96**	**−1.13**	**−0.97**	−0.71	−0.39	0.12
11	Podowaras	−0.34	−0.17	−0.71	−0.70	−0.93	−0.93	**−1.10**	**−1.20**	**−1.10**	−1.03	−0.81	−0.56
12	Kedung Pucung	1.15	0.87	0.35	0.38	−0.25	−0.57	**−0.73**	**−1.14**	**−1.06**	−0.73	0.04	0.33
13	Subah	2.03	2.48	0.18	−0.12	−0.49	−0.64	**−0.70**	**−1.08**	**−0.91**	−0.62	−0.08	0.28
14	Limpung	2.09	2.25	0.73	0.57	−0.19	−0.41	**−0.76**	**−1.01**	**−0.90**	−0.43	0.29	0.87
15	Simbang	1.59	2.09	−0.09	−0.28	−0.60	−0.74	**−0.81**	**−1.04**	**−0.98**	−0.77	−0.39	−0.06
16	Blado	3.52	3.37	2.23	1.55	0.88	0.07	**−0.53**	**−0.84**	**−0.76**	0.25	1.26	2.05

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17	Reban	3.73	4.20	2.39	2.08	1.02	−0.07	**−0.60**	**−0.58**	**−0.53**	0.01	1.14	2.59
18	Klareyan	1.57	1.12	0.40	−0.20	−0.68	−0.56	**−0.78**	**−0.97**	**−0.71**	−0.91	−0.43	0.48
19	Gringsing	1.33	1.87	−0.14	−0.27	−0.43	−0.65	**−0.85**	**−1.09**	**−0.97**	−0.72	−0.09	0.37
20	Jumo	0.41	0.53	0.76	0.28	−0.37	−0.91	**−0.90**	**−1.11**	**−0.91**	−0.44	0.14	0.39
21	Ngadirejo	0.80	0.66	0.72	0.39	−0.38	−0.82	**−1.03**	**−1.09**	**−0.88**	−0.62	0.11	0.78
22	Kandangan	0.74	0.16	0.42	0.15	−0.53	−0.97	**−0.87**	**−1.03**	**−0.87**	−0.31	0.37	0.64
23	Tretep	1.47	1.20	1.09	0.99	0.04	−0.60	**−0.83**	**−1.06**	**−0.73**	−0.24	0.70	1.52
24	Singorojo	0.98	0.57	0.32	0.17	−0.50	−0.81	**−1.03**	**−1.18**	**−1.01**	−0.53	0.06	0.77
25	Garung	1.75	1.47	1.90	1.35	0.36	−0.50	**−0.77**	**−0.89**	**−0.62**	0.39	1.45	1.92
	Max	3.73	4.20	2.39	2.08	1.02	0.07	**−0.53**	**−0.58**	**−0.53**	0.39	1.45	2.59
	Min	−0.34	−0.17	−0.71	−0.70	−0.93	−0.97	**−1.10**	**−1.20**	**−1.10**	−1.03	−0.81	−0.56
	Average	1.37	1.38	0.48	0.25	−0.27	−0.63	**−0.85**	**−1.06**	**−0.90**	−0.53	0.12	0.66

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Figure 4 shows the driest rainfall stations based on monthly SPI. The driest month~~s are~~ was August followed by July and September, which showed moderately dry and dry conditions. ~~From this figure, it is confirmed~~The ~~that the driest months are in July, August, and September. Furthermore, the~~ rainfall records showing the driest conditions ~~are~~ were ~~records at stations of~~those from Kedung Wungu, Ketapang, Sekopek, Podowaras, Simbang, Klareyan, and dan Singorojo stations. ~~These are stations with the driest condition~~ based on both monthly and yearly SPI~~'s~~.

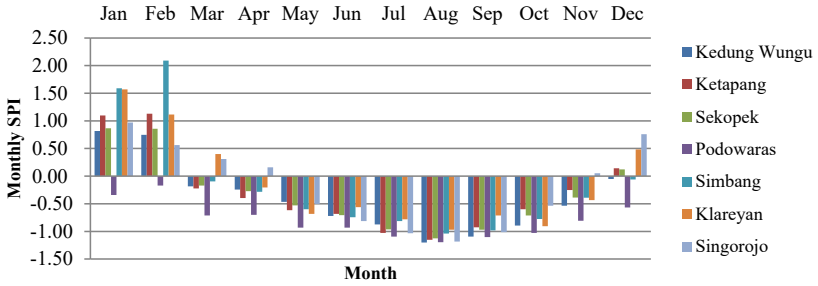

Figure 4. Monthly SPI at ~~Some~~ driest rainfall stations.

Figure 5 shows the number of rainfall stations ~~which~~ that were experiencing moderately dry or worse conditions. During the driest months of July, August, and September, all rainfall records indicated moderately dry or worse conditions. Figure 6 shows the number of months in the year ~~(out of 12 months)~~ where the rainfall records showed~~s~~ moderately dry or worse conditions.

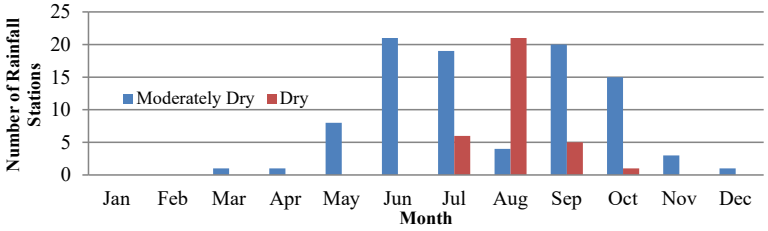

Figure 5. Number of rainfall stations experiencing moderately dry or worse conditions.

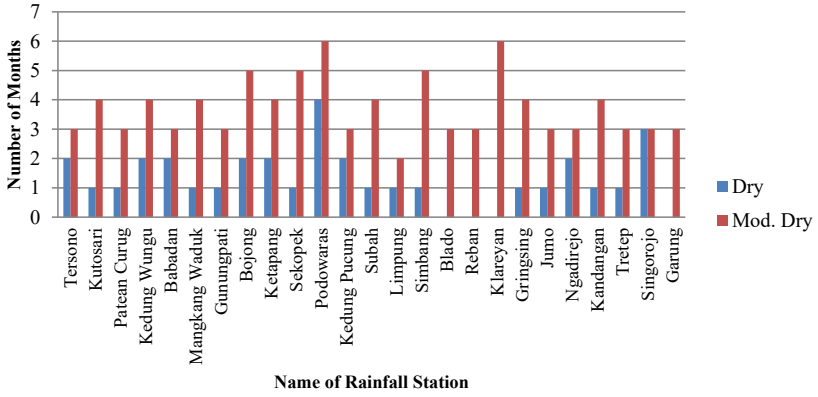

Figure 6. Frequency of rainfall stations experiencing moderately dry or worse conditions in the Bodri-Kuto watershed.

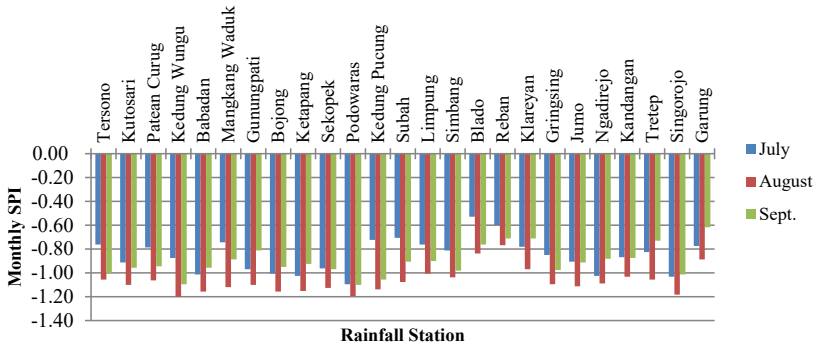

Figure 7. Monthly SPI ~~at~~ of the driest months of July, August, and September in the Bodri-Kuto watershed.

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4. Discussion

4.1. Spatial Distribution of Drought

The spatial distribution of monthly drought in the Bodri ~~-~~Kuto watershed during July, August, and September is shown in Figure 8. ~~Based on monhtly SPI, The~~, where yellow ~~shows~~ indicates ~~areal of~~ moderately dry areas and ~~while~~ the dark yellow ~~is~~ indicates dry conditions. ~~During~~ In July, ~~there were~~ 19 stations were moderately dry and 6 stations were dry. The ~~location of 6~~six stations ~~in~~ reporting dry conditions ~~during~~ in July were: Babadan, Bojong, Ketapang, Podowaras, Ngadirejo, and Singorojo, ~~and~~ which are mostly located in the cent~~r~~er of the watershed (~~the~~ dark yellow area). ~~During~~ In August, ~~there were~~ only four stations ~~which are~~reported moderately dry conditions (Blado, Reban, Klareyan, and Garung), which are located at the north ~~-~~east part of the watershed (~~the~~ yellow area). ~~Meanwhile, during~~In September, ~~there were 5~~five stations (Tersono, Kedungungu, Podowaras, Kedung Pucung, and Singorojo) ~~which~~ experienced dry conditions (dark yellow).

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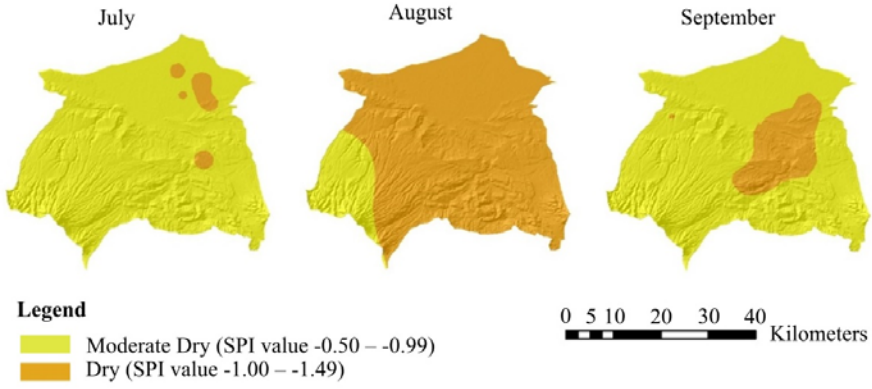

Figure 8. Spatial ~~Monthly~~monthly SPI d~~D~~istribution ~~over~~ in the Bodri-Kuto Watershed.

Commented [KO26]: In legend, replace en dash that indicates the word "to" with the word, e.g., –0.5 to –0.99.

The ~~severety~~severity of drought ~~condition is based on~~was determined on the basis of the criteria in Table 2 and is shown in Figure 9. ~~Station~~ Podowaras and Singorojo stations experienced continuous dry conditions ~~during~~ in July, August, and September. The areas shown in (Figure 9 in, dark brown~~)~~ ~~is~~ are most ~~very~~ suitable for the ~~the~~ construction of small reservoir ~~s~~location. The areas ~~of~~ indicated in brown ~~is~~ are suitable, ~~while~~ whereas the areas ~~of~~ indicated in light brown ~~is~~ are moderately suitable. ~~In Figure 9, it is also overlayed with the~~The drought severity map in Figure 9 is overlaid with locations of small reservoirs (constructed and ~~on going~~under construction) and locations of emergency water supp~~l~~lies~~y~~ (water truck and pumped irrigation). ~~It~~ The figure shows that the emergency water supply in Curug Sewu, Sidodadi, Jatirejo, Pekuncen, and Wonosari ~~are relevan~~aligns with ~~to~~ the drought-affected areas.

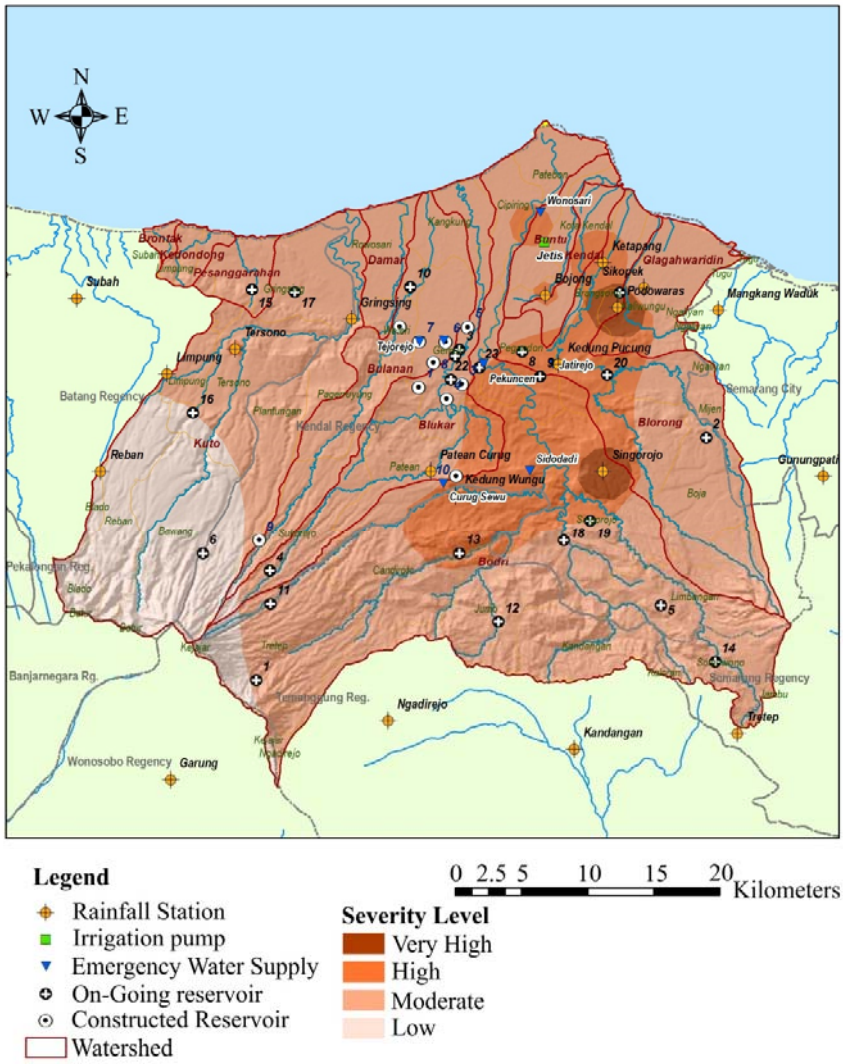

Figure 9. Overlay of small ~~resevoir~~reservoir s' locations and drought ~~severety~~severity map.

4.2. Location Suitability of Constructed Reservoirs

The l~~L~~ocations of some constructed reservoirs overlaid with the drought ~~severely~~severity map ~~is~~ are shown in Figure 9 and ~~its~~ the location suitability is ~~shown~~ listed in Table 4. ~~It can be seen that there is only~~ Only one reservoir (~~reservoir~~ No. 10, Sidokumpul) ~~which~~ is located in a suitable area (i.e., ~~at~~ with high ~~severely~~severity ~~dry~~drought) ~~area~~. This ~~is in concordance~~finding agrees with ~~previous~~ that previously reported ~~study~~ [3]. The other nine reservoirs (90%) are located in moderately dry areas, which are thus in moderately suitable locations. Compared ~~to~~ with the previous study [3], ~~there were~~ 80% ~~locations~~ of ~~constructed~~ small reservoirs ~~which~~ were constructed in ~~are~~ less suitable locations.

Table 4. Location suitability of constructed small rReservoirs.

No.	Name ~~of Small Res.~~	Drought ~~Severety~~Severity	Suitability
1	Kedungasri	Moderate	Moderate ~~Suitable~~
2	Bumiayu	Moderate	Moderate ~~Suitable~~
3	Triharjo	Moderate	Moderate ~~Suitable~~
4	Sojomerto	Moderate	Moderate ~~Suitable~~
5	Rowobranten	Moderate	Moderate ~~Suitable~~
6	Ringinarum	Moderate	Moderate ~~Suitable~~
7	Tejorejo	Moderate	Moderate ~~Suitable~~
8	Ngerjo	Moderate	Moderate ~~Suitable~~
9	Harjodowo	Moderate	Moderate ~~Suitable~~
10	Sidokumpul	High	Suitable
		~~Counting:~~Total:	
		Very Suitable	0 (0%)
		Suitable	1 (10%)
		Moderately Suitable	9 (90%)
		Less Suitable	0 (0%)

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The result ~~is relevant to the~~aligns with the field conditi~~o~~ons. The Sidokumpul small reservoir is used for supplying domestic water needs, cattle, and irrigation. ~~Additionally, the~~The Sidokumpul reservoir is also used to supply water to Sojomerto Weir, thus extending its services to a wider irrigation area.

4.3. Location Suitability of ~~On Going~~ Reservoirs Under Construction

~~Location~~ The locations of ~~on going~~ reservoirs under construction overlaid ~~in~~ on the drought ~~severety~~severity map ~~is~~ are shown in Figure 9 and ~~in its~~their suitability is ~~shown~~ listed in Table 5. ~~It can be seen that out of~~ Of 23 ~~on going~~ reservoir under construction, ~~one~~ 1 reservoir (4%) is in a very suitable location (~~reservoir~~ Karangtengah, No. 7), 6 reservoirs (26%) are in suitable locations, 15 reservoirs (65%) are in moderately suitable location, and only ~~one~~ 1 reservoir (~~reservoir~~ Blumah) is located in a less suitable location. ~~Previous~~ The other study [3] showed that ~~there were~~ 57% ~~of on going~~ small reservoirs ~~which are~~under construction were in less suitable locations.

Table 5. Location suitability of ~~of on going~~ small reservoirs under construction.

No.	Name ~~of Small Res.~~	Drought ~~Severety~~Severity	Suitability
1	Wonoboyo	Moderate	Moderate ~~Suitable~~
2	Trisobo	Moderate	Moderate ~~Suitable~~
3	Kedunggading	Moderate	Moderate ~~Suitable~~
4	Tamanrejo	Moderate	Moderate ~~Suitable~~
5	Kedungboto	Moderate	Moderate ~~Suitable~~
6	Blumah	Low	Less ~~Suitable~~
7	Karangtengah	Very High	Very ~~Suitable~~
8	Wonosari	High	Suitable
9	Jatirejo	High	Suitable
10	Wonotenggang	Moderate	Moderate ~~Suitable~~
11	Nglarangan	Moderate	Moderate ~~Suitable~~
12	Gemawang	Moderate	Moderate ~~Suitable~~
13	Bejen	High	Suitable
14	Sumowono	Moderate	Moderate ~~Suitable~~
15	Sawangan	Moderate	Moderate ~~Suitable~~
16	Ngaliyan	Moderate	Moderate ~~Suitable~~
17	Gringsing	Moderate	Moderate ~~Suitable~~

18	W. Cening	Moderate	Moderate ~~Suitable~~
19	W. Banyuwaringin	High	Suitable
20	W. Kedungsuren	High	Suitable
21	Kdg Gading2	Moderate	Moderate ~~Suitable~~
22	Sojomerto2	Moderate	Moderate ~~Suitable~~
23	Triharjo2	High	Suitable
		~~Counting:~~Total:	
		Very Suitable	1 (4%)
		Suitable	6 (26%)
		Moderately Suitable	15 (65%)
		Less Suitable	1 (4%)
		~~Total~~	~~23 (100%)~~

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~~In~~ Overall, ~~it can be seen from~~ Table 6 shows that out of total 33 reservoir locations, ~~there is one~~1 (3%) ~~location~~ is very suitable, ~~seven~~ 7 (21%) ~~locations~~ are suitable, 24 (73%) ~~locations~~ are moderately suitable, and only ~~one~~ 1 (3%) location ~~which~~ is less suitable.

Table 6. Overall location suitability.

No.	Suitability	Constructed	~~On Going~~Under Construction	Total	
1	Very Suitable	0 (0%)	1 (4%)	1	3%
2	Suitable	1 (10%)	6 (26%)	7	21%
3	Moderately Suitable	9 (90%)	15 (65%)	24	73%
4	Less Suitable	0 (0%)	1 (4%)	1	3%
	Total	**10 (100%)**	**23 (100%)**	**33**	**100%**

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5. Conclusions

~~1.~~ For ~~constructed~~ the locations of existing small reservoirs, ~~there are one~~1 (10%) is suitable and ~~nine~~9 (90%) are moderately suitable ~~locations~~. ~~Meanwhile, for on-going small~~For small reservoirs under construction, ~~there are~~ 1 (4%) is very suitable, 6 (26%) are suitable, 15 (65%) are moderately suitable, and ~~only~~ 1 (4%) is less suitable. ~~It gives improvement on the~~This is an improvement in the suitability percentage compared to ~~previous~~ the findings reported previously ~~study~~ [3].

~~2.~~ ~~In~~ Overall, ~~out~~ of 33 reservoirs under construction in the Bodri-Kuto watershed, ~~there are~~ 8 (24%) ~~of construction of small reservoir in Bodri Kuto Watershed which~~ are either very suitable ~~and~~ or suitable. The ~~number of~~ suitability ~~increase for on-going~~of the planned and under-construction reservoirs is increasing ~~and planned small reservoirs~~.

~~3.~~ ~~Most~~The ~~of the~~ locations of 24 small reservoirs (~~=~~73%) are moderately suitable as they are located in ~~the~~ drought-prone areas. ~~It is also shown.~~ We also found that the ~~number of~~ suitability ~~increase for on-going~~of under-construction and planned small reservoirs is increasing.

~~4.~~ To improve the effectiveness of reservoir construction, ~~it is important to also consider~~ the drought ~~severety~~severity ~~for~~ in the areas surrounding ~~the location of~~ the reservoir should be considered.~~,~~

~~5.~~ The use of spatial and temporal SPI can help ~~access~~ determine ~~the~~ suitable locations~~ility~~ for reservoir-~~slocation~~.

~~6.~~ The ~~location changes experienced during the construction of~~ small reservoirs ~~from~~ constructed ~~technically ideal locations to~~in available land locations instead of technically ideal locations are still located within ~~the~~ suitable dry or moderately dry areas.

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Author Contributions: Conceptualization and methodology: S. ~~S.~~ and T.N.S.H.; software: T.N.S.H. and I.S.; validation, formal analysis, investigation, resources: ~~S, I.S., T.~~N.S.H., and F.S.; data T.N.S.H.; writing—original draft preparation: S. and, I.~~S.; writing—~~review and editing: S., I.S., and F.S.; visu~~alization: I.~~S., T.N.S.H., and F.S.

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Conflicts of Interest: The authors declare no conflict of interest.

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On 2020/3/2 19:02, _____wrote:

REVIEWER 1 : ROUND 1

Journal	Water (ISSN 2073-4441)
Manuscript ID	water-717922
Type	Article
Number of Pages	15

Title: Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI

Authors

Abstract: Despite efforts to develop and conserve water resources, almost every year during the dry season, some areas in Central Java province in Indonesia still experience lack of water, especially in rural villages. These areas require water supply via water trucks and/or portable pumps to obtain water from rivers and groundwater. The Central Java government committed to implementing a program involving the construction of 1000 small reservoirs by 2020 to overcome water shortages. However, the technically ideal sites are mostly privately owned, which requires lengthy and costly land acquisition. To avoid the uncertainty of land acquisition, some small reservoirs were placed on state-owned land, which did not require land acquisition. The shift from technically ideal sites to available state-owned land for the construction of small reservoirs put into question the location suitability of those reservoirs. In this study, we evaluated the suitability of the location of small reservoirs in the Bodri-Kuto Watershed using the monthly standardized precipitation index (SPI). We used rainfall records of 25 stations in the watershed from 2000 to 2016 and analyzed yearly and monthly rainfall data. The yearly analysis shows that the dry conditions (SPI < −0.5) from 2005 to 2009 affected more than half of rainfall stations (>50%), whereas the rainfall stations that experienced more dry years included Kedung Wungu, Babadan, Bojong, Ketapang, Sekopek, and Podowaras (more than 9 out of 17 years). The monthly SPI shows that during July, August, and September, all the rainfall stations experience moderately dry or worse conditions (SPI < −0.50). Using 25 rainfall stations, we determined the spatial spread of dry conditions using monthly SPI values from July, August, and September. Overlay of the spatial spread of dry conditions with the location of small reservoirs can be used to evaluate the suitability of small reservoir locations. We found that 1 (3%) location is very suitable, 7 (21%) locations are suitable, 24 (73%) locations are moderately suitable, and 1 (3%) location is less suitable. The findings indicate that spatial distribution of SPI can be used as an additional criterion for evaluating the suitability of small reservoirs' locations should technically ideal locations be unavailable.

REVIEW REPORT FORM :

English language and style

( ) Extensive editing of English language and style required
( ) Moderate English changes required
(x) English language and style are fine/minor spell check required
( ) I don't feel qualified to judge about the English language and style

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant	(x)	( )	( )	( )

references?

Is the research design appropriate?	( )	(x)	( )	( )
Are the methods adequately described?	( )	(x)	( )	( )
Are the results clearly presented?	( )	( )	(x)	( )
Are the conclusions supported by the results?	( )	( )	(x)	( )

COMMENTS AND SUGGESTIONS FOR AUTHORS

1. This is a very interesting paper dealing with the important issue of the suitability of the location of the construction of hydraulic plans, in this case, reservoirs.
2. The paper is very well written and the use of the English language is excellent.
3. There are some issues though in the applied methodology, the use of data and information and the conclusions.
   a) First of all, the authors emphasize in the use of meteorological data, and more specifically, the Standardized Precipitation Index (SPI), for the identification or the characterization of the suitability of specific locations selected for the construction of reservoirs. I am afraid this is just one of the criteria that need to be applied. The suitability of a location for the construction of a reservoir depends also on its location within the watershed, the flow of water, the characteristics of the soil, the cost of water allocation works, etc. All these issues are not even mentioned by the authors.
   b) The authors state that the reservoirs were built not on the optimal locations but on locations that were available (public instead of private). This is, of course, a very important issue, often found in the construction of public works. They don't indicate though these locations compared to the ones that were actually selected. If the distance is small, then the meteorological conditions are not likely to differ and thus, the whole approach, using the SP Index, doesn't seem to be of significance.
   c) In the main map of results (Figure 9) the authors point out a single location as, the only one reservoir (No. 10, Sidokumpul) which is located in a suitable area. I cannot see any differences between location 10 and locations 15 and 17, for example, which seem to be in the same drought significance severity area. Actually, reservoir 10 seems to be in a moderate and not a high severity area.
   d) Another map is needed, accompanying Figure 1, to show on a larger scale, the study area.

Submission Date 28 January 2020
Date of this review 08 Feb 2020 13:03:17

AUTHORS' RESPONSES TO REVIEWER'S COMMENTS (REVIEWER 1)

Author's Notes

1. Dear Reviewer 1, thank you very much for some inputs and points for the improvement of the paper.
2. Yes, definitely. There are more factors influencing the selection of a reservoir such as mention by the reviewer. In the paper, there are 30 small reservoirs that are field storage rain fed and whose capacity is below 100.000 m^3. These small storages must be located near the point of demand because the water transmision to further distance may not effective. I have included the table (Table 1 and Table 2) of the small reservoirs analysed to give clearer figures on the scale of the small reservoirs. The other 3 reservoirs are real reservoir whose capacity are at least 10 million m^3, which therefore their locations are determined by some factors that are mentioned by the reviewer 1.
3. The authors meant that "the change from its technically ideal location" occurred during the design phase of rain-fed small reservoirs or field storages. In practices, partly due to difficulties in land acquisition, there were more consideration and priorities on selecting location for rain-fed small reservoirs or field storages to

be on state-owned land. These have caused shift further from demand's point. The authors have corrected the sentences accordingly.

4. The SPI indicator uses rainfall as the main input. In hily areas such as those in the middle and in the upstream of the Bodri-Kuto watershed, the variation of monthly rainfall can be high. Therefore, the use of monthy SPI in the area of highly varied rainfall can still significant even in small distance.
5. In Figure 9, there are two type of reservoir, i.e., the already constructed (10 reservoirs) and the one that are still on going reservoirs (23 reservoirs). Reservoir No. 10 Sidokumpul is within the constructed reservoir, whose location is in barely the middle of the Figure (look at the sign : **black dot in the small circle** for constructed), upper side of text "Patean Curug". While reservoir number 15 and 17 which are located in the left upper of the Figure is within the on going reservoirs (look at the sign : **white cross within black small circle**).

Best Regards,

MATRICES OF AMENDMENTS FOR REVIEWER 1 ROUND 1

Comments and Suggestions for Authors	Author's Responds
This is a very interesting paper dealing with the important issue of the suitability of the location of the construction of hydraulic plans, in this case, reservoirs.	Thank you very much for some inputs and points for the improvement of the paper.
The paper is very well written and the use of the English language is excellent.	
There are some issues though in the applied methodology, the use of data and information and the conclusions.	
1. First of all, the authors emphasize in the use of meteorological data, and more specifically, the Standardized Precipitation Index (SPI), for the identification or the characterization of the suitability of specific locations selected for the construction of reservoirs. I am afraid this is just one of the criteria that need to be applied. The suitability of a location for the construction of a reservoir depends also on its location within the watershed, the flow of water, the characteristics of the soil, the cost of water allocation works, etc. All these issues are not even mentioned by the authors.	Yes, definitely. There are more factors influencing the selection of a reservoir such as mention by the reviewer. In the paper, there are 30 small reservoirs that are field storage rain fed and whose capacity is below 100.000 m3. These small storages must be located near the point of demand because the transmision to further distance may not effective. I have included the table (Table 1 and Table 2) of the small reservoirs analysed to give clearer figures on the scale of the small reservoirs. The other 3 reservoirs are real reservoir whose capacity are at least 10 million m^3, which therefore their locations are determined by some factors that are mentioned by the reviewer.
2. The authors state that the reservoirs were built not on the optimal locations but on locations that were available (public instead of private). This is, of course, a very important issue, often found in the construction of public works. They don't indicate though these locations compared to the ones that were actually selected. If the distance is small, then the meteorological conditions are not likely to differ and thus, the whole approach, using the SP Index, doesn't seem to be of significance.	The authors meant that "the change from its technically ideal location" occurred during the design phase of rain-fed small reservoirs or field storages. In practices, partly due to difficulties in land acquisition, there were more consideration and priorities on selecting location for rain-fed small reservoirs or field storages to be on state-owned land. These have caused shift further from demand's point. The authors have corrected the sentences accordingly. The SPI indicator uses rainfall as the main input. In hily areas such as those in the middle and in the upstream of the Bodri-Kuto watershed, the variation of monthly rainfall can be high. Therefore, the use of monthy SPI in the area of highly varied rainfall can

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4.	Another map is needed, accompanying Figure 1, to show on a larger scale, the study area.	Figure 1 has been modified to be more clearer

REVIEWER 2 : ROUND 1

Journal	Water (ISSN 2073-4441)
Manuscript ID	water-717922
Type	Article
Number of Pages	15
Title	Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI
Authors	

Abstract

Despite efforts to develop and conserve water resources, almost every year during the dry season, some areas in Central Java province in Indonesia still experience lack of water, especially in rural villages. These areas require water supply via water trucks and/or portable pumps to obtain water from rivers and groundwater. The Central Java government committed to implementing a program involving the construction of 1000 small reservoirs by 2020 to overcome water shortages. However, the technically ideal sites are mostly privately owned, which requires lengthy and costly land acquisition. To avoid the uncertainty of land acquisition, some small reservoirs were placed on state-owned land, which did not require land acquisition. The shift from technically ideal sites to available state-owned land for the construction of small reservoirs put into question the location suitability of those reservoirs. In this study, we evaluated the suitability of the location of small reservoirs in the Bodri-Kuto Watershed using the monthly standardized precipitation index (SPI). We used rainfall records of 25 stations in the watershed from 2000 to 2016 and analyzed yearly and monthly rainfall data. The yearly analysis shows that the dry conditions (SPI < −0.5) from 2005 to 2009 affected more than half of rainfall stations (>50%), whereas the rainfall stations that experienced more dry years included Kedung Wungu, Babadan, Bojong, Ketapang, Sekopek, and Podowaras (more than 9 out of 17 years). The monthly SPI shows that during July, August, and September, all the rainfall stations experience moderately dry or worse conditions (SPI < −0.50). Using 25 rainfall stations, we determined the spatial spread of dry conditions using monthly SPI values from July, August, and September. Overlay of the spatial spread of dry conditions with the location of small reservoirs can be used to evaluate the suitability of small reservoir locations. We found that 1 (3%) location is very suitable, 7 (21%) locations are suitable, 24 (73%) locations are moderately suitable, and 1 (3%) location is less suitable. The findings indicate that spatial distribution of SPI can be used as an additional criterion for evaluating the suitability of small reservoirs' locations should technically ideal locations be unavailable.

REVIEW REPORT FORM

English language and style

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( ) Moderate English changes required

(x) English language and style are fine/minor spell check required

( ) I don't feel qualified to judge about the English language and style

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	(x)	( )	( )	( )
Is the research design appropriate?	( )	(x)	( )	( )
Are the methods adequately described?	( )	(x)	( )	( )
Are the results clearly presented?	(x)	( )	( )	( )
Are the conclusions supported by the results?	( )	(x)	( )	( )

COMMENTS AND SUGGESTIONS FOR AUTHORS

1. The subject of this study is to suggest the location suitability of reservoir through SPI analysis.In the case of the drought index, various indices are currently proposed, and in addition to the SPI, the application of the drought index considering the amount of evapotranspiration in the target region is also worth proposing.
2. Sufficient opinion should also be given as to whether the droughts presented through the SPI is observed in real areas.
3. The decision was based solely on SPI for location suitablility. I think there are enough factors to consider in this research.
4. The conclusions need to be specifically described in this study for uncertainties and new findings.

Submission Date 28 January 2020
Date of this review 07 Feb 2020 06:20:33

AUTHORS' RESPONSES TO REVIEWER'S COMMENTS (REVIEWER 2)

Author's Notes

Dear Reviewer 2, The authors thank you very much for the comments and suggestion for improving the paper.

1. Yes, I definitely agree that the use of more indicators will be better representing the drought phenomena. There are many drought index in literatures such as in “Handbook of Drought Indicatros and Indices, GWP, WMO 1173.”. The indices which use evapotranspiration are among others Aridity Anomally Index (AA), Evaporative Stress Index (ESI), and Agregate Dryness Index (ADI). They are mostly aimed to address impacts of drought to agriculture. While the issue addressed in the paper is more on hydrological drought. SPI has been proved to be widely used indice and yet simpel.
2. The discussion has been improved to address the real situation compared to the results of the paper. The dry condition as well as the areas needed water truck supply indicate on the need of reservoir or storages.
3. Yes, definitely. There are more factors influencing the selection of a reservoir such as mention by the reviewer. In the paper, there are 30 small reservoirs that are field storage rain fed and whose capacity is below 100.000 m3. These small storages must be located near the point of demand because the transmision to further distance may not effective. I have included the table (Table 1 and Table 2) of the small reservoirs analysed to give clearer figures on the scale of the small reservoirs. The other 3 reservoirs are real reservoir whose capacity are at least 10 million m^3, which therefore their locations are determined by some factors that are also mentioned by the reviewer 1.
4. The uncertainties will include the location of rainfall stations, and on the completeness on the data itself. It is suggested that the analysis be performed for shorter time period e.g. weekly basis to capture the high variation in the rainfall (temporal and spatial).

Best Regards,

MATRICES OF AMENDMENTS FOR REVIEWER 2 ROUND 1

Comments and Suggestions for Authors	Author's Responds
1. The subject of this study is to suggest the location suitability of reservoir through SPI analysis.In the case of the drought index, various indices are currently proposed, and in addition to the SPI, the application of the drought index considering the amount of evapotranspiration in the target region is also worth proposing.	The authors thank you very much for the comments and suggestion for improving the paper. Yes, I definitely agree that the use of more indicatros will be better representing the drought phenomena. There are many drought index in literatures such as in "Handbook of Drought Indicatros and Indices, GWP, WMO 1173.". The indices which use evapotranspiration are among others Aridity Anomally Index (AA), Evaporative Stress Index (ESI), and Agregate Dryness Index (ADI). They are mostly aimed to address impacts of drought to agriculture. While the issue addressed in the paper is more on hydrological drought. SPI has been proved to be widely used indice and yet simpel.
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water

MDPI

Article

Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI

* Correspondence: s

Received: date; Accepted: date; Published: date

Abstract: Despite efforts to develop and conserve water resources, almost every year during the dry season, some areas in Central Java province in Indonesia still experience lack of water, especially in rural villages. These areas require water supply via water trucks and/or portable pumps to obtain water from rivers and groundwater. The Central Java government committed to implementing a program involving the construction of 1000 small reservoirs by 2020 to overcome water shortages. However, the technically ideal sites are mostly privately owned, which requires lengthy and costly land acquisition. To avoid the uncertainty of land acquisition, some small reservoirs were placed on state-owned land, which did not require land acquisition. The shift from technically ideal sitesconsideration on putting more emphasize to available state-owned land rather than technically ideal site for the construction of small reservoirs put into questionraise the issue on the location suitability of those reservoirs. In this study, we evaluated the suitability of the location of small reservoirs in the Bodri-Kuto Watershed using the monthly standardized precipitation index (SPI). We used rainfall records of 25 stations in the watershed from 2000 to 2016 and analyzed yearly and monthly rainfall data. The yearly analysis shows that the dry conditions (SPI < −0.5) from 2005 to 2009 affected more than half of rainfall stations (>50%), whereas the rainfall stations that experienced more dry years included Kedung Wungu, Babadan, Bojong, Ketapang, Sekopek, and Podowaras (more than 9 out of 17 years). The monthly SPI shows that during July, August, and September, all the rainfall stations experience moderately dry or worse conditions (SPI < −0.50). Using 25 rainfall stations, we determined the spatial spread of dry conditions using monthly SPI values from July, August, and September. Overlay of the spatial spread of dry conditions with the location of small reservoirs can be used to evaluate the suitability of small reservoir locations. We found that 1 (3%) location is very suitable, 7 (21%) locations are suitable, 24 (73%) locations are moderately suitable, and 1 (3%) location is less suitable. The findings indicate that spatial distribution of SPI can be used as an additional criterion for evaluating the suitability of small reservoirs' locations should technically ideal locations be unavailable.

Keywords: SPI; drought index; Bodri-Kuto watershed; location suitability

1. Introduction

Since the issuance of water resources law No. 7/2004 as modified by law No. 17/2019 in Indonesia, the development of water resources has been intense, including efforts to conserve and develop water resources, implementing programs for mitigating water-related disasters, water

~~18.~~20. Parvin, I. and Saleh, A. F. M.. Assessment of Agricultural Drought in 2006 Aman Season and Its Management by the Farmers : A Case Study in Rajshahi District Bangladesh. J. Indian Water Resour. Soc., 2013, Vol. 33 No. 1.

~~19.~~21. ESRI. Understanding interpolation analysis. 2012. (http://resources.arcgis.com/en/help/main/10.1/index.html#//003100000008000000).

~~20.~~22. Cavus, Y.; Aksoy, H. Spatial Drought Characterization for Seyhan River Basin in the Mediterranean Region of Turkey. Water 2019, 11, 1331, doi:10.3390/w11071331.

~~21.~~23. Espinosa, L.A.; Portela, M.M.; Pontes Filho, J.D.; Studart, T.M.D.C.; Santos, J.F.; Rodrigues, R. Jointly Modeling Drought Characteristics with Smoothed Regionalized SPI Series for a Small Island. Water 2019, 11, 2489, doi:10.3390/w11122489.

6. Second revision: Minor revisions (7-3-2020)

[Water] Manuscript ID: water-717922 - Minor Revisions

Nicole Ma <nicole.ma@mdpi.com>

Sab 07/03/2020 21.23

Kepada:
Cc:

Dear Dr. ,

Thank you for submitting your manuscript:

Manuscript ID: water-717922
Type of manuscript: Article
Title: Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI
Authors:
Received: 28 January 2020
E-mails:
Submitted to section: Water Use and Scarcity,
https://www.mdpi.com/journal/water/sections/Water_Use_Scarcity

It has been reviewed by experts in the field and we request that you make minor revisions before it is processed further. Please find your manuscript and the review reports at the following link:
https://susy.mdpi.com/user/manuscripts/resubmit/4281e3d90432238c56fd9c1be9ba9c9b

Your co-authors can also view this link if they have an account in our submission system using the e-mail address in this message.

Please revise the manuscript according to the reviewers' comments and upload the revised file within *2* days. Use the version of your manuscript found at the above link for your revisions, as the editorial office may have made formatting changes to your original submission. Any revisions should be clearly highlighted, for example using the "Track Changes" function in Microsoft Word, so that they are easily visible to the editors and reviewers. Please provide a short cover letter detailing any changes, for the benefit of the editors and reviewers. Please detail the revisions that have been made, citing the line number and exact change, so that the editor can check the changes expeditiously. Simple statements like ‘done’ or ‘revised as requested’ will not be accepted unless the change is simply a typographical error.

If the reviewers have suggested that your manuscript should undergo extensive English editing, please address this during revision. We suggest that you have your manuscript checked by a native English speaking colleague or use a professional English editing service. Alternatively, MDPI provides an English editing service checking grammar, spelling, punctuation and some improvement of style where necessary for an additional charge (extensive re-writing is not included), see details at https://www.mdpi.com/authors/english.

Do not hesitate to contact us if you have any questions regarding the revision of your manuscript or if you need more time. We look forward to hearing from you soon.

Kind regards,
Nicole Ma
Assistant Editor
Email: nicole.ma@mdpi.com

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http://www.mdpi.com/journal/water/

7. Second revision submitted (12-3-2020)

-Revisions and Amends

-Revised version with highlights

[Water] Manuscript ID: water-717922 - Manuscript Resubmitted

susy@mdpi.com <susy@mdpi.com>
atas nama
Submission System <submission@mdpi.com>
Kam 12/03/2020 17.42

Kepada:
Cc:

Dear Dr. ,

Thank you very much for resubmitting the modified version of the following manuscript:

Manuscript ID: water-717922
Type of manuscript: Article
Title: Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI
Authors:

Received: 28 January 2020
E-mails:

Submitted to section: Water Use and Scarcity,
https://www.mdpi.com/journal/water/sections/Water_Use_Scarcity
https://susy.mdpi.com/user/manuscripts/review_info/4281e3d90432238c56fd9c1be9ba9c9b

A member of the editorial office will be in touch with you soon regarding progress of the manuscript.

Kind regards,

MDPI

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Postfach, CH-4020 Basel, Switzerland
Office: St. Alban-Anlage 66, CH-4052 Basel
Tel. +41 61 683 77 34 (office)
Fax +41 61 302 89 18 (office)
E-mail: water@mdpi.com
https://www.mdpi.com/journal/water/

*** This is an automatically generated email ***

REVIEWER 1 : ROUND 2

Journal	Water (ISSN 2073-4441)
Manuscript ID	water-717922
Type	Article
Number of Pages	15
Title	Location Suitability for Small Reservoirs at Bodri-Kuto River Basin Based on Spatial Monthly SPI
Authors	

Abstract

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Are the results clearly presented?	( )	(x)	( )	( )
Are the conclusions supported by the results?	(x)	( )	( )	( )

COMMENTS AND SUGGESTIONS FOR AUTHORS

The response of the authors is considered to be sufficient.

The only thing that in my opinion would improve the paper is, as it was asked during the original review, a map, accompanying Figure 1, to show on a larger scale, the study area.

Submission Date 28 January 2020
Date of this review 07 Mar 2020 14:50:45

AUTHORS' RESPONSES TO REVIEWER'S COMMENTS (REVIEWER 1)

Author's Notes

Dear Reviewer 1.

Thank you very much for reminding me on the point that I missed to responds.

In the 2nd revised paper, I already provide the figure on larger scale accompanying previous Figure 1. I hope that will provide the answer. Thank you very much.

Best Regards

MATRICES OF AMENDMENTS FOR REVIEWER 1 ROUND 2

Comments and Suggestions for Authors	Author's responds
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21. ESRI. Understanding interpolation analysis. 2012. (http://resources.arcgis.com/en/help/main/10.1/index.html#//003100000008000000).
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8. Paper accepted (14-3-2020)

[Water] Manuscript ID: water-717922 - Accepted for Publication

nina.yang@mdpi.com <nina.yang@mdpi.com>
atas nama
Nicole Ma <nicole.ma@mdpi.com>
Sab 14/03/2020 10.46

Kepada:
Cc:

Dear Dr. ,

We are pleased to inform you that the following paper has been officially accepted for publication:

Manuscript ID: water-717922
Type of manuscript: Article
Title: Location Suitability for Small Reservoirs at Bodri-Kuto Watershed Based on Spatial Monthly SPI
Authors:

Received: 28 January 2020
E-mails:

Submitted to section: Water Use and Scarcity,
https://www.mdpi.com/journal/water/sections/Water_Use_Scarcity
https://susy.mdpi.com/user/manuscripts/review_info/4281e3d90432238c56fd9c1be9ba9c9b

We will now make the final preparations for publication, then return the manuscript to you for your approval.

If, however, extensive English edits are required to your manuscript, we will need to return the paper requesting improvements throughout.

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Kind regards,
Nina Yang
Managing Editor
E-mail: nina.yang@mdpi.com

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9. Author requested title adjustments (17-3-2020)

Bls: [Water] Manuscript ID: water-717922 - Accepted for Publication

Sel 17/03/2020 13.13

Kepada: Nicole Ma <nicole.ma@mdpi.com>; Water Editorial Office <water@mdpi.com>

Dear Miss Nicole,
Thank you very much for the notification on that my paper is accepted for publication.

Meanwhile, may I ask for the notification mention the new title of my paper which change the word "Watershed" into "River basin".
Thank you very much.

Sincerely Yours

--

10. Adjustments approved (17-3-2020)

Re: Bls: [Water] Manuscript ID: water-717922 - Accepted for Publication

Ms. Nicole Ma/MDPI <nicole.ma@mdpi.com>

Sel 17/03/2020 13.22

Kepada:
Cc: water@mdpi.com <water@mdpi.com>

Dear Dr. ,

Thank you very much for your reply. We have changed the word "Watershed" into "River basin" in your paper's title. Your paper is undergoing the final check and will be published on the receipt of the APC amount.

Thank you very much for your support of open access publishing and Water journal. We look forward to hearing from you.

Kind regards,

Ms. Nicole Ma
Assistant Editor, MDPI
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Article

Location Suitability for Small Reservoirs at the Bodri-Kuto River Basin Based on Spatial Monthly SPI

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* Correspondence:

Received: 28 January 2020; Accepted: 14 March 2020; Published: 1 April 2020

Abstract: Despite efforts to develop and conserve water resources, almost every year during the dry season, some areas in Central Java province in Indonesia still experience a lack of water, especially in rural villages. These areas require water supply via water trucks and/or portable pumps to obtain water from rivers and groundwater. The Central Java government committed to implementing a program involving the construction of 1000 small reservoirs by 2020 to overcome water shortages. However, the technically ideal sites are mostly privately owned, which requires lengthy and costly land acquisition. To avoid the uncertainty of land acquisition, some small reservoirs were placed on state-owned land, which did not require land acquisition. The consideration of putting more emphasis on state-owned land rather than technically ideal sites for the construction of small reservoirs raise the issue on the location suitability of those reservoirs. In this study, we evaluated the suitability of the location of small reservoirs in the Bodri-Kuto river basin using the monthly standardized precipitation index (SPI). We used rainfall records of 25 stations in the river basin from 2000 to 2016 and analyzed yearly and monthly rainfall data. The yearly analysis shows that the dry conditions (SPI < −0.5) from 2005 to 2009 affected more than half of the rainfall stations (>50%), whereas the rainfall stations that experienced more dry years included Kedung Wungu, Babadan, Bojong, Ketapang, Sekopek, and Podowaras (more than 9 out of 17 years). The monthly SPI shows that during July, August, and September, all the rainfall stations experience moderately dry or worse conditions (SPI < −0.50). Using 25 rainfall stations, we determined the spatial spread of dry conditions using monthly SPI values from July, August, and September. Overlay of the spatial spread of dry conditions with the location of small reservoirs can be used to evaluate the suitability of small reservoir locations. We found that 1 (3%) location is very suitable, 7 (21%) locations are suitable, 24 (73%) locations are moderately suitable, and 1 (3%) location is less suitable. The findings indicate that the spatial distribution of SPI can be used as an additional criterion for evaluating the suitability of small reservoirs' locations should technically ideal locations be unavailable.

Keywords: SPI; drought index; Bodri-Kuto river basin; location suitability

1. Introduction

Since the issuance of water resources law No. 7/2004 in Indonesia, as modified by law No. 17/2019, the development of water resources has been intense, including efforts to conserve and develop water resources, as well as implementing programs for mitigating water-related disasters,

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23. Espinosa, L.A.; Portela, M.M.; Pontes Filho, J.D.; Studart, T.M.D.C.; Santos, J.F.; Rodrigues, R. Jointly Modeling Drought Characteristics with Smoothed Regionalized SPI Series for a Small Island. *Water* **2019**, *11*, 2489. [CrossRef]

11. Paper accepted for publication (25-3-2020)
-Final paper

Re: Bls: [Water] Manuscript ID: water-717922 - Final Proofreading Before Publication

Ms. Nicole Ma/MDPI <nicole.ma@mdpi.com>

Rab 25/03/2020 13.26

Kepada:
Cc: water@mdpi.com <water@mdpi.com>; T

Dear Dr. ,

Thank you for submitting your paper to Water. Your paper is undergoing the final check and will be published immediately on the receipt of the APC amount.

Thank you very much for your support of open access publishing and Water journal. In case of any questions, please feel free to contact us.

Kind regards,

Ms. Nicole Ma
Assistant Editor, MDPI
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The 8th World Sustainability Forum https://sciforum.net/conference/WSF-8
will be held from 15-17 September 2020 in Geneva, Switzerland.
Abstract Submission are now open: http://sci.fo/60c

12. Paperpublished (1-4-2020)
- Certificate

[Water] Manuscript ID: water-717922; doi: 10.3390/w12040993. Paper has been published.

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Dear Authors,

We are pleased to inform you that your article "Location Suitability for Small Reservoirs at the Bodri-Kuto River Basin Based on Spatial Monthly SPI" has been published in Water and is available online:

Abstract: https://www.mdpi.com/2073-4441/12/4/993
PDF Version: https://www.mdpi.com/2073-4441/12/4/993/pdf
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Kind regards,

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Authored by:

Published in:

Water **2020**, Volume 12, Issue 4, 993

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