

Eco-drainage Pond in Non Irrigated Land for the Conservation of Land and Water Based on Community Participation

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Abstract: There are some bad impacts from a critical land such as flood in rainy season and dryness in dry season. Long dryness could cause shortage of water for human consumption, industry and agriculture. Prevention has been made to avoid the both bad impacts by building hydraulic structures like reservoirs and ponds in order to reduce the peak flow during the rainy season and to store the water for use during the dry season. However, they gradually become full of sediment. This will make them work insufficiently and will cause high maintenance cost. Moreover, wells in agriculture field used as retention also suffer dryness to make crop failure. This study aims to develop a model of pond for conservation of land and water in non irrigated land. Community participation is crucial in order to solve the flood and dryness problems. The community, especially the farmers will participate actively in the implementation and maintenance of the model. There are benefits in using the pond model such as: (1) to control sediment transport to the rivers, reservoir or other hydraulic structures; (2) to reduce flood rate; (3) to increase ground water recharge; (4) to contain water for agriculture and (5) to control the fertility of land. The cost of making a unit of model (sedrainpond) of 1.5 m diameter and 1.5 meter depth is relatively cheap between \$10 to \$20 (US), and the maintenance is done by the farmers. When the pond model becomes functional, besides containing water in the rainy season, the water can be used to sustain water for agriculture in the dry season to avoid any crop failure. When the pond becomes dry, the farmers can harvest the suspended load sediment such as clay or silt to spread onto their land to keep its fertility.

Key words: Model of drain, eco-drainage system, model of pond.

1. Introduction

Damage of watershed is one of the results caused by the global warming and climate. During the rainy season the rain is shorter to make the rainfall intensity high and has potential to generate flooding, while during the dry season the drought is longer to make the river flow rate small and not able to flow the water requirement such as domestic water, industry and agriculture.

Ministry of Indonesian Agriculture [1] defined that

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watershed is a land united with rivers and tributaries which functions to collect, store and flow the rain water, and finally to discharge it to the lake or the sea naturally. A watershed is bordered by topography and sea water. For the critical land, if the rain falls on the ground it will cause sheet erosion, so that the surface water which consists of suspended load sediment could cause the silting up in the water structures or reservoirs to shorter its life time. In another statement from the Ministry of Indonesian Agriculture, critical land is defined as a land where the physical condition is poor so that the land cannot function properly as the media of production or the media of water management. In the

land of paddy, there is no storage of water so that the product of paddy is not optimal and often experiencing failure of the products. Efforts have been made by developing reservoirs, barrages etc.. However, a reservoir gradually will be silted up so that the management of water is useless, and if optimization of management is implemented, the cost of maintenance will be expensive. The excavated wells will dry as well so that the paddy field and inhabitant area will face shortage of water.

Ministry of Indonesian Agriculture [2] defined that conservation of land and water is an effort to use the land properly using several conditions to prevent the damage of land. While the objective of conservation of land and water is to keep the land and water from its damage through controlling the erosion, sedimentation and flood so that the land and water can be used optimally for the benefit of mankind. The Ministry of Agriculture of Indonesia through the Guidance of Forest Rehabilitation Technique also suggests that in the effort of water conservation it is necessary to build a dead end drain that functions to collect water and infiltrates it to the ground with the purpose to reduce the surface water runoff and to store the sediments. The weakness of this drain is the capacity of storage, after the rain abated the water in the drain is less. This kind drain is effective to control erosion, but not effective to collect the sediment load.

Unami and Kawachi [3] have assessed flood mitigation in a tank irrigated paddy fields area. Hydraulic models are developed to represent flood dynamics in irrigation tanks, paddy fields, and drainage channels. This method has the advantage of assessing flood mitigation even in the case of an increase in the total runoff ratio.

Loaciga and Huang [4] did a similar research as Unami and Kawachi based on the equation of Green-Ampt. They found that the depth of water in the pond is influenced by the rate of infiltration. In this research, the trapped sediment in the pond is not considered and does not involve the community

directly.

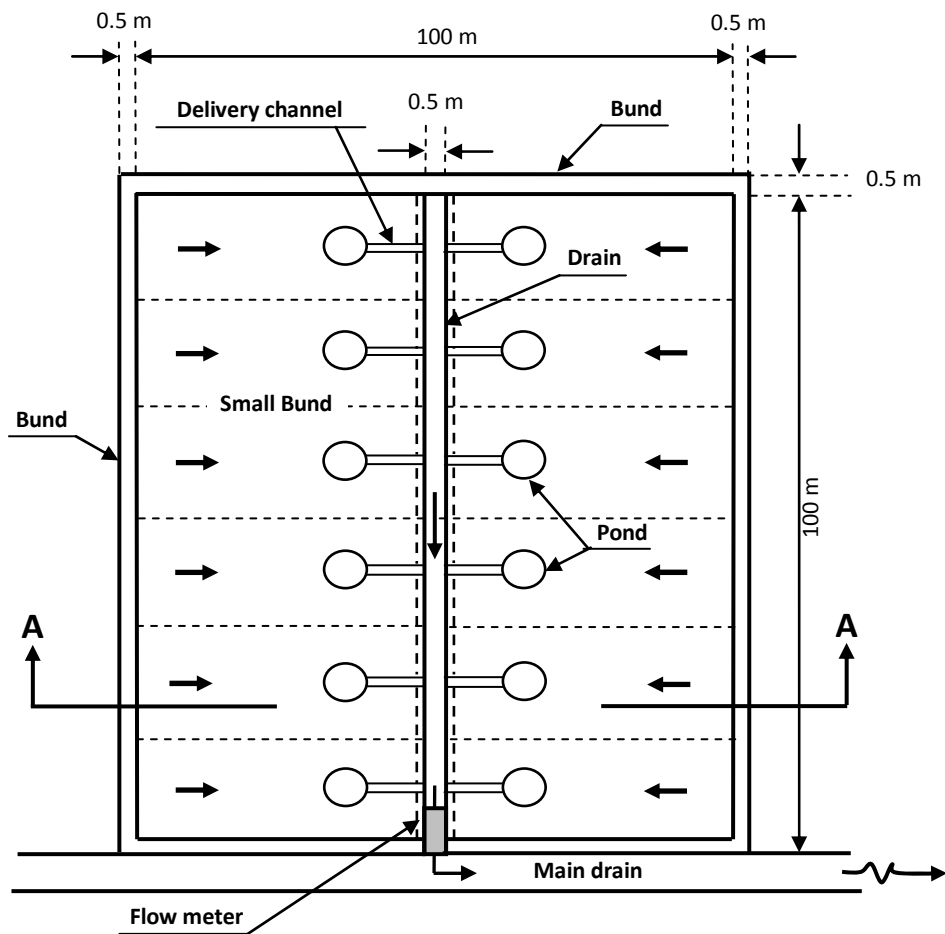
Powell et al. [5] also did a similar research using model of detention basin, where the model is able to reduce the peak discharge 20%. This model does not consider the trapped sediment, the infiltration and the involvement of the community directly.

Cheng [6] has done a research about discharge of sediment towards flood water stored in the pond, where his evaluation shows the magnitude of sediment in the pond is dependent on the location of inlet.

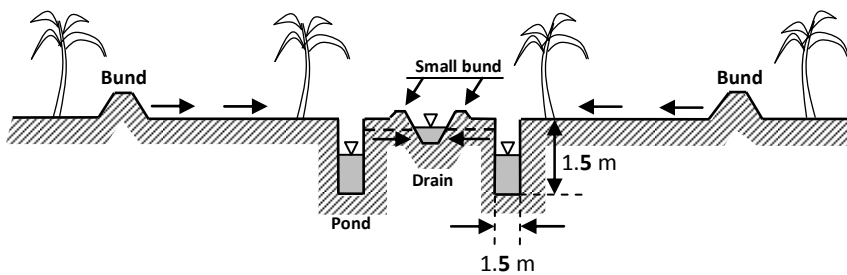
Nguyen et al. [7] proposed a model named Okubo pond which is an agricultural pond located in the Itoshima area of Fukuoka Prefecture, Japan. It was constructed for irrigating a nearby cultivated area. In this study, a one box ecosystem model was developed to obtain an insight into the seasonal variations in the algal concentration and chemical components of the Okubo pond with the aims of protecting its aquatic ecosystem and maintaining its water quality.

Camnasio and Becciu [8] did a study in a phase of design feasibility analysis, of whether a flood detention pond can be adapted to act as water storage during irrigation periods in order to reduce agricultural water shortages; it simulates detention pond response to floods and droughts under different hydraulic conditions and reservoir management rules. The results demonstrate that the use of a flood detention pond as an irrigation reservoir is not only possible, if it complies with the operating rules that emerge from this study, but also it brings tangible benefits in reducing agricultural water deficit.

However, all the researches above were done mostly in an irrigated land, not consider the trapped sediments and also not consider the increase of crop product; in which the increase of crop product can be used to convince the farmers for involving in the operation and maintenance of the model. And hence, this study aims to find out whether the proposed system of eco-drainage pond (model) will be able to conserve land and water to solve the flood and dryness problems in non irrigated land (Fig. 1). The other objectives of



Layout of Sedrainpond



A-A Cross Section

Fig. 1 Layout of the pond model.

this study are to find out whether the proposed system is able: (1) to control sediment transport to the rivers (main drain), reservoirs or other hydraulic structures; (2) to reduce flood rate; (3) to increase ground water recharge; (4) to contain water for agriculture; (5) to control the fertility of land; and (6) to increase the crop

product.

2. Research Methodology

2.1 Implementation of the Pond Model in a Paddy Field

Pond model is a kind of model of eco-drainage

system which comprises drain as inlet, pond as reservoir for increasing the capacity of absorption and sediment collection, and delivery channel that functions to connect the inlet and the pond in the area of paddy field (Fig. 1 and Fig. 2).

The pond in the selected paddy field was built with size of 1.5 m diameter and depth of 1.5 m. The cost of setting up the ponds was subsidized by the Management of Water Resources of Upper Bengawan Solo River, Centre Java, Indonesia with \$15 (US) per pond. The implementation of pond model was 12 ponds/ha or 1,800 ponds for 150 ha paddy field in the Kamplong Village, District of Wonogiri, Centre Java, Indonesia.

The mechanism of the model is when the rain water flow to the drain (inlet) through the delivery channel, then the provided ponds will be filled up by the surface water and suspended load sediment. It is necessary to inundate every piece of paddy field with 5 cm depth of water. The small bund of piece of paddy field is made 5

cm height, so when the inundation is more than 5cm, then the water will over flow to the drain or to another piece of paddy field (Fig. 1 and Fig. 2). This means there is time for suspended load sediment to settle in the pond and paddy field. Maintenance of the pond is also necessary done by the farmers. If the stored water in the pond is up in the dry season, then the farmers can take up the sediment and distribute onto the paddy field.

2.2 Structure of the Pond Model

The structure of model consists of drainage channel as the inlet, pond as the storage of water and suspended load sediment and delivery channel as the channel connector. The drain is made from the cutting soil and grass block while the pond is formed rectangular or circular and strengthened with rock or brick if the soil is weak (Fig. 2). The pond is placed in the middle of paddy field with hope the distribution of water storage is even and the trapping of sediment in the field is easy.

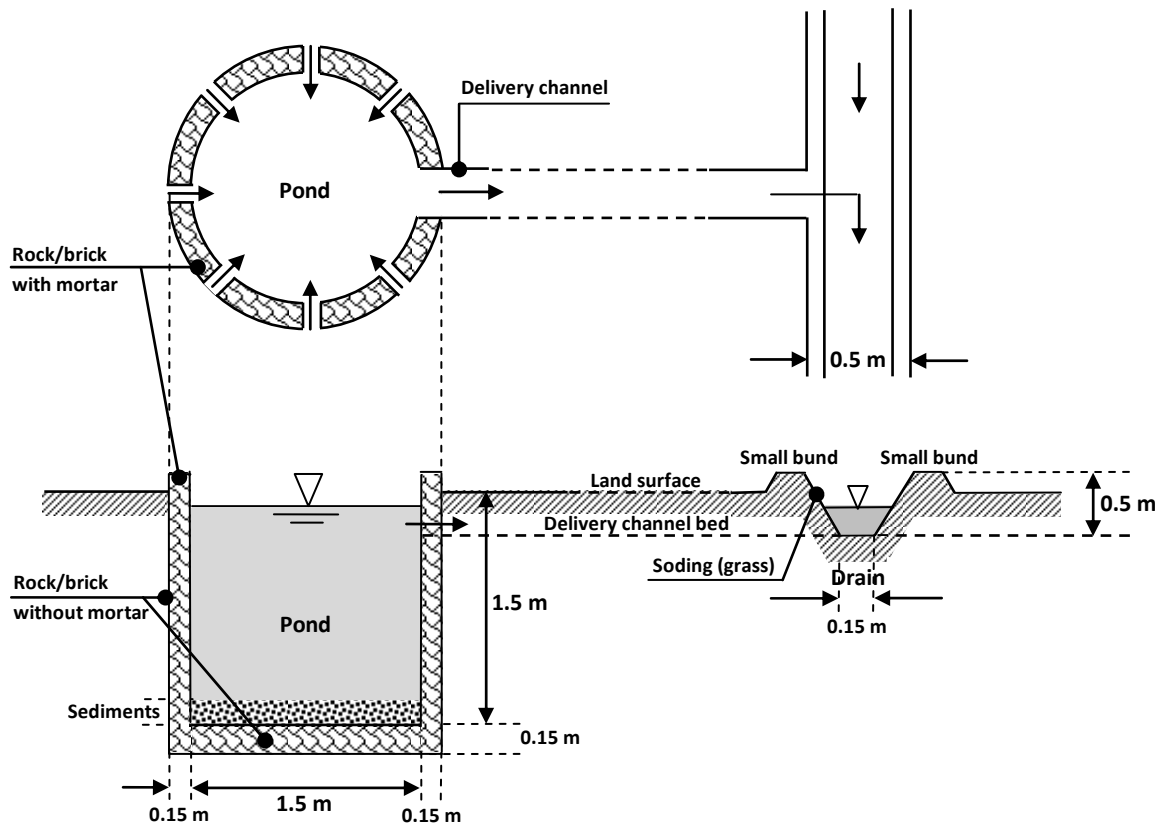


Fig. 2 Structures of pond and drain.

2.3 Data Collection

The collection of data comprises data of soil, discharge, rainfall, crop product, water table and farmer's participation. The soil data were taken in the paddy field using undisturbed sample for soil classification, hydraulic conductivity and soil moisture tests. Another soil data were done on the spot for infiltration rate using infiltrometer. The discharge data were taken at the outlet of drain using automatic flow meter in which the data is divided into two types, the first one were done before construction of the pond and the second one were done after construction of the pond. The rainfall data were collected on the spot using rain gauge located in the paddy field. The water table was measured at the monitoring well which is available in the model. The crop product data were collected from the farmers who are the owner of the paddy field. The data of crop product is also divided into two types, the first one was collected before constructing the pond and the second one was done after constructing the pond. The data of farmer's participation were collected since in the beginning of study until the end of study to monitor the participation of the farmer's to involve in the implementation and maintenance of the model.

2.4 Building of the Community Participation

The model was implemented based on the participation of the community (farmers) in which the farmers were involved directly in the implementation and maintenance of the model. It is an effort of community building where the building of community is a holistic approach from the government to the people (farmers) with integrated action of development of physic and non physic to gain income for the community. Once the model functions, their agriculture land will have storage of water, increasing of absorption, so that the product of agriculture increased. They also will harvest the suspended load sediment or fine material of silt or clay which is good for the growing of paddy. And hence, the farmers will

be aware that they have done a benefit for their selves, so then the implementation of the model is guaranteed long lasting.

2.5 Stepwise Implementation of the Model

Model of pond was built in different catchment areas in order to optimize the result. The type of catchment differs based on the location i.e. upstream field area and cistern paddy fields. The stage of implementation of model development was as follows: (1) Collection of data from the involved institutions such as Department of Drainage and Irrigation, Department of Natural Resources and Environment, and Department of Agriculture. These data are used as initial information, critical land condition, status of land ownership, and system of land use; (2) Orientation to the site with the involved institutions in order to do initial survey, checking the condition of land as the matter of evaluation towards the availability data. And, as soon as possible to see the head of village, head of city or farmer representative. The farmer representative is used to gain information of land condition, social and culture; (3) Implementing socialization to the people about function of the model that can give benefit to them. If the farmers aware and accept the method, then an association is necessary to be established as the media of communication; (4) Suggesting the farmers who have the paddy field to build ponds for collecting water and sediment that can be used for their plants to grow; (5) Implementing survey in the proposed location of paddy field or cistern paddy field; (6) Using the existing drain as the main drain; (7) Designing layout of model; (8) Determining the elevation of inlet towards the pond in order to obtain gravitational flow; (9) Making the pond in the size of 1.5 m diameter and depth of 1.5 m; (10) Providing rocks or bricks to strengthen the soil if the soil is weak to keep the stability of the pond.

3. Result and Discussion

The type of soil of paddy field is sandy clay loam

with particle size of 0.1524-2.54 mm, soil infiltration rate of 11-107 mm/hour, and existing water table of -36.75 m. It can be concluded that there is unconfined aquifer in the sub soil where the groundwater is stored between the particles of sandy clay loam soil. After the the ponds had been constructed, evaluation was made to find out the impact of the model to the paddy field. Before the construction, the product of dry season crops (maize) was between about 600 to 900 kg/ha/harvest, while after the construction, the product of maize was between about 1.0 to 1.2 ton/ha/harvest (Table 1). It can be concluded that there is an increase of harvest of maize about 350 kg/ha/harvest. The water table in the monitoring well also tends to increase from -36.75 m into -31.50 m and the soil moisture also increased from $\pm 10\%$ into $\pm 27\%$, which means that there is an increase of groundwater recharge. The discharge data at the outlet were recorded from 1.70 to 15.8 liter/s and 0.0 to 11.9 liter/s before and after the construction of the ponds, respectively. It means there is reducing of rain water runoff at the outlet about 20 to

35%. And sediments in the ponds can be trapped up to 50 mm/year (Table 2).

The success of implementation of the model within conservation technology of land and water is dependent on the conformity and capacity of the land, the cheap cost, the role of community to involve in the implementation and maintenance of the model and the impact of the model to the increase of income of the community (farmers) in which in the implementation is directed to do technology which is friendly environment and acceptable by the people.

The concept of implementation of the model is to build the capability of people, especially the farmers supported by the government. Responsibility of the farmers is to involve directly in the implementation and maintenance of the model. The farmers involve in the development of ponds and delivery channel related with the ownership of land. While in the maintenance, the farmers take the harvest of sediment in the ponds and delivery channels and distribute it to the paddy field or cistern paddy field evenly for the fertility of the

Table 1 Harvest of dry season crops (maize) in Kamplong Village.

	2006	2007	2008	2009	2010
Dry season crops (maize) (ton/ha/harvest)					
Before construction of ponds	603	876	685	-	-
After construction of ponds	-	-	-	1,095	1,207

Source: Association of farmers of Kamplong Village, district of Wonogiri, centre Java, Indonesia.

Table 2 Discharge of drain outlet in the 1 ha Paddy field of Kamplong Village.

	Discharge (liter/s)							Note
	1	2	3	4	5	6	7	
Before construction of ponds	15.8	12.2	9.95	8.20	5.65	4.00	1.70	Selected rainfall intensity: 5-70 mm/hr Selected rainfall duration: ± 30 min Soil moisture: $\pm 10\%$ Position of water table: -36.75 m
After construction of ponds	11.9	9.90	7.90	5.45	3.90	1.40	0.00	Selected rainfall intensity: 5-70 mm/hr Selected rainfall duration: ± 30 min Soil moisture: $\pm 27\%$ Position of water table: -31.50 m
Type of soil:	Sandy clay loam with particle size of 0.1524-2.54 mm							
Soil infiltration rate:	11-107 mm/hour							
Diameter or width of pond:	1.5 m							
Depth of pond:	1.5 m							
Number of pond:	12 units/ha							
Infiltrated water in the pond:	107 mm/hour							
Sediment in the pond:	50 mm/year in the form of silt containing substances of Fe, Ca, and Mn							

Source: Measurement in the field and laboratory testing.



Fig. 3 Community's and terraced land at upstream area.

soil. The support from the stake holders of government or private agencies is also necessary. The form of support is the fund for developing the ponds and its accessories such as delivery channel and drain, and also the technical support during the construction and socialization about the benefit of the model. All of the supports are required to achieve the dream of all people in the country.

The upstream field area should be the buffer of a catchment area. But not all areas are owned by the government, some of them are owned by the community. And hence, it is not easy to control them for not using their land for agricultural industry because this activity will accelerate process of erosion and will be the source of sediment (Fig. 3A). To avoid erosion, the steep land is made terraced and every piece of land should have bund and planted with grass (Fig. 3B). The location of cistern paddy field should have drain or afvour to obtain optimal result. During rainy season this drain is functioned as delivery channel where the surface water contains suspended load sediment (Fig. 3C).

4. Conclusion

From the results of the study it can be concluded that there are some benefits in developing model of pond. The pond model equipped with 12 ponds of 1.5 m diameter and 1.5 m depth implemented in 1 ha paddy field is able to reduce the rain water runoff up to 35%. Ignoring the soil parameter differences, this achievement is better than the similar research using model of detention basin done by Powell et al. [5] where their model is only able to reduce the peak

discharge up to 20%. The capacity of recharge has increased which is indicated by the increasing of the water table from -36.75 m to -31.50 m and the increasing of the soil moisture content from $\pm 10\%$ to $\pm 27\%$. This wetter condition can support the growing of crops. The occurrence of ponds is able to reduce the rate of sediment that should enters the rivers, reservoirs or other hydraulic structures. The trapped sediments in the pond are up to 50 mm/year. This amount of sediments is quite useful in term of sediment control as the previous researchs by Loaciga and Huang [4] and Powell et al. [5] did not consider the trapped sediments. However, the influence of inlet location is not observed where according to the research of Cheng [6] shows that the magnitude of sediment in the pond is dependent on the location of inlet. The implementation of pond model (sedrainpond) will reduce the cost of maintenance since it will delay the silting up in the rivers or reservoirs so that the function of rivers and reservoirs will be longer due to the part of sediments are trapped in the ponds. The fertility of soil is controlled because the sediment that had been settled in the field will make the soil fertile, and the trapped sediments in the pond which will be taken and distributed onto the field also contribute to the increasing of soil fertility due to the sediments contain usefull elements such as Fe, Ca, and Mn. The agro industry products are also increased, especially the dry season crop (maize). The product of harvest of maize has increased from 600-900 kg/ha/harvest to 1,100-1,200 kg/ha/harvest. It is caused by the availability of water in the ponds during the dry season makes the plant does not face water shortage. The

achievement of increasing the crop products had been proved in the initial study of the model development of sedrainpond at the villages of Kamplong, Ngadirojo, and Nguntoronadi, District of Wonogiri, Province of Centre Java. The other benefit of implementing the sedrainpond model is low maintenance cost because the maintenance is done by the farmers where they are aware that the pond model will give them benefit in the increasing of their income. However, it is necessary to do a further research on the pond model within physical model or mathematical model with various different parameters of soil and layout in order to obtain a handy solution in solving a critical land by implementation of a pond model for the conservation of land and water.

Acknowledgments

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