Performance of sumur gendong (SeDrainPond) technology on harvesting water and sediment with respect to effective rainy days

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Performance of Sumur Gendong (SeDrainPond) Technology on Harvesting Water and Sediment with Respect to Effective Rainy Days

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Abstract – *Land degradation and climate change are reducing soil fertility and water availability in agricultural areas. So, agricultural production is reduced, which is detrimental to food security and farmers' livelihoods. These problems must be mitigated together with farmers. The farmers-based technology called Sumur Gendong (SeDrainPond) technology has been used and its performance has been analysed, in order to give farmers a basis to determine farming strategy. The performance of Sumur Gendong in harvesting water and sediments in relation to effective rainy days has been studied for this paper. The fertility of the harvested sediment has been also analysed, and a suggestion has been proposed to improve it. The study has been carried out using a combination of field measurements and laboratory analyses on 10 (ten) test ponds with average diameter 1 m and depth between 2 and 2.5 m on 5 hectares of paddies. The volume of water harvested from the pond annually has been 567 m^3 and the one of harvested sediment has been 344 kg. The fertility of the harvested sediment has been moderate across the study area, on the basis of the combined soil chemical properties (CEC, AS, C-organic, P_2O_5 and K_2O).*

Keywords: *Effective Rainy Day, Fertility, Performance, Sediment and Water Harvesting, Soil, Sumur Gendong (SeDrainPond)*

I. Introduction

Land degradation and climate change are interrelated processes with biophysical and human drivers [1]-[40]. They pose major risks to global food security.

Land degradation is caused by soil erosion, soil poisoning, soil contamination, and bad soil conditions arising from bushfires [2], resulting in a decreased agricultural productivity [3]. It is a result of a number of parameters, including climate change and human activity on barren, semi-arid land [4].

Climate change, especially during the dry season, will have a global impact due to the possibility of drought. Even though drought is temporary and not every dry season leads to it, it is a recurrent event caused by reduced rainfall over a long period of time [5] as an effect of uncertain meteorological conditions and it is a natural disaster for the agricultural sector that cause decreased agricultural productivity [6]-[9].

Farmers must apply farming techniques suited to this condition [10].

Developing countries have experienced degradation to approximately 40% of their land, and this is projected to increase to 78% by 2100 [1]. In Indonesia, the area of critically degraded land is now 48.2 million hectares, 25.1% of the country's total area [11]. On agricultural land of Indonesia, the land productivity is lower due to physical, chemical and biological damage to the soil [12].

It is necessary to restore degraded agricultural land through soil conservation [13].

Sumur Gendong or Sedimentation Drainage Pond (SeDrainPond) technology works by harvesting sediment (recovering degraded land that is measurable in quantity) [14]-[16] and water in irrigation and drainage system [17] to support agricultural yields [14]. In addition, researchers have proven that in order to enhance water availability in agricultural field, harvesting water also reduces water run-off or flood discharge. One of the problems is that Sumur Gendong has been applied in the field but the total volumes of water and sediments on the effective rainy days of all seasons (wet, dry and transitional) has not been taken into account.

An effective rainy day is a rainy day with rainfall above 5 mm so that the evapotranspiration effect can be neglected [25], thus becoming effective for farming purposes. It is important to study this in order to give farmers the data on deciding the best planting time for different kinds of plant as a responsive strategy [26] whereas to date, farmers neglect planning for planting [27].

Another problem is that the fertility level of harvested sediment has never been analyzed before. It is essential to study the fertility data, since the purpose is to use the harvested sediment in the ponds to recover the degraded land. In order to solve these problems, the objective of this study has been the one to determine the performance of Sumur Gendong in harvesting water and sediments in respect of effective rainy days, as well as analyzing the fertility of the harvested sediment.

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II. Methods

II.1. Field Location

The research has been conducted on Jragung irrigation area, Tlogorejo Village, Karangawen Sub-district, Demak District, Indonesia. The irrigation area comprises 5 hectares of paddy fields at approximately 7°4' S and 110°33' E. It borders on Karangawen Village in the north, Padang Village (E), Jragung Village (S) and Wonosekar Village (W). Ten (10) ponds within the area have been used in the study. Their average diameter is 1 m and the depth is between 2 and 2.5 m (Fig. 1).

Fig. 1. Pond locations–Jragung irrigation area

II.2. Sampling Technique and Laboratory Work

II.2.1. Water Sampling Obtaining Sediment Concentration

Sampling has been done upstream of the ponds using a 1 to 2 litres sampling tool after each of 3 rain events, resulting in 30 samples in total. The sediment concentration has been measured from the water sample.

II.2.2. Soil Sampling Obtaining Sediment Weight and Soil Fertility

The sediment weight has been determined in each pond and its fertility level has been analysed in the Soil Laboratory, Diponegoro University Semarang using the combined chemical properties – i.e., P_2O_5, K_2O, TOC, cation exchange capacity (CEC) and alkalinity saturation (AS).

III. Data Analysis

The analysis of the annual harvested water volume has taken into account the pond's volumetric capacity, the number of effective rainy days in 2017, and the season coefficient. The annual theoretical sediment weight has been derived by multiplying the sediment concentration with the pond's volumetric capacity, the number of effective rainy days, the season coefficient, and the bed load (10%). This value has been compared to the annual actual sediment weight, which also takes into account the number of effective rainy days and the season coefficient. The fertility level of the harvested sediment has been determined from the soil's combined chemical properties (Tables I and II).

TABLE I
CHEMICAL PROPERTY ASSESSMENT CRITERIA

Very Acid pH H_2O	Acid	Slightly Acid	Neutral	Slightly Alkaline	Alkaline
< 4.5	4.5 - 5.5	5.6 - 6.5	6.6 - 7.5	7.6 - 8.5	>8.5

TABLE II
CHEMICAL PROPERTIES DETERMINING SOIL FERTILITY STATUS

Property/Determinant	High	Moderate	Poor	Very Poor
CEC (me/100 g)	> 25	17-25	< 5-16	< 5
AS (%)	> 50	35-50	< 35	-
P_2O_5 (me/100 g)	> 40	20-40	< 20	-
K_20(mg/100 g)	> 40	20-40	< 20	-
TOC (%)	> 3	2-3	1-2	< 1

IV. Results and Discussion

IV.1. Sumur Gendong Working System

Figs. 2 and 3 show the Sumur Gendong system. Water flows from the inlet along the carrier channel to fill the ponds with water and suspended sediment, constituting a closed system [14]. The Sumur Gendong is reinforced with concrete tubes 50 cm above and below ground level in order to inhibit land erosion.

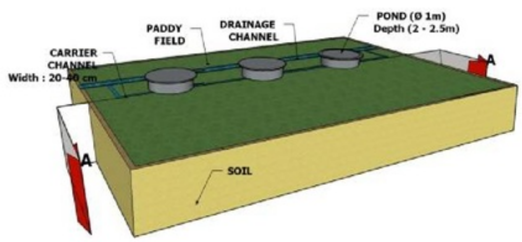

Fig. 2. Sumur Gendong (SeDrainPond) technology system

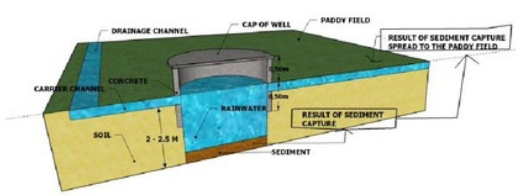

Fig. 3. Vertical section through a Sumur Gendong pond

Farmers harvest water and sediment from the pond as part of a community-based approach [28]. In the dry season, when the water in the pond is low, the suspended sediment is harvested to be spread evenly on the paddy fields, in order to preserve soil fertility for land conservation [14]. The climatology station at Jragung recorded a total of 124 rainy days and 81 effective rainy days in 2017 (Table III). The wet season was from January to March and December, the dry season was from June to October and the transitional season was in May and November.

TABLE III
RAINY DAY AND RAINFALL RECORDS

Item	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual rainy days (day)	18	14	12	14	6	6	7	4	1	4	18	20
Effective rainy days (day)	11	7	8	11	5	5	6	2	0	2	13	11
Actual rainfall (mm)	225	241	185	297	88	89	182	45	3	31	286	227
Effective rainfall (mm)	205	227	177	290	84	84	179	38	0	27	266	206

IV.2. Rainy Day and Rainfall Registration

The relationship between the numbers of rainy days and the effective rainy days through the year is shown, on a monthly basis (Fig. 4).

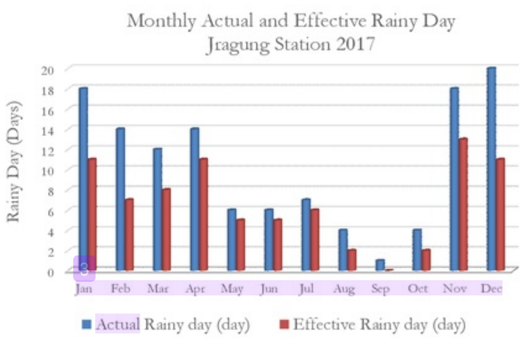

Fig. 4. Monthly actual and effective rainy days, Jragung Station, 2017

IV.3. Water Harvesting Performance

The capacity of the ponds used in the study has been between 1.57 and 1.96 m^3. The harvested water volume from each pond in the dry season, with 0 to 6 effective rainy days and the season coefficient of 1, has been between 35.36 and 106.07 m^3.

In the wet season, with 7 to 11 effective rainy days and a season coefficient ranging from 0.1 to 0.2, the harvested water volume was between 12.38 and 58.34 m^3.

In the transitional seasons, 44.2 m^3 of water have been harvested in May with 5 effective rainy days, and 114.91 m^3 in November with 13 effective rainy days. Each one had a season's coefficient of 0.5. In total, Sumur Gendong has been able to harvest 567.48 m^3 of water annually from effective rainy days (Fig. 5).

The different season coefficients resulted from the different proportions of water harvested from the ponds. In the wet and transitional seasons, some 10 to 50% of the water has been harvested, while in the dry season 100% recovery has been achieved.

The values have been the same for harvested sediment calculation.

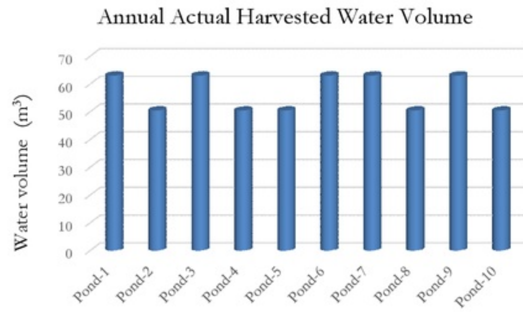

Fig. 5. Annual actual harvested water volume

IV.4. Sediment Harvesting Performance

IV.4.1. Theoretical Harvested Sediment Weight

The sediment concentrations (*Csd*) across the 30 samples taken from the ponds have been between 498 and 876 mg/l. This has been used as a base for calculating the theoretical harvested sediment weight (*TSW*). With a total of 81 effective rainy days in a year and the same season coefficient as in the harvested water calculation, the calculated TSW for individual ponds has been in the range 27.63 to 48.61 kg, or 382.45 kg from all ponds annually (Fig. 6).

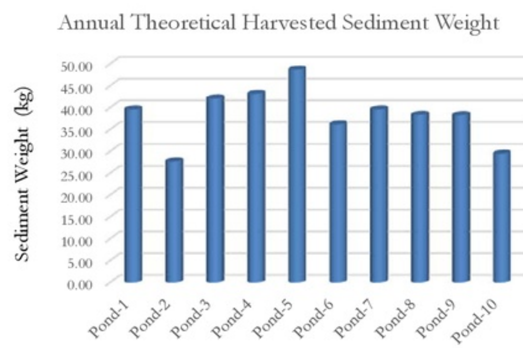

Fig. 6. Annual theoretical harvested sediment weight

IV.4.2. Actual Harvested Sediment Weight

With an annual total of 81 effective rainy days and the same season coefficient as in the harvested water calculation, the theoretical harvested sediment weight has been between 28.25 and 41.89 kg for the individual ponds, or 343.88 kg for all ponds annually (Fig. 7). The theoretical and the actual sediment weights have differed by about 11% on average with a noticeable difference especially in the dry season (Fig. 8). It has reflected the disproportion phenomenon between the water volumes entering the ponds and the volumes harvested from them because of low rainfall in the dry season. The theoretical weight has been calculated from the sediment concentration in the water samples taken upstream of the ponds, and the result has not been affected by this phenomenon. The only reliable result for determining the harvested sediment has been the actual sediment weight – 343.88 kg in total in the year from all ponds – since it has represented the real conditions.

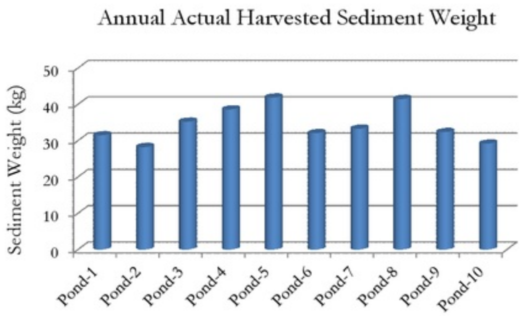

Fig. 7. Annual actual harvested sediment weight

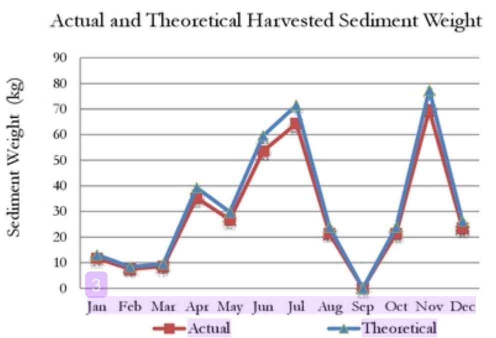

Fig. 8. Annual actual and theoretical harvested sediment weight

The evaluation of the Sumur Gendong (SeDrainPond) water and sediment harvesting performance (Table IV) in the wet season with 7–11 effective rainy days is 0.15% of the total pond capacity (17.68 m³) with 10–30% water harvested. The low output on the sediment weight resulted from the balanced volume mechanism. In the wet season, there has been plenty of water resources that meant the water from the pond was saved rather than exploited. Because of this, the volume of water supplied to the pond has become low due to the capacity limit, and the suspended sediment trapped in the pond as a factor of water volume has become low as well. Meanwhile, in the dry season with 0–6 effective rainy days, the water volume harvested has been 100% of the total pond capacity (17.68 m³) so the sediment weight harvested has also increased to 0.69%. The greater the volume harvested is (volume out), the greater the volume supplied is (volume in), as the case with the amount of sediment that could be harvested (Fig. 9).

IV.5. Soil Fertility Level from Harvested Sediment

The Laboratory results for the contained sediment samples, analysed using the combined chemical properties (P_2O_5, K_2O, TOC, CEC and AS), can be seen in Table V. It shows that the TOC content has been moderate almost everywhere, except around ponds 5 and 10, where it has been high. The soil's TOC content has been converted into its organic content by multiplying it by the constant 1.724, giving an organic content of between 3.62 and 5.43%, which has been considered high [29]. The organic content sources in soil comprise the remains of plants and animals, and trigger soil fertility by supplying nutrients for autotrophic organisms (plants) and energy sources for heterotrophy (animals and microorganisms). Increasing biological activity in soils improves their fertility [30]. The CEC values show the soil's cationic content – Ca^{2+}, Mg^{2+}, K^+, Na^+, $NH4^+$, H^+ and Al^{3+} – where these were in forms available to plants and microorganisms. CEC is positively correlated with pH, organic content, water retention capacity, and clay content [31]. The AS values have showed the proportional magnitude of alkaline cations that can be transferred into soil colloids. In general, young alkaline cations have been washed out. The high AS value shows the low washed out rate of alkaline cations. Alkalinity saturation is positively correlated with soil pH [32]. Soil pH is a determining factor affecting nutrient solubility in soil. The soil pH level has been neutral in all research areas. A neutral soil pH level provides all the macro nutrients for plantation, for example phosphor (P) and calcium (K).

The availability of P_20_5 and K_20 at all locations was at a moderate level. The harvested sediment is used to maintain soil fertility on the paddies [33]. The fertility of the harvested sediment has been evaluated using its combined chemical properties [34]. The evaluation shows that the soil fertility has been moderate across the study area. Soil fertility and agricultural sustainability can be improved by raising the organic content to increase the nutrient content and thus crop production, so sustaining agricultural sectors.

Adding manure into the soil at a rate of 10–20 ton/ha will increase the productivity and the continuity of the fodder plant *P. maximum* dan *S. grandiflora* [35]. The use of organic mulch can improve the soil organic content by adding 3–6 ton/ha paddy straw to increase the production and quality of the fodder plant [36].

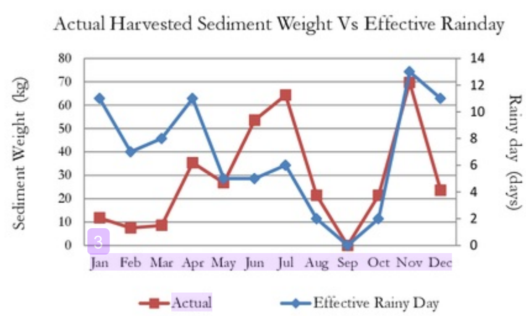

Fig. 9. Actual harvested sediment weight vs effective rainy days

TABLE IV
ANNUAL ACTUAL HARVESTED WATER AND SEDIMENT

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Effective rainy days	11	7	8	11	5	5	6	2	0	2	13	11	
Season coefficient	0.1	0.1	0.1	0.3	0.5	1	1	1	1	1	0.5	0.2	
Ponds	Monthly water volume (m^3)												Annual water volume (m^3)
	Monthly sediment weight (kg)												Annual sediment weight (kg)
Pond-1	2.16	1.38	1.57	6.48	4.91	9.82	11.79	3.93	0.00	3.93	12.77	4.32	63.05
	1.08	0.69	0.78	3.24	2.45	4.91	5.89	1.96	0.00	1.96	6.38	2.16	31.49
Pond-2	1.73	1.10	1.26	5.19	3.93	7.86	9.43	3.14	0.00	3.14	10.21	3.46	50.44
	0.97	0.62	0.70	2.90	2.20	4.40	5.28	1.76	0.00	1.76	5.72	1.94	28.25
Pond-3	2.16	1.38	1.57	6.48	4.91	9.82	11.79	3.93	0.00	3.93	12.77	4.32	63.05
	1.21	0.77	0.88	3.62	2.75	5.49	6.59	2.20	0.00	2.20	7.14	2.42	35.25
Pond-4	1.73	1.10	1.26	5.19	3.93	7.86	9.43	3.14	0.00	3.14	10.21	3.46	50.44
	1.32	0.84	0.96	3.97	3.01	6.01	7.21	2.40	0.00	2.40	7.81	2.64	38.58
Pond-5	1.73	1.10	1.26	5.19	3.93	7.86	9.43	3.14	0.00	3.14	10.21	3.46	50.44
	1.44	0.91	1.04	4.31	3.26	6.53	7.83	2.61	0.00	2.61	8.48	2.87	41.89
Pond-6	2.16	1.38	1.57	6.48	4.91	9.82	11.79	3.93	0.00	3.93	12.77	4.32	63.05
	1.10	0.70	0.80	3.30	2.50	4.99	5.99	2.00	0.00	2.00	6.49	2.20	32.06
Pond-7	2.16	1.38	1.57	6.48	4.91	9.82	11.79	3.93	0.00	3.93	12.77	4.32	63.05
	1.14	0.73	0.83	3.42	2.59	5.19	6.22	2.07	0.00	2.07	6.74	2.28	33.29
Pond-8	1.73	1.10	1.26	5.19	3.93	7.86	9.43	3.14	0.00	3.14	10.21	3.46	50.44
	1.42	0.91	1.03	4.27	3.23	6.47	7.76	2.59	0.00	2.59	8.40	2.84	41.51
Pond-9	2.16	1.38	1.57	6.48	4.91	9.82	11.79	3.93	0.00	3.93	12.77	4.32	63.05
	1.11	0.71	0.81	3.33	2.52	5.04	6.05	2.02	0.00	2.02	6.55	2.22	32.36
Pond-10	1.73	1.10	1.26	5.19	3.93	7.86	9.43	3.14	0.00	3.14	10.21	3.46	50.44
	1.00	0.64	0.73	3.00	2.27	4.55	5.46	1.82	0.00	1.82	5.91	2.00	29.20
Cum. water volume (m^3)	19.45	12.38	14.14	58.34	44.20	88.39	106.07	35.36	0.00	35.36	114.91	38.89	**567.48**
Cum. sediment weight (kg)	11.78	7.50	8.57	35.35	26.78	53.56	64.28	21.43	0.00	21.43	69.63	23.57	**343.88**

TABLE V
SOIL FERTILITY LEVEL IN RESEARCH AREA

No	Location	CEC (mw/100g)	AS (%)	P_2O_5* (mg/100g)	K_2O (mg/100g)	TOC (%)	pH	Fertility Level
1	Pond-1	20.80 (M)	35 (M)	20.1 (M)	21.2 (M)	2.3 (M)	6.9 (N)	Moderate
2	Pond-2	22.00 (M)	47.64 (M)	22.5 (M)	35.5 (M)	2.5 (M)	7 (N)	Moderate
3	Pond-3	19.30 (M)	35.7 (M)	30 (M)	30.5 (M)	3 (M)	7.2 (N)	Moderate
4	Pond-4	25.50 (H)	37.5 (M)	35.5 (M)	25.5 (M)	2.9 (M)	6.7 (N)	Moderate
5	Pond-5	19.90 (M)	65.38 (H)	31.4 (M)	32.6 (M)	3.1 (H)	7.3 (N)	Moderate
6	Pond-6	24.70 (M)	45.5 (M)	20.1 (M)	31.3 (M)	2.4 (M)	6.8 (N)	Moderate
7	Pond-7	24.00 (M)	40.6 (M)	22.5 (M)	37.5 (M)	2.1 (M)	7.1 (N)	Moderate
8	Pond-8	23.30 (M)	37.7 (M)	30 (M)	32.4 (M)	3 (M)	6.95 (N)	Moderate
9	Pond-9	24.50 (M)	41.5 (M)	35.5 (M)	35.6 (M)	2.8 (M)	7.4 (N)	Moderate
10	Pond-10	20.20 (M)	33.3 (M)	31.4 (M)	39.9 (M)	3.15 (H)	7.5 (N)	Moderate

V. Conclusion

a. The objective of this study has been to analyse the performance of Sumur Gendong in harvesting water and sediments in relation to effective rainy days as well as to analyse the fertility of the harvested sediment.

b. The performance of Sumur Gendong in harvesting water with respect to effective rainy days annually has been 567 m^3 volume of water.

c. The performance of Sumur Gendong in harvesting sediment with respect to effective rainy days annually has been 344 kg weight of sediment. This value has been taken from actual sediment weight measurement.

d. The theoretical sediment weight is not reliable as it does not represent the field condition.

e. The evaluation of Sumur Gendong performance on water and sediment harvesting in the wet season with 7–11 effective rainy days has been 0.15% of the harvested sediment from the total pond capacity (17.68 m^3), with 10–30% water harvested.

f. In the dry season, with 0–6 effective rainy days, the water volume harvested has been 100% of the total pond capacity (17.68 m^3), with 0.69% sediment harvested.

g. The fertility of the sediment harvested at all locations has been moderate.

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