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Spatial Modelling for Land Use Change and Identification of Erosion and Sediment Source at Ciriung sub-Watershed, Cidanau Watershed

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ABSTRAK

Uncontrolled land use change will increase erosion, sediment and runoff. Spatial modeling conducted to analysis and to identify source of erosion and sediment in Watershed. Integration WEPP model and GIS show significant result when become 40%, runoff increased 68.69%-88,40%, while un-irrigated area become 60%, sediment increased 259,38%-450,0% and erosion increased 205,95%-282,85%. In general Ciriung sub watershed not yet in critical condition. Based on OFE/GRID analysis identified that grid/land as source of sediment and erosion. Analysis result indicated there 3 ha (grid) land were exceeding erosion more than tolerable soil loss at existing condition, and also 8 ha (grid) land at un-irrigated area become 100%. Approximately 8 ha land undeveloped as land farm, while 114 ha land can be developed as land farm.

Keywords: Spatial model, hydrological model, erosion, sediment, runoff

INTRODUCTION

At 1984 noted, 22 watersheds in critical condition, 1992 amount of critical watershed become 39, and 1998 becoming 59 DAS. According to Minister of Public Work in Jakarta, that indication of existence 62 critical watershed at now. Which is located in all Java, Aceh, North Sumatra, West Sumatra, Bengkulu and Lampung that in rehabilitation program. While according to Director-General of Water Resource, critical watershed cause about 21 million hectare of land become critical also (Agriceli, 2004).

One criteria of critical watershed is lowering of land covering, height of annual erosion, height of maximum and minimum discharge ratio, and also sediment load (Suripin, 2002).

Critical watershed was beginning from degradation and damage of land inside. Erosion is one of cause the land damage. Erosion can make land damage inside watershed or at downstream. Impact of erosion for example is deteriorating of chemistry and physical of soil then decreasing productivity. While in downstream cause sedimentation in river, reservoir and irrigation channel.

Uncontrolled land use change is one of cause that increasing of erosion, sediment and runoff in watershed. The other factors are climate, topography, soil and human being (Arsyad, 2000). Some factors could be manipulation. Which is crop factor, soil and topography (Asdak, 1995).

Effort to maintain existence of land cover is most effective and economic to prevent increasing the erosion (Asdak, 1995).

OBJECTIVES

The main objectives of research are to develop hydrological model for prediction of erosion, sediment and runoff on the effort of detecting watershed damage and supporting water resources management. The detail objectives of research follow as:

1. To analysis effect of land use change that increasing of erosion, sediment and runoff.
2. To identify source of erosion and sediment in watershed at now condition and un-irrigated area become 100%.

The result is could use to make Standard Operation Procedure for management and to compile technical plan on water resources in watershed.

METHOD

Location

Location of research at upstream of Cidanau watershed that is Ciriung sub watershed, Kubang Baros village, Cinangka sub district, Serang regency, Banten Province. Geographically Ciriung sub watershed is located at 105° 54' 51" – 105° 55' 7" longitude and 60° 11' 24" – 60° 13' 9" latitude. Elevation of Ciriung is range from 100 - 250 m above sea level. Wide of Ciriung about 121,6 ha. Land use consist of mix garden about 108,8 ha, un-irrigated area about 11,8 ha, and settlement 1,0 ha (Fig 1 and 2).

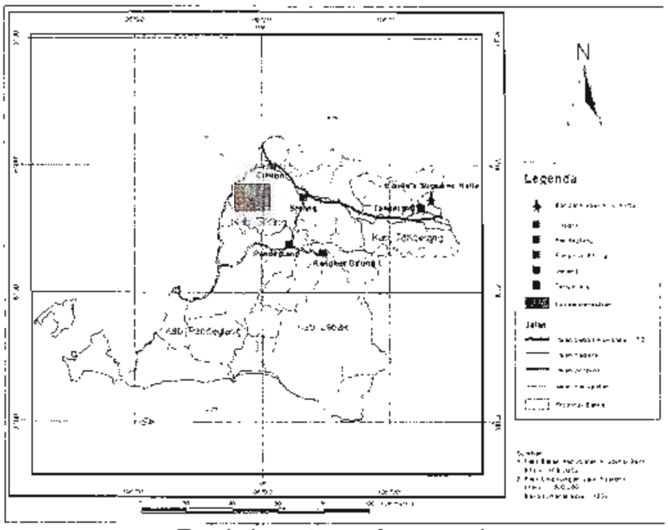

Fig 1. Location of research

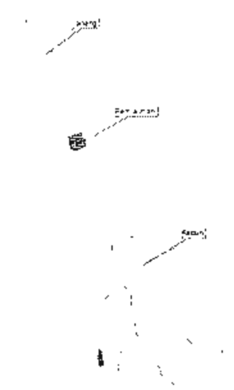

Fig 2. Land use

Material and Instrument

Material used is earth map scale 1:45.000, thematic map scale 1:10.000 for example topography and land use map. Instrument used in this research for example automatic rainfall recorder (HOBO H6), and thermo recorder censor (TR-71S) for the air temperature. Discharge measured by weir, and water level measured by automatic water level recorder (AWLR) with data logger (standard diver). Sediment measurement used bottle sample then analysis in laboratory. Watershed morphological calculated with Map-info/Arc-info/Arc-view software. GPS to delineation land use, and simulation use WEPP model.

WEPP Model

WEPP (Water Erosion Prediction Project) is a process-oriented model, based on modern hydrological and erosion science, designed to replace the Universal Soil Loss Equation for the routine assessment of soil erosion by organizations involved in soil and water conservation and environmental planning and assessment. The erosion component applies the continuity equation for sediment transport down slope in the form (Morgan, 1995):

$$\frac{dQs}{dx} = Di + Dr \quad \ldots\ldots \quad (1)$$

Where Qs is the sediment load per unit width per unit time, x is the distance down slope, Di is the delivery rate of particles detached by inter-rill erosion to rill flow and Dr is the rate of detachment or deposition by rill flow. The inter-rill erosion rate (Di) is given (Morgan, 1995):

$$Di = Ki \times I^2 \times Ce \times Ge \times \left(\frac{Rs}{w}\right) \ldots\ldots \quad (2)$$

Where Ki is an expression of inter-rill erodibility of the soil, I is the effective rainfall intensity, Ce is expresses the effect of the plant canopy, Ge expresses the effect of ground cover, Rs is the spacing of rills and w is the width of the rill computed as a function of the flow discharge. The canopy effect is estimated by (Morgan, 1995):

$$Ce = 1 - F.e^{-0.34PH} \quad \ldots\ldots \quad (3)$$

Where F is the fraction of the soil protected by the canopy and PH is the canopy height. The ground cover effect is estimated by (Morgan, 1995):

$$Ge = e^{-2.5gi} \quad \ldots\ldots \quad (4)$$

Where gi is fraction of the inter-rill surface covered by ground vegetation or crop residue. This relationship does not consider inter-action between detachment and sediment load, this is allowed for by adopting the equation (Morgan, 1995):

$$\left(\frac{Df}{Dc}\right) + \left(\frac{Qs}{Tc}\right) = 1 \quad \ldots\ldots \quad (5)$$

Where Dc and Tc are respectively the detachment and transport capacities of the rill flow. The detachment of soil particles by rill flow is given by (Morgan, 1995):

$$Df = Dc\left(1 - \frac{Qs}{Tc}\right) \quad \ldots\ldots \quad (6)$$

Where Dc is the detachment capacity, Qs is the sediment load in the flow and Tc is the sediment load at transport capacity. Detachment capacity is expressed as (Morgan, 1995):

$$Dc = Kr(\tau - \tau c) \quad \ldots\ldots \quad (7)$$

Where Kr is the rill erodibility of the soil, τ is the flow shear stress acting on the soil and τc is the critical flow shear stress for detachment to occur. The transport capacity of the flow is obtained from (Morgan, 1995):

$$Tc = kt \times \tau^{3/2} \quad \ldots\ldots \quad (8)$$

Where kt is a transport coefficient and τ is the hydraulic shear acting on the soil. Alternatively, if the sediment load is greater than the transport capacity, deposition will occur. The rate of deposition (Dp) is determined by (Morgan, 1995):

$$Dp = \alpha \times (Tc - Qs) \quad \ldots\ldots \quad (9)$$

Where α is a first order reaction coefficient. Its value is defined by (Morgan, 1995):

$$\alpha = \xi \times \left(\frac{Vs}{Qw}\right) \quad \ldots\ldots \quad (10)$$

In which Vs is the particle fall velocity, Qw is the rate of runoff per unit width and ξ = 0,5 for overland flow and 1,0 for channel flow

Vegetative Simulation Method

The scenario (Fig 3 and 4) for simulation was changing mix garden area to un-irrigated area from upstream to downstream and on the contrary.

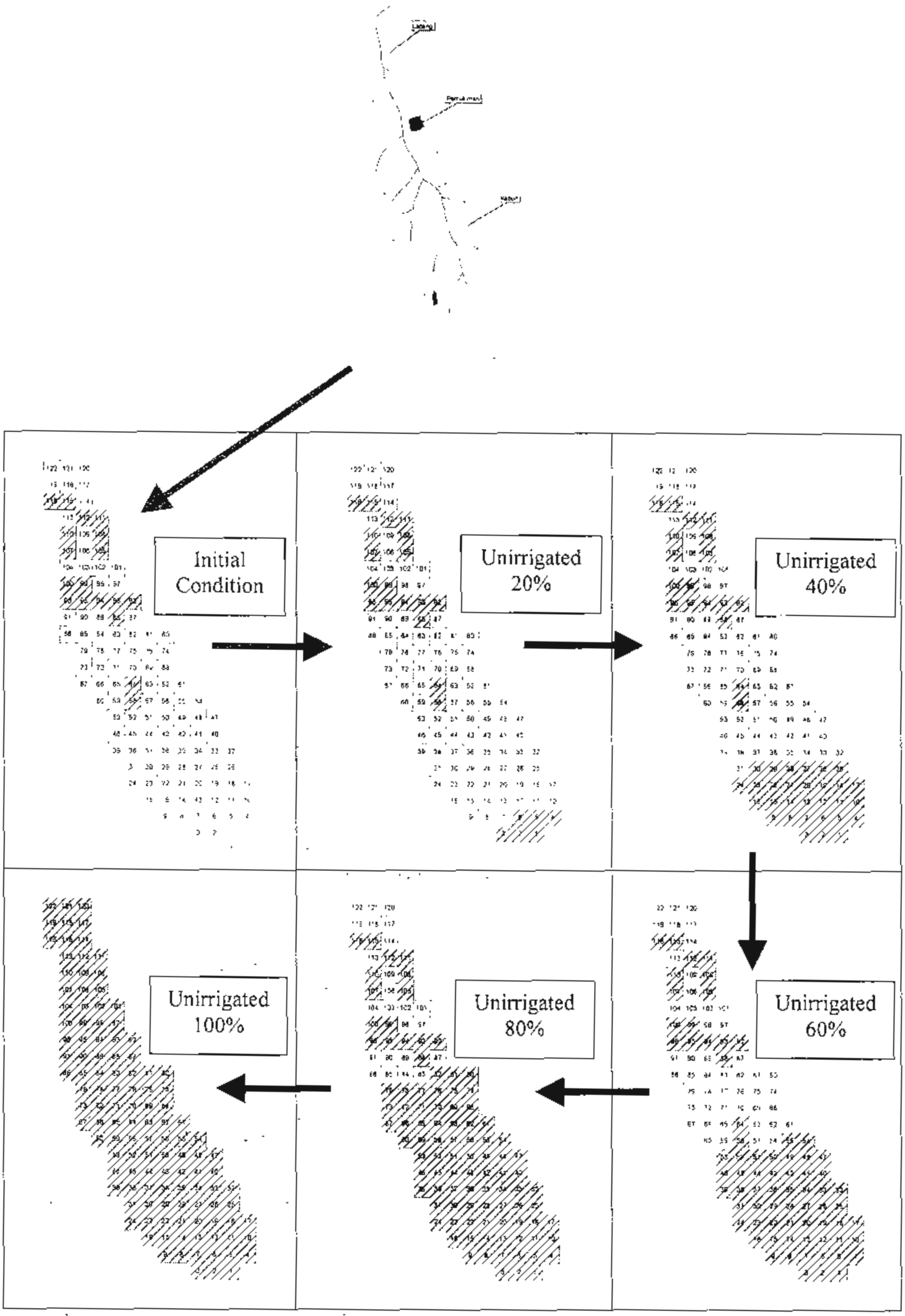

Fig 3. Scenario of land use change from upstream to downstream

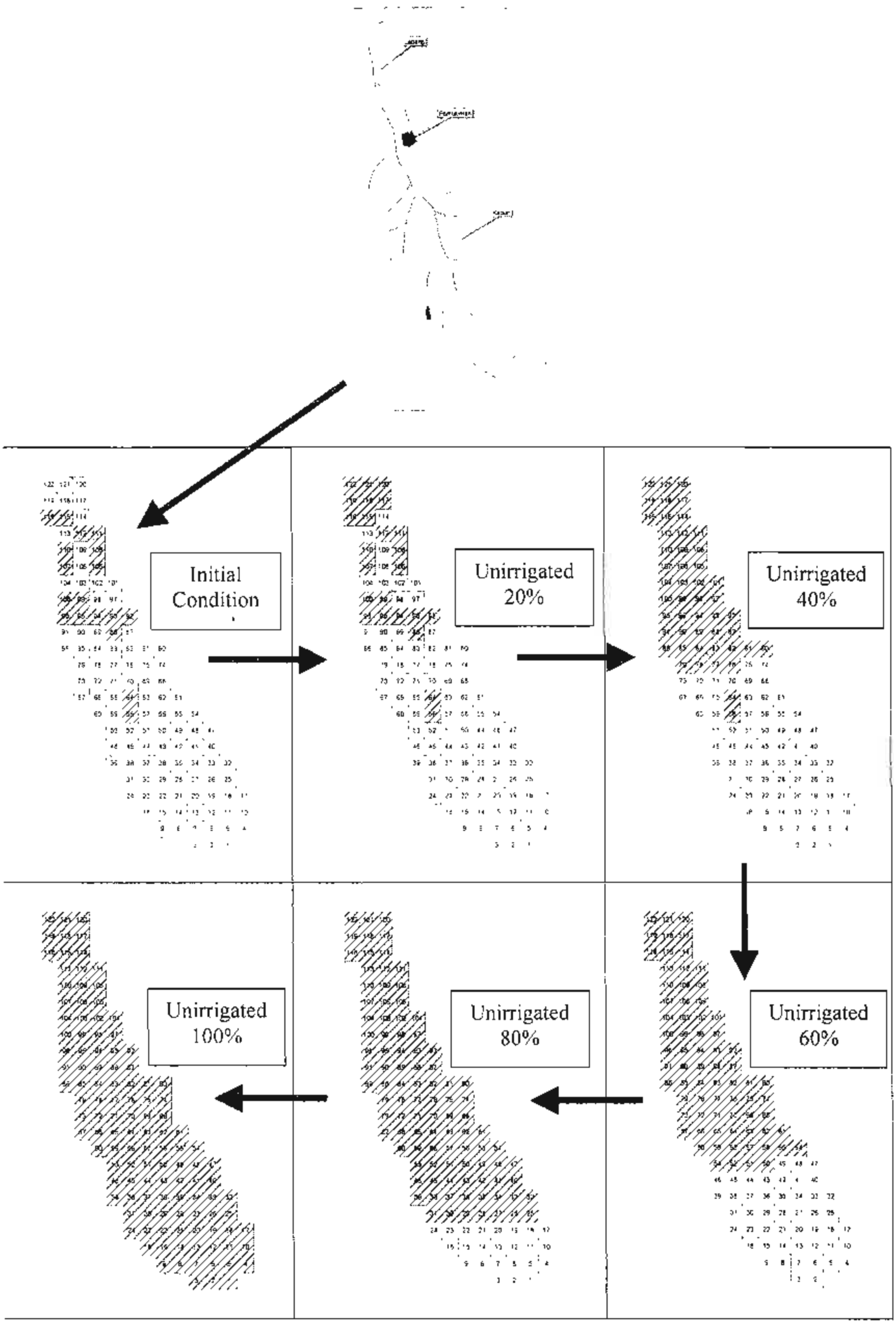

Fig 4. Scenario of land use change from downstream to upstream

The result of scenario of land use change at Ciriung sub watershed showed significantly runoff increased especially when un-irrigated area become 49 ha (40%) cause runoff will increase 68,69% (upstream to downstream) and 88,40% (downstream to upstream). Significantly sediment and erosion increased especially when un-irrigated area become 73 ha (60%) cause sediment will increase 450,0% (upstream to downstream) and 259,38% (downstream to upstream), while erosion will increase 282,85% (upstream to downstream) and 205,95% (downstream to upstream). Base on Erosion Danger Index (Hammer, 1981 *in* Arsyad, 2000) showed Ciriung sub watershed is not yet in critical condition and can be developed as land farm.

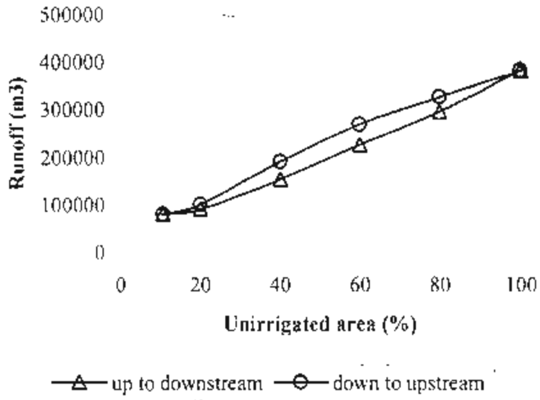

Fig 5. Runoff and land use change

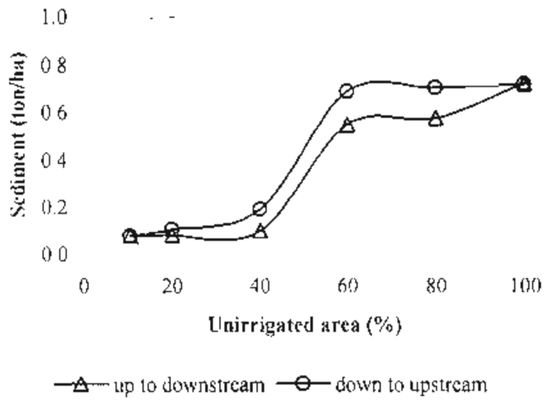

Fig 6. Sediment and land use change

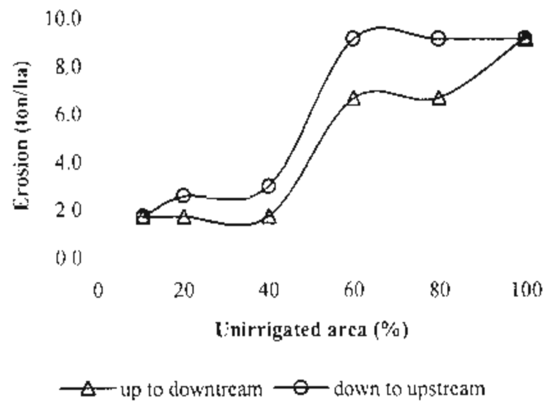

Fig 7. Erosion and land use change

Fig 5 showed trend of land use change to runoff is go up linearly, when un-irrigated area is 40%, change from downstream to upstream showed runoff increased more than on the contrary. The effort to control runoff in Ciriung sub watershed is preventing extension un-irrigated area from downstream to upstream with maximal area about 40%.

Fig 6 and 7 showed trend of land use change to sediment and erosion are go up by polynomial, when un-irrigated area is 60%, change from downstream to upstream showed runoff increased more than on the contrary. The effort to control runoff in Ciriung sub watershed is preventing extension un-irrigated area from downstream to upstream with maximal area about 60%.

Existing Condition

Based on analysis used WEPP model indicated Ciriung sub watershed is not yet in critical condition. It condition do not mean Ciriung sub watershed has no problem. Based on OFE/GRID analysis identified that grid/land as source of sediment and erosion. Fig 8 showed erosion source and erosion danger index. Analysis result indicated there 3 ha (grid) land were exceeding erosion more than tolerable soil loss. The grids as source of erosion and sediment are:

1. 58th (very heavy)
2. 96th and 110th (moderate)

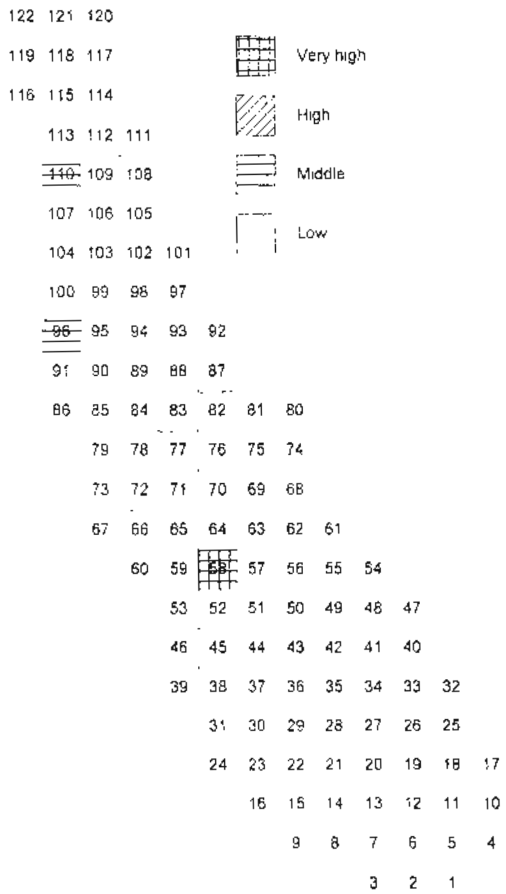

Fig 8. The grids as source of erosion and sediment at present condition

Un-irrigated Area 100%

If all land use of Ciriung sub watershed are un-irrigated area (100%), it still not yet in critical condition. But it condition do not mean Ciriung sub watershed has no problem. Based on OFE/GRID analysis identified that grid/land as source of sediment and erosion. Fig 9 showed erosion source and erosion danger index. Analysis result indicated there 8 ha (grid) land were exceeding erosion more than tolerable soil loss. The grids as source of erosion and sediment are:

1. 52nd and 58th (very heavy)
2. 50th, 87th, 114th and 117th (heavy)
3. 96th and 110th (moderate)

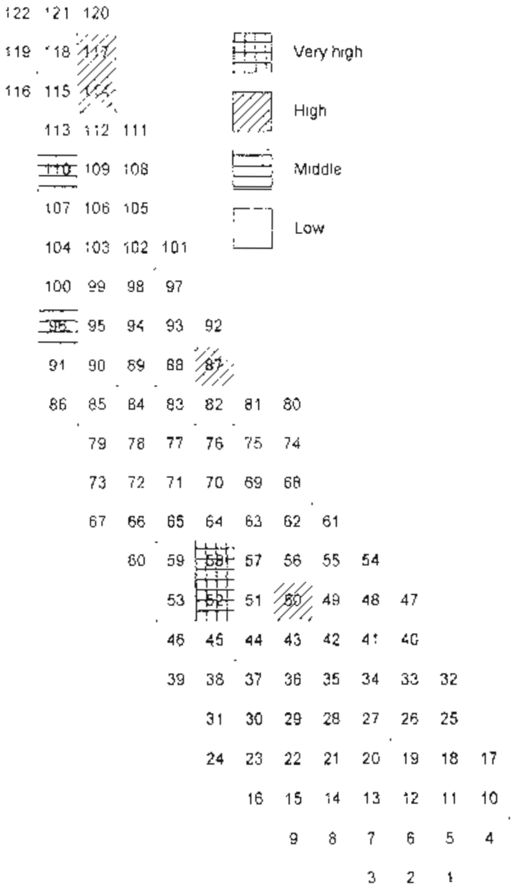

Fig 9. The grids as source of erosion and sediment at un-irrigated area 100%

CONCLUSION

1. Trend of land use change to runoff is go up linearly, while to erosion and sediment are go up by polynomial.
2. The effort to control runoff in Ciriung sub watershed is preventing extension un-irrigated area from downstream to upstream with maximal area about 40%, while to control sediment and erosion with maximal area about 60%.
3. Based on analysis used WEPP model indicated Ciriung sub watershed is not yet in critical condition and can be developed as land farm.
4. Based on OFE/GRID analysis identified there 3 ha (grid) land at existing condition were exceeding erosion more than tolerable soil loss, and also 8 ha (grid) land at un-irrigated area become 100%.
5. Approximately 8 ha land undeveloped as land farm, while 114 ha land can be developed as land farm.

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