The Environmentally Design of Water Management System for Sustainable Peat Land Development in Indonesia

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1. ABSTRACT

The peat land development for agriculture in Indonesia has been started since 1960. However the results of development in term of agriculture production and farmers income are still questionable. By learning the experiences and traditional technologies developed by Banjarnese and Bugisnese, and personal experiences in lowland development in several parts of Indonesia, then the Environmentally Water Management System for Sustainable Peat Land Development is proposed in this paper.

Basically the land-use planning should be based on the land suitability map for some crops planned to be grown, as commonly used by Agronomist and Soil Scientist. Environmental function of peat land in term of bio-diversity and hydrology are combined together into The Water Management System.

Research results of The Research Center for Soil and Agro-climate (Bogor) showed that the one-way flow of surface and ground water in agricultural field has an ability to improve chemical properties of soil by leaching process of toxic substances created by oxidation process in soil profile. The one-way flow system can be created by using separated channels of irrigation and drainage. The difference of water level in those channels should be around 50 cm. Traditional technologies created by Bugisnese farmers in Pulau Kijang (Riau) are tried to be applied in this proposed design.

The main objective of this paper is to design of Water Management System which has an ability to maximize the agricultural potential of peat land by increasing cropping intensity, in line with minimizing the negative impact of environmental by maximizing the peat dome's function as water retention and bio-diversity.

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2. PROBLEM FORMULATION

Agronomist and Soil Scientist have proposed the land suitability criteria of peat land development. The peat land suitability criteria for agriculture in Indonesia are written in Table 1. The parameters used are depth of peat, depth of pyrite layer, and organic acids content. The criteria should be studied carefully since field observations showing that Acacia and Palm oil are grow well on peat depth more than 3 m.

Table 1. The criteria used for peatland suitability for agriculture

Parameter	Paddy sawah	Upland paddy, cash crops, vegetable	Perrenial crops and Horticulture	Forestry
Depth of peat (cm)	< 130	< 130	< 300	>300
Depth of pyrite (cm)	> 50	> 50	> 150	
Organic acids (mmol)	< 0.5	< 0.1	< 0.1	

[1)] Source: IPB. Regional Environmental Assessment of 1 millon hectare peat land development in Central Kalimantan, November 1996.

Generally, land elevation between two rivers showing that further away from river the peat depth and elevation are increasing formed a peat dome on the center. The elevation difference between peat dome and the levee of river is about 2-4 meter. Based on hydro topography classification the dome part is classified as class C and D. The cross-section profile of peatland topography along two rivers can be used for peatland development planning for agriculture and conservation. Figure 1 showing an example of the cross section topography of the Block A in 1 million hectare rice project.

In fact, in reclaimed tidal peatland area in Indonesia the canals has two function i.e. as supply and drainage canal. However, for hydro-topography C and D that canal mainly has function as controlled drainage. Water control at paddy plot can not be managed well then cropping intensity (CI) mostly only one (i.e. rainfed farming). Increasing CI requires good water control in wet season and irrigation water availability in dry season.

Good water management at field level in wet season can be managed by water level control structures at field channels (either supply or drainage) by using stop log over flow type structure *(tabat).* Generally, water levels elevation on supply canal at 0.25 m below surface can maintain flooding water 5 – 10 cm on paddy field. In other hand, water deficit occurred in dry season therefore paddy and palawija crops require additional irrigation water. Pumping irrigation for paddy sawah in some part show economically caused by low percolation rate due to mixing of organic and mineral soil. But in other parts are still uneconomic due to high percolation rate (20-50 mm/day). At this condition dry paddy or palawija should be considered since irrigation water can be applied efficiently.

3. PROPOSED WATER MANAGEMENT ZONE

Agricultural development zone can be divided into five water management zone (WMZ). The WMZ-1 used as a green belt conservation of 1 km wide on right and left side along main river[2]. The WMZ-2a used for food crops which has potentially CI=3, i.e. cropping plan paddy-paddy-palawija/vegetable. The WMZ-2b used for food crops which has potentially CI=2, i.e. cropping plan paddy-paddy/palawija/vegetable. The WMZ-3 used for perennial and horticulture crops. The WMZ-4 used for industrial forestry and estate crops. The WMZ-5 is used as protected forest due to peat dome area. The WMZ scheme is shown on Figure 2 and 3. Detailed operating procedure and characteristics of agricultural development for each WMZ zone is described on Table 2.

In other to prevent entering harmful organic acids from WMZ-4 to WMZ-3 and WMZ-2, the interceptor drainages are constructed at every boundary of WMZ. That interceptor drainage should be designed parallel with contour line ended to a boundary canal outside of agricultural developed area (WMZ-2a, WMZ-2b, and WMZ-3).

The interceptor drainage function is to intercept surface and subsurface flow from upstream area and drain controlled to outside area of agricultural development. Beside that, if necessary the water can be used as water supply to WMZ-2a and WMZ-2b. The drainage level at boundary canal should be designed about 20-30 cm below land surface, by using several water control structures (overflow type) at appropriate locations along the boundary canal. Controlled structure-1 (Bk-1) is located at the border of WMZ-1 with WMZ-2a, Bk-2 at the border of WMZ-2a with WMZ-2b; Bk-3 at the border of WMZ-2b with WMZ-3. To prevent wild pig destroying agricultural land the side slope of canal should be designed as vertically as possible.

Controlled structures of Bk-1, Bk-2, and Bk-3 has a function to maintain water level in boundary interceptor canal about 20-30 cm below land surface in wet season and together with drainage channels are able to drain water on paddy plots during land preparation, liming, fertilizing, and one week before harvesting. In dry season irrigation water available on secondary or tertiary supply canal using low-lift pump (axial-pump). The

[2] The green belt of 1 km width left and right along the main river is proposed for environmentally life condition of Bekantan (endemic monkey in Kalimantan)

farmers group in Lamunti (2008) use the 5 HP centrifugal pump using groundwater well (30 m depth) are able to irrigate economically 10 ha corn and soybeans crops during dry season.

Principally, in wet season if flooding paddy plot about 5 cm then the water level in interceptor drain is maintained 50 cm below land surface, in dry season water level could be maintained as high as possible at 20 cm below land surface. In WMZ-3 area all of canals have a function as controlled drainage therefore the canals should be directed to Int-2. Water collected in Int-2 then used as necessary to supply WMZ-2. Int-3 at the boundary of WMZ-4 and WMZ-5 only used as a boundary canal make vertically side slope to prevent wild pig destroying agricultural land. In WMZ-5 no canal permitted since this area is used as protected and conservation forest function of water recharge area.

In WMZ-1 and WMZ-2 the primary canal or navigation canal is constructed as a main canal to supply high tide and drain in low tide, and used also for ships transportation. At every 400 m crossing primary canal, the secondary canal is constructed (the same as *handil* at conventional system) equipped with automatic gate at the head part. Also at 400 m spacing secondary drainage canals are constructed alternately also equipped with automatic gate at the head part. Those automatic gate are constructed at the location of border between housing and agricultural area. Construction type of automatic gate look as culvert sloping end where the gate is located made by wood or masonry.

If the gate is located at downstream part then it will close at high tide and open at low tide, suitable for drainage canal. If the gate is located at upstream part then it will open at high tide and close at low tide, suitable for supply canal. Using this system the water level difference of 0.5 m between supply and drainage canal can be maintained, and then one way groundwater flow will leach out the toxic substances in the soil profile can be realized.

.Table 2. Land use planning, water management zone, and operational system

Zone	WMZ-1	WMZ-2a	WMZ-2b	WMZ-3	WMZ-4	WMZ-5
Land Characteristics	Levee area, mineral soils, pyrite depth <50cm or > 50 cm	Peaty mineral soils, pyrite depth > 50 cm, medium-high percolation rate	Peat depth < 130 cm, pyrite depth >50 cm, high percolation rate, low WHC	Peat depth 130-300 cm, pyrite depth >150 cm	Peat depth > 300 cm up to the border of peat dome	Peat dome area
Land suitability for agriculture	Green belt, perennial and horticulture crops, river parks	Paddy sawah 1 x/year, can be intensified to 2 x/year using soil conditioning and water pump	Wet season: paddy sawah/paddy gogo; Dry season: palawija, vegetable, can be intensified by soil dressing (mixing with mineral soils) and pump irrigation	Perennial and estate crops. Controlled drainage	Forest crops, estate crops . Controlled drainage	Conservation. Protected forest enriched with genuine tree species
Water management layout	Main drainage canals for ship transportation, no control structure	Drainage and secondary/tertiary supply canals, minimum slope, controlled structure with automatic gate at the border of housing and agricultural land. Bk 1 at boundary interceptor canal to control water level in wet and dry season.	Drainage and secondary/tertiary supply canals, minimum slope, controlled structure with automatic gate at the border of housing and agricultural land. Bk-2 and Bk-3 at boundary interceptor canal to control water level in wet and dry season.	Interceptor drainage at Int-2 and Int-1 drain organic acids outside WMZ-2. Vertically side slope to prevent wild pig entering the agricultural land	Interceptor drainage with vertically side slope Int-1 to drain out organic acids and prevent wild pig from forest area.	No canals. Interceptor drain Int-3 vertically side slope used as a border between WMZ-4 and WMZ-5, and prevent wild pig from forest area.

Zone	WMZ-1	WMZ-2a	WMZ-2b	WMZ-3	WMZ-4	WMZ-5
Water management operational	Free flowing at high and low tide, good water quality at high tide and bad water quality at lower tide	Starting MT1 (wet season) during land preparation, Bk-1 is open to flush organic acids. Then Bk-1 is closed or operated to maintain water level 30 cm below land surface, Bk-1 is open at 1-2 weeks before harvest. Automatic gate at drainage and supply canal work to maintained water level as required. Starting MT2 (dry season) Bk-1 is open during land preparation, then closed to store water from upstream part (WMZ 3 and WMZ-4) If necessary water pump can be used for irrigation. Automatic gate work automatically. Dry season groundwater depth < 1 m to prevent fire hazard	Starting MT1 (wet season) during land preparation, Bk-2 dan Bk-3 are open to flush organic acids. Then Bk-2 and Bk-3 are closed or operated to maintain water level 30 cm below land surface. The gate are open again at 1-2 weeks before harvest. Automatic gate at drainage and supply canal work to maintained water level as required Starting MT2 Bk-2 and Bk-3 are operated as required, open during land preparation, and then closed to store water from upstream area (WMZ-3 and WMZ-4). If necessary water pump can be used for irrigation. Automatic gate work automatically. Dry season groundwater depth < 1 m to prevent fire hazard	Starting MT1 acid water in interceptor drainage is drain out from WMZ-2. Starting MT 2 water level in interceptor drain is maintained as high as possible supplying water to WMZ-2. Dry season groundwater depth < 1 m to prevent fire hazard	Starting MT1 acid water in interceptor drainage is drain out from WMZ-2. Starting MT 2 water level in interceptor drain is maintained as high as possible supplying water to WMZ-2. Dry season groundwater depth < 1 m to prevent fire hazard	As a recharge area. Storing excess water in wet season and release slowly in dry season to meet water deficit at agricultural land area in dry season. Dry season groundwater depth < 1 m to prevent fire hazard

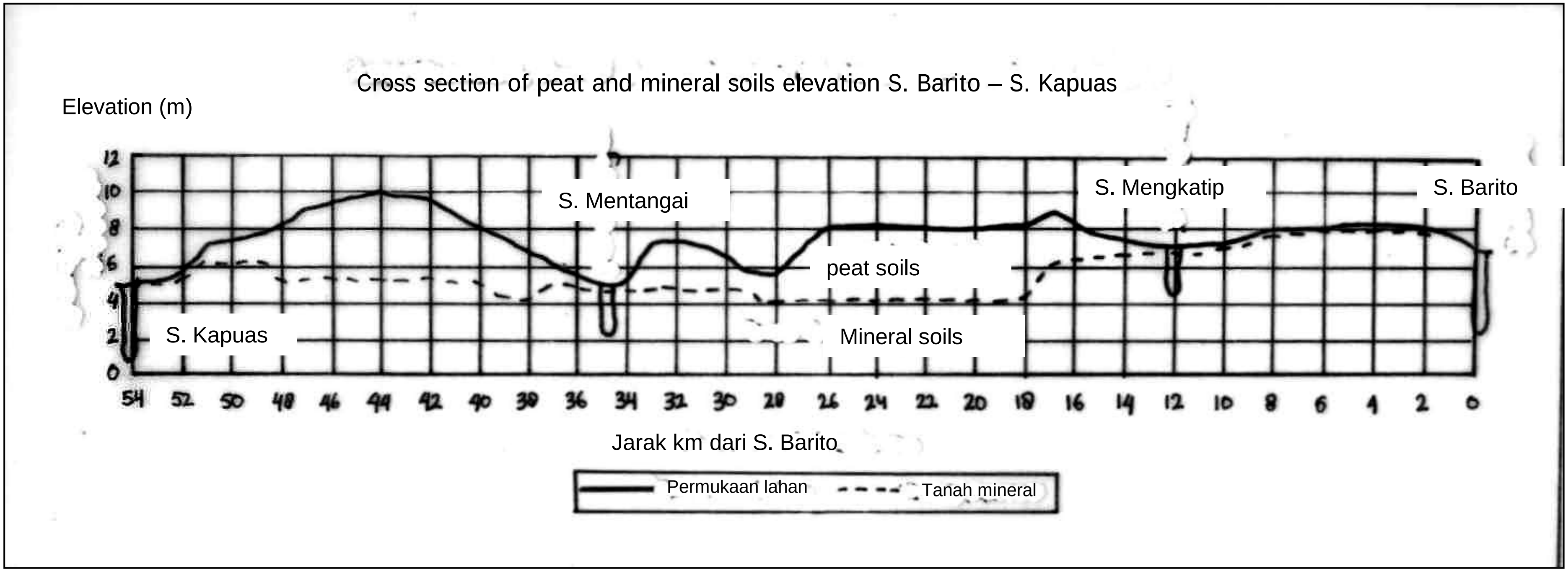

Figure 1. The cross section profile of peat land and mineral soils elevation between Barito and Kapuas River

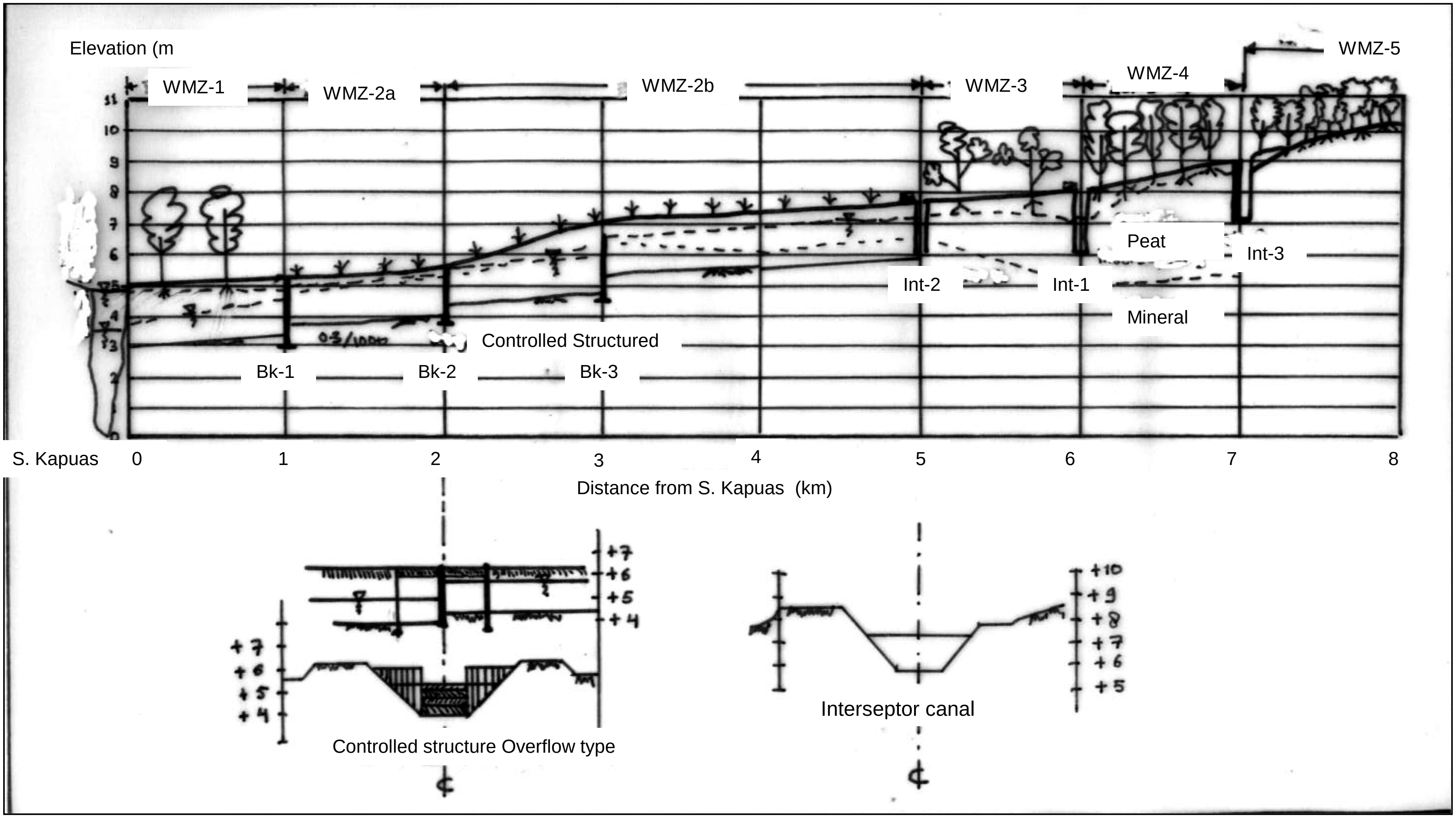

Figure 2. Cross section of land elevation and Agricultural development zoning

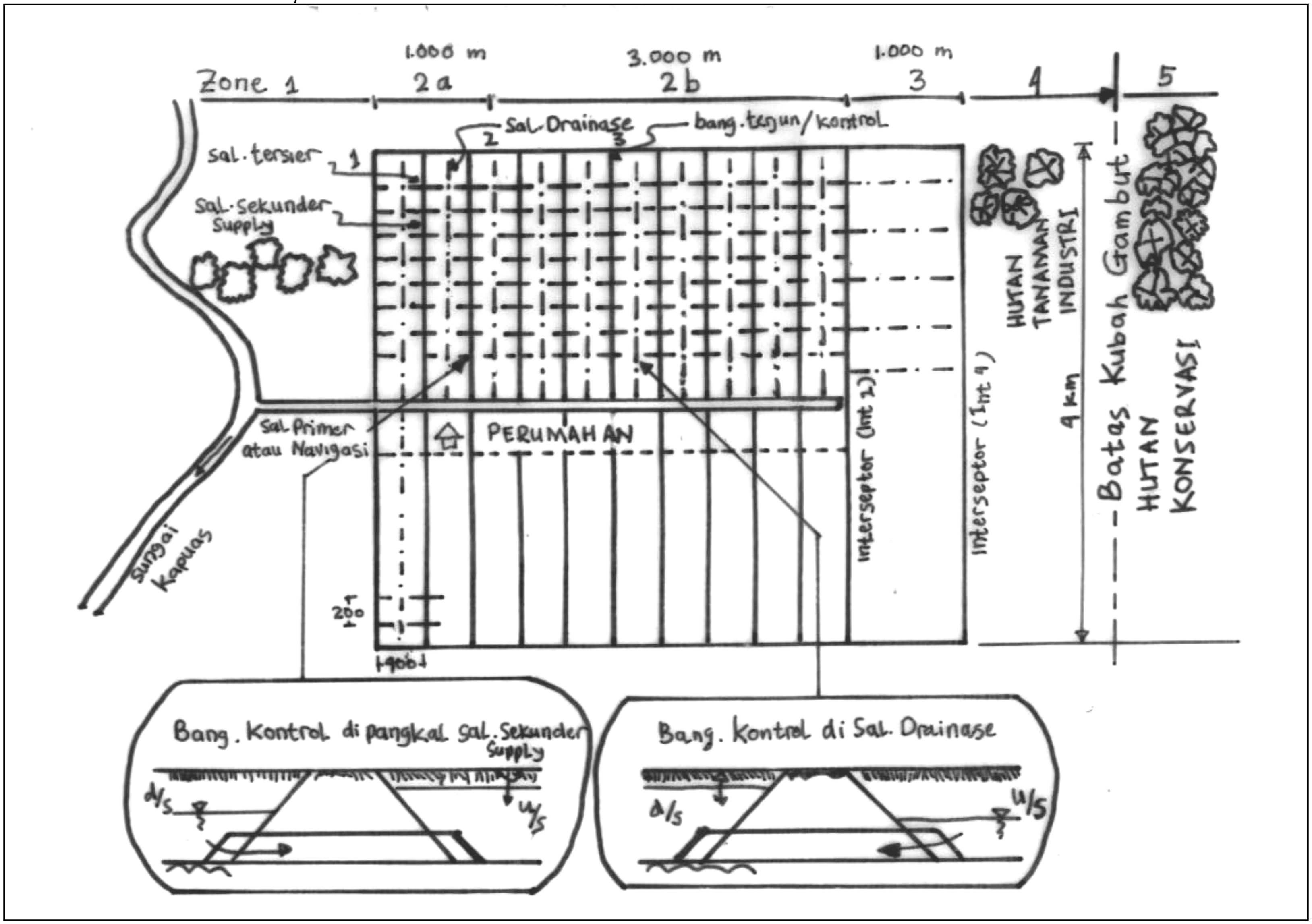

Figure 3. Typical water management system in S. Kapuas

4. PEAT DOME CONSERVATION MODEL

Considering the spirits of Keppres 32/1990 there are two things related to the sustainable development concept. Firstly, the conservation function to protect the surrounding or below area to manage water system protecting flood in wet season and fire hazard due to dryness in dry season. Secondly, the peat depth more than 3 meter, perhaps at this time already known that is unsuitable for food crops, but we do not have experience for perennial and forestry crops.

Considering the water conservation function of peatland area, there are two things should be considered. First, the high elevation as conservation area, secondly the lower part as agriculture development area. The high elevation part is known as peat dome area. How to delineate those areas?

Using the water balance approached between the surplus water at wet season in protected area and water deficit at dry season in agriculture development area, shown in Fig 4 schematically.

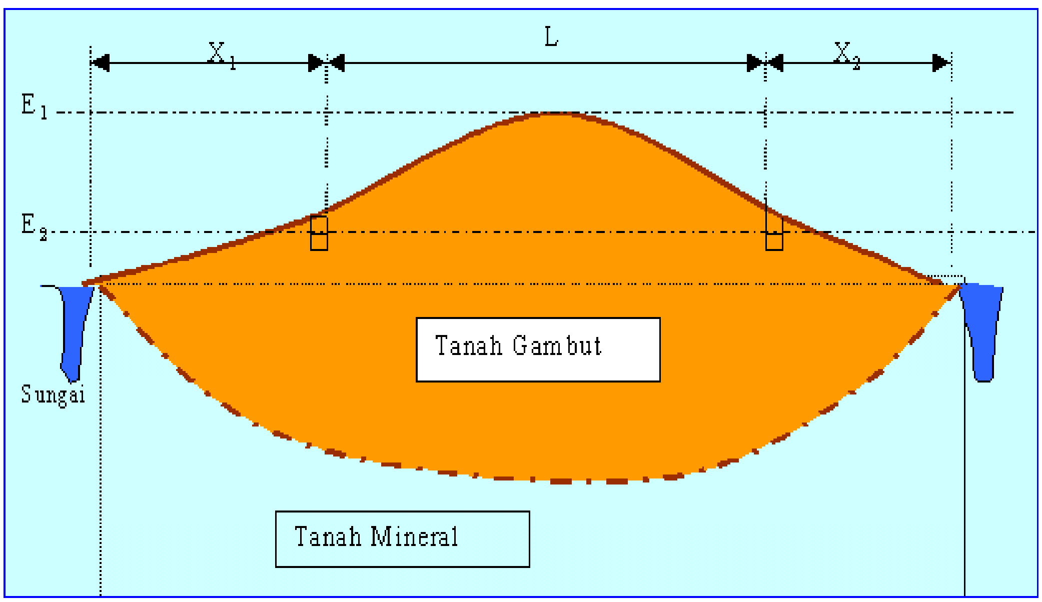

Figure 4. Peat dome schematization

Note:
L: the width of protected at peat dome area; X_1 and X_2: the width of peatland can be developed for agriculture; E_1: peak peat dome elevation; E_2: the highest water level in drainage canal (drainage level)

The quantity of water hold at conservation area in wet season should be equal or greater than the quantity of water deficit in dry season at development area (Equation 1).

$$(X_1 + X_2) \times \textit{Water deficit DS} \leq (E_1 - E_2) \times SF \times L \times n \times FD \quad .../1/$$

SF: shape factor (0.6); n: total porosity (0.8~0.9); FD: depletion factor (0.5) i.e. a part of total water retention which can be drained by gravity. DS: dry season. Water deficit at DS can be calculated as cumulative monthly deficit, where monthly rainfall (for a certain exceedance probability) less than Crop Potential Evapotranspiration (ETc). The value of total porosity representing maximum soil water holding capacity. Depletion factor representing total water drained by gravity. The actual water can be hold by peat soil is (1 - FD) x Total Porosity. The value of n and FD depend on the mature of peat soil. Using the average value of n and FD expressed with Equation 2.

$$(X_1 + X_2) \times \textit{Water deficit DS} \le (E_1 - E_2) \times L \times 0.255 \quad .../2/$$

$$\frac{\textit{Water deficit DS}}{(E_1 - E_2) \times 0.255} \le \frac{L}{(X_1 + X_2)} \quad .../3/$$

Equation /3/ showing it is used sign of = if the water management at agricultural area is quite good, the sign of < if water management is not good. Those equation can be used for calculating the proportion of L with ($X_1 + X_2$), depend on local specific conditions.

5. CONCLUSION

(1) The water management system for sustainable tidal peatland development in Indonesia has been proposed in this paper. The proposed model should be discussed, implemented in the field, monitored and improved.

(2) The peatland suitability criteria for agricultural development (Table 1) should be discussed and improved.

(3) The protected peat dome area (WMZ-5) should be calculated based on the water balance analysis. This model has been proposed in this paper.

(4) The criteria of 1 m maximum groundwater depth in dry season for preventing fire hazard should be verified in the field.

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