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THE EFFECT OF FLOOD TO QUALITY INDEX OF SOIL PHYSICAL PROPERTIES AT THE DOWNSTREAM OF KURANJI RIVER WATERSHED, PADANG CITY

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ABSTRACT: The downstream of the Kuranji watershed of Padang City is vulnerable to flood due to the changes of land use into settlements area. Land use changes have changed the soil physical properties and its infiltration. The inundation has changed soil physical properties, such as layers, textures, volume weight, pores, permeability, and soil organic matters. The objective of this research is to analyze the quality index of soil physical properties due to flood at the watershed of the downstream area of Kuranji River of Padang City. Research methodology adopted is by conducting a field survey. Location of the soil sample is selected by purposive random sampling and was analyzed at the Department of Soil Science Andalas University. Soil physical properties data was arranged as minimum data sets (MDS) to be analyzed with principal component analysis to identify the main factors most affected by the flood. The results show that the main soil physical properties influenced by the flood are texture and soil organic matter. Based on the calculation of selected values from the MDS data, the quality of the downstream Kuranji watershed is moderate to good.

Keywords: Flood, Watershed, Soil quality index, Soil physical properties

1. INTRODUCTION

Floods can be inferred as a relatively high flow that transcends natural or artificial embankments in the river, varying magnitude by season, month to month, year to year [1]. Flooding can also be inferred as the flow of river water flow that is relatively larger than usual as a result of rain down in the upstream or in a specific place continuously so that can not be accommodated by the existing river flow, the water overflows out and inundates the area surrounding [2]. Flood is an ordinary natural event, then becomes a problem when it interferes with human life and livelihood.

Fig. 1 Area Flooded at Dadok Tunggul Hitam, Downstream of Kuranji Watershed.

Flood happens in Padang frequently, especially in the downstream of watersheds such as Kuranji watersheds (Fig. 1). The flood itself is a natural occurrence that occurs not suddenly but always preceded by symptoms. These symptoms can, among others, arise due to the improper natural management of humans. Floods frequently occur in areas that have low elevation. According to Aprisal et al [3] floods generally are influenced by three main factors, namely (1) meteorological factors, (2) watershed factors, and (3) human factors. Critical meteorological factors are precipitation or rain.

The amount of rainfall in the upper watershed area of Kuranji river is quite high with an annual average of about 3,000-5,000 mm, and the erosion (rain damage to soil 5,603.11) is also high. Therefore, when viewed from the aspect of conservation, some of the land conditions in Kuranji watershed are critical because the surface flow and erosion of this land are quite high. This can be seen every time the incidence of heavy rain then visible fluctuations of river flow Kuranji river is very high with the color of dark brown (dirty water). This condition is an indicator that such rapid fluctuations are due to the high surface flow of rainfall due to low soil absorption. Correspondingly, high soil erosion causes the water to become cloudy. Whereas, the upstream watershed is expected to produce water that can flow into the middle of the city and as a source of life for the people of Padang. Frequent flooding in some areas downstream Kuranji watershed this floods occur due to high surface runoff and soil recharge that decreases due to damage to soil physical properties. According to the Public Works Department [4] floods are overflowing of water in river bodies due to silting by high sedimentation, urban drainage channels and punishment whose capacity is smaller than the peak discharge of surface runoff due to more rain. This flood will inundate the lower regions.

2. RESEARCH METHODOLOGY

2.1 Time and Place

This research was conducted from March to May 2018 at the downstream Kuranji watershed in Padang city, West Sumatera province (Fig. 2). The name of specific locations are also shown in Fig. 2 that are:

1 Aie pacah 1
2 Aie Pacah 2
3 Gunung Sariek
4 Kurao Pagang
5 Gunung Pangilun
6 Ampang
7 Korong Gadang
8 Dadok Tunggul Hitam.

2.2 Tools and Materials

The tool used in this research was a set of computer with ArcView / ArcGIS program, Microsoft Excel, measuring cylinder, bucket, Global Positioning System (GPS), infiltrometer, roller meter, ring sample, plastic, rubber, and book munsel.

Materials used in this study are Digital Elevation Model (DEM) data in the form of Triangulated Irregular Network (TIN), Kuranji watershed administrative map, land use map, soil type map, monthly rainfall data and water flow of Kuranji river.

2.3 Research Methodology

The research method conducted in the field was a survey method consisting of several stages: (1) preparation, including secondary data collection; (2) preliminary survey; (3) main survey; (4) analysis of soil in the laboratory; and (5) data processing and report preparation.

2.3.1 Preparation (collection and secondary data review)

a. Topographic maps

The basic maps used are 1: 200,000 scale topographic maps and SRTM data. This topographic map is used as the basis for drawing the boundary of the study site and the basis for the slope grade determination.

b. Slope class map

The slope map is derived from a 1: 200,000 topographic map interpretation and DEM data as well as the contours of SRTM processed using ArcGIS 10.2 software. From the slope map is obtained classification of the slope class.

c. Land use map

Land use map is the result of interpretation of land cover map Indonesia year 2012 sheet 0814 Padang which then digitized using ArcGIS software 10.2.1.

d. Land map

The land map was obtained from the Land Sheet and Land Unit Map of Padang by the Soil and Agro-climate Research Center, Bogor in 1990 with a scale of 1: 250,000. Based on the map of land unit Padang sheet will be obtained land units in the river area Kuranji Padang.

e. Field unit map

Map of land was obtained by overlapping slope maps, land use maps and land maps. From overlay of slope map, land use map and land type map.

f. Rainfall data

Rainfall data used was the result of rainfall recordings from the rainfall precipitation station in Kuranji watershed area.

2.3.2 Preliminary Survey

The preliminary survey was to review secondary data, such as rainfall data, flood data or inundation in Kuranji watershed, especially in downstream areas. Then also to know the real state of the field and prepare and facilitate the primary survey. In the preliminary survey, checks on each unit of land. Inspections were conducted on land slope, land use and soil type, to determine the sampling points of the soil.

2.3.3 Main survey

At this stage, soil sampling was conducted for the analysis of soil physical characteristic determined by Purposive Random Sampling on units of land that have been identified as flood-prone areas. In addition, the measurement of infiltration rate of soil using double ring infiltrometry in each set of land has been determined. To establish a position at the point of sampling of the land that has been determined in the preliminary survey used Global Positioning System (GPS).

2.3.4 Laboratory analysis

Laboratory analysis was performed to assess the soil quality, analyzing the bulk density, total pore space by using the gravimetric method, the organic material percentage by Walkley and Black method, soil permeability using Constant Head Permeability method, and soil surface texture by pipette and sieve method, while soil structure observed in the field. Analysis of rainfall data and its relation to Kuranji river debit of each rainfall by using the rainfall-runoff method.

2.3.5 Data processing

Data analyzing was done in two ways, first was the measurement data analysis using Microsoft Office Excel. Data analysis using Microsoft Office Excel is done by using the necessary equations and then entering the data into the equations. Second, used Minitab 17 software, for correlation analysis of soil physics and principal component analysis (PCA).

Soil quality can not be measured directly, but the indicator of soil quality is measurable. Each of these indicators is assigned a value and weight which will then be used as the basis for calculating the Soil Quality Index. The soil quality indicator is the nature, characteristic, or process of physics, chemistry, and biology that can describe soil conditions [5]. According to Partoyo [6], soil quality can be measured based on indicators of soil quality, the measurement of soil quality indicator will produce soil quality index. The soil quality index is an index calculated based on the value and weight of each indicator of soil quality. These soil quality indicators are selected from the characteristics that indicate the capacity and function of the soil.

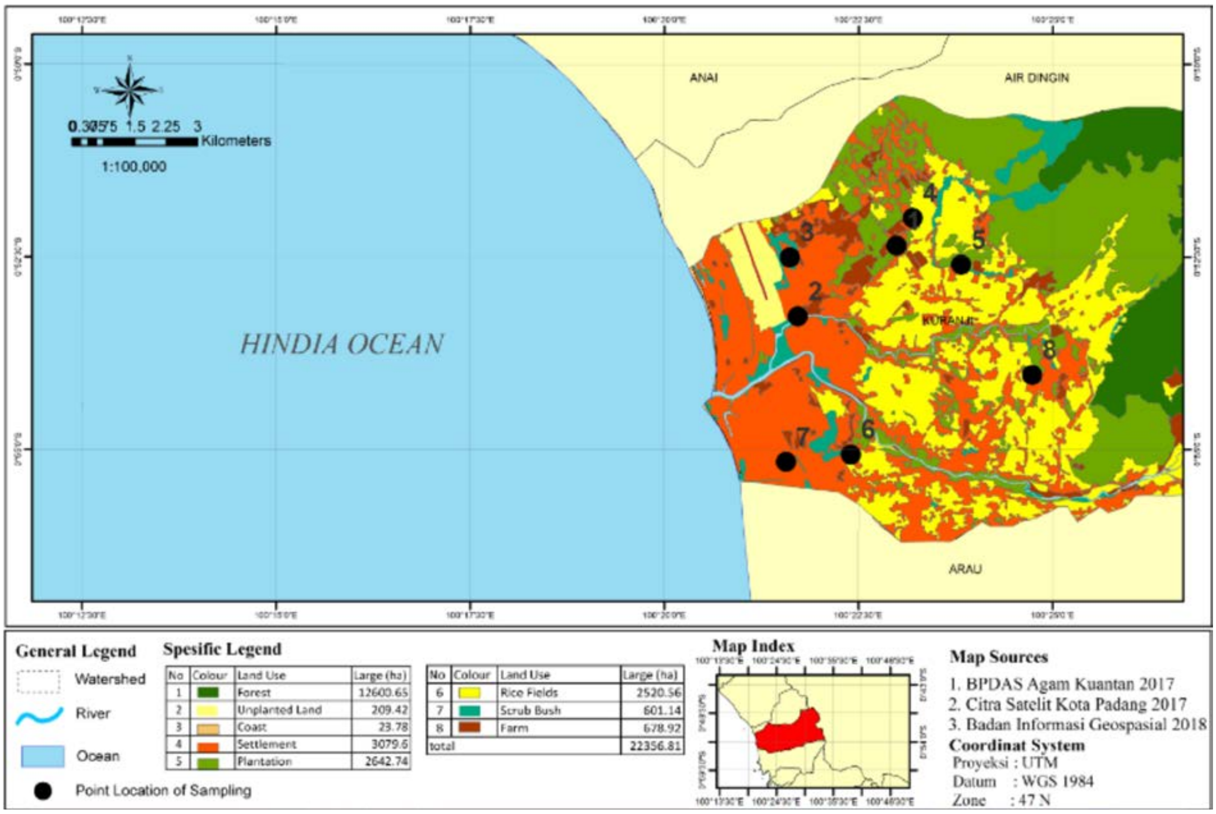

Fig. 2 Map of Kuranji Watershed Padang, plan of research location.

The sum of the indicator scores into an index of soil quality is carried out using the formula disclosed by Andrews et al. [7]: Soil quality calculation is done by multiplying the weight of MDS and scores of soil analysis results then summing the scores obtained on each land use. The data analysis score is 1-5. Systematically, soil quality rating can be calculated using Soil Quality Index (SQi) formula as follows;

$$\boldsymbol{SQ_i = \sum_{i=1}^{n}(W_i \times S_i)} \quad (1)$$

Annotation :

SQ_i = Soil quality index
W_i = Weighting factor in PC
S_i = Score index
PC = Primary component of soil quality

If the index value has been obtained and to facilitate the quality of the soil in the lower

Kuranji watershed, it can be done as described in Table 1. The result of Soil Quality Index (SQI) has a range between 0-1. The closer the SQI to 1, the better the value.

No	Value	Soil Quality Criteria
1	0.80 -1.00	Very Good
2	0.60 - 0.79	Good
3	0.40 - 0.59	Fair
4	0.20 - 0.39	Bad
5	0.00 - 0.19	Very Bad
	Source	Partoyo, 2005

Table 1 Soil Quality Index

Table 2 Soil Quality Indicator Score Criteria

No.	Indicator	Score					Sources
		1	2	3	4	5	
1	Depth of rooting (cm)	<10	10-15	15-20	20-25	>25	
2	Infiltration cm/hour	<5	5-10	10-15	15-20	>20	Arsyad, 2000 [8]
3	Soil content C–Org (%)	<1	1-2	2-3	3-5	>5	Balittanah, 2005
4	BV (g/cm^3)	>1,52	1,14-1,51	0,86-1,13	0,67-0,85	<0,66	Modification of LPT Bogor, 1979
5	Porosity (%)	<57	58-64	>88	75-88	65-74	Modification of LPT Bogor, 1979
6	Texture	S, Si	LS	SL, L, SiL	SiC, SC, SCL	SiCL, SC, C	Balittanah, 2005
7	Aggregate stability (%)	<40	41-104	105-200	201-328	<328	Modification of Balittanah, 2005
8	Permeability (cm/hour)	<0,5	0,6-10,4	10,5-25,4	25,5-45,3	>45,4	Modification of Arsyad, 2000 [7]

Remarks :

S	: *Sandy*	S$_i$C	: *Silty Clay*
S$_i$	: *Silty*	CL	: *Clay Loam*
LS	: *Loamy Sand*	SCL	: *Sandy Clay Loam*
SL	: *Sandy Loam*	S$_i$CL	: *Silty Clay Loam*
L	: *Loam*	SC	: *Sandy Clay*
S$_i$L	: *Silty Loam*	C	:*Clay*

3. RESULT AND DISCUSSION

3.1 Principal Component Analysis

Based on the results of principal component analysis and correlation analysis (Table 1 and 2) shows that soil physical properties of porosity, permeability, volume weight, organic matter, infiltration, sand, dust, clay and soil depth are correlated. All physical factors are then analyzed using principal component analysis (PCA). In the research used as an MDS indicator based on principal component analysis are a sand fraction, volume weight, effective soil depth, and dust fraction (Table 3). The soil quality index is calculated only on the basis of the selected variables from the PCA analysis [9]. From the results of the major component analysis, there are some main factors that influence the quality of Kuranji watershed section based on the analysis of soil syphilis properties.

3.2 Correlation Between Soil Physics Characteristics in the Lower Kuranji Watershed

Soil porosity characteristics indicate the quality of soil because the porosity of soil determines the movement of water into the soil. The weight of the soil volume also indicates whether the soil conditions are solid or loose. The volume weight corresponds to the porosity of the soil; if the weight of the soil volume is high, then this indicates the soil is dense enough to be penetrated by the roots so that the plant can not develop properly.

Purkait [10] also states that soil physical characteristics are often determined by soil texture, since soil texture greatly affects other physical properties, such as bulk density, groundwater movement, specific surface area and soil density.

Soil Quality Index (SQI) in downstream Kuranji watershed will be analyzed using correlation analysis with sampling point taken to see the correlation between sampling site characteristics with Kuranji river basin downstream SQI from soil physical characteristics aspect. The physical properties of the soil are greatly influenced by the processes occurring in the soil. According to Arsyad [7], the mechanisms in the binding of primary grains such as sand, dust, and clay to aggregate work in the soil, namely (1) the physical binding of primary grains by fungal mycelia and actinomycetes. The formation of this structure can occur the existence of clay fraction; (2) chemical bonding of the primary grains by bonding between the positive part of the clay grains with the negative cluster of long-chain organic compounds; (3) chemical bonding of clay grains by bonding between the negative part of the clay and the negative group in long-chain organic compounds with the base linkage (Ca, Mg, Fe) and hydrogen bonds; (4) chemical bonding of clay grains through the negative bonds with the positive cluster (ammine, amide, amino) groups in organic compounds in the form of polymer chains; (5) chemical bonding of negatively charged clay beam through cation linkage and in this event dipole water molecules play an essential role at the initial stage; (6) chemical bonding of clay grains through the positive part of a grain with another part of the negative-grain.

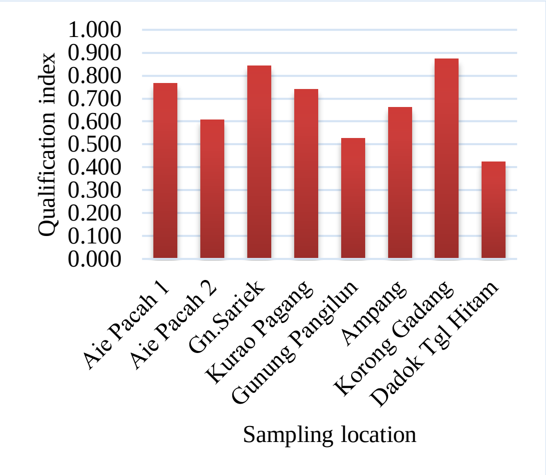

Fig. 3 Quality Index at the Sampling Location in Kuranji Padang Downstream.

3.3 Quality Index of Kuranji Downstream Watershed

Quality index of Kuranji downstream watershed from the soil physical characteristic aspect is shown in the Table. The quality range of the lower Kuranji watershed was 0.424 to 0.873.

Based on the analysis of the soil quality indicator characteristic of the physical aspects of

the watershed, the value of the soil quality index (Table 3) was obtained. The result of calculation of soil quality index found that soil physical properties factors that affect the quality index are texture properties, bulk density, and effective depth of soil. The excellent soil quality index value is found in Aie Pacah 1, Aie Pacah 2, Gunung Sariek, Kurao Pagang, Ampang, and Korong Gadang. The excellent quality of soil in this area is caused by the soil is still overgrown by vegetation that can improve the soil properties due to the influence of the crops. Supriyadi et al. [8] and [11] it also shows that tree crops such as agroforestry can improve soil physical characteristics due to a significant amount of cellulose content and litter produced. This material will be composed to improve soil characteristics.

Bad condition was found in the area of Gunung Pangilun and Dadok Tunggul Hitam (Fig. 3). The occurrence of soil quality index decline in some locations in downstream Kuranji watershed, caused by the damage to physical properties such as soil texture due to the enrichment of materials inundation and sedimentation ponds. This also leads to soil compaction due to soil pores that are softened by fine factions such as sand, dust and clay from sedimentary materials. This causes the difficulty of water flow to the deeper layer of soil and easily caused puddle in case of more rain. Soil damage will also increase if water puddles occur for a long period of time. Usually, this kind of effective soil depth is also swallowed. For example Dadok Tunggul Hitam area and Gunung Pangilun, the groundwater is only about 20 cm. So in these areas often occur inundation if more rain happened. Harjowigeno [12]. In addition, the soil in the downstream river basin is strongly influenced by the nature of texture, organic matter and soil porosity as well as ground material. This soil is generally an alluvial soil which is the soil of sediment from the runoff of the flood. These soil characteristics greatly affect the quality of the soil in the watershed. The degradation of soil quality will be due to the ecological function of the soil in the watershed. According to Seybold et al. [13]: (1) maintain the activity, diversity, and biological productivity of soil, (2) regulate the availability of water and solutes, (3) as filters and buffers, suppress immobilization and detoxification (1998) organic and inorganic materials including industrial and municipal wastes, (4) storing and recycling organic and inorganic elements in the earth's biosphere; (5) providing socio-economic structural support and protecting archaeological remains related to human habitation.

Table 3 Correlation of Soil Characteristic Variables in Lower Kuranji Watershed, Padang

	KI	BV	TRP	C ogk	Perme	Sand	Dust	Clay
BV	-0.186							
	0.631							
TRP	0.186	-1.000						
	0.631	*						
C ogk	-0.351	0.116	-0.116					
	0.355	0.765	0.765					
Perme	0.819	-0.386	0.386	-0.004				
	0.007	0.305	0.305	0.991				
Sand	0.572	-0.774	0.774	-0.358	0.709			
	0.107	0.014	0.014	0.344	0.033			
Dust	-0.635	0.521	-0.521	0.135	-0.723	-0.861		
	0.066	0.150	0.150	0.729	0.028	0.003		
Clay	-0.404	0.822	-0.822	0.467	-0.553	-0.910	0.572	
	0.281	0.007	0.007	0.205	0.123	0.001	0.107	
Depth	0.640	-0.062	0.062	-0.672	0.322	0.451	-0.539	-0.287
	0.063	0.874	0.874	0.047	0.399	0.223	0.134	0.454

Cell Contents: Pearson correlation, P-Value

Table 4 Result of MDS (Minimum Data Set) Analysis Using Principal Component Analysis

Eigenvalue	5.1358	1.8711	1.2268	0.4349	0.2283	0.0831	0.0201	0.0000	0.0000
Proportion	0.571	0.208	0.136	0.048	0.025	0.009	0.002	0.000	0.000
Cumulative	0.571	0.779	0.915	0.963	0.989	0.998	1.000	1.000	1.000
Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
KI	0.303	0.411	-0.280	0.352	-0.435	0.437	-0.396	-0.000	0.000
BV	-0.341	0.428	-0.132	0.067	0.395	-0.041	-0.144	0.499	-0.501
TRP	0.341	-0.428	0.132	-0.067	-0.395	0.041	0.144	0.499	-0.501
C ogk	-0.177	-0.355	-0.673	-0.261	-0.144	-0.315	-0.448	0.000	0.000
Perme	0.333	0.122	-0.509	0.381	0.085	-0.386	0.560	0.000	-0.000
Sand	0.431	-0.061	0.007	-0.094	0.381	0.022	-0.216	-0.553	-0.551
Dust	-0.371	-0.095	0.268	0.587	-0.320	-0.398	-0.139	-0.280	-0.279
Clay	-0.392	0.176	-0.230	-0.327	-0.352	0.289	0.461	-0.343	-0.342
Depth	0.234	0.529	0.221	-0.441	-0.314	-0.561	-0.093	0.000	0.000

Table 5 Quality Index Value of Physical Aspects of Downstream Kuranji Watershed, Padang

1	Aie pacah 1	0.766	Good
2	Aie Pacah 2	0.608	Good
3	Gunung Sariek	0.843	Very Good
4	Kurao Pagang	0.741	Good
5	Gunung Pangilun	0.527	Fair
6	Ampang	0.663	Good
7	Korong Gadang	0.873	Very Good
8	Dadok Tgl. Hitam	0.424	Fair

4. CONCLUSION

Based on the research in downstream Kuranji watershed in Padang, it can be concluded:

1. The result of correlation analysis of soil physics showed that each soil physics characteristics has a strong correlation.
2. PCA analysis results show that the main factors in influencing soil quality in downstream Kuranji watershed are soil texture characteristics, bulk density, and soil depth.
3. Based on the soil physical characteristics calculation, the quality index on the downstream Kuranji watershed includes the criteria of moderate to excellent. Dadok

Tunggul Hitam area is a concern because it is somewhat more prone to flood.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] ChowVenTe, Maidment, Mays Larry W.,1988, Applied Hydrology, McGraw-Hill International Edition.

[2] Agriculture Dictionary. 1997. Published PT. Penebar Swadaya, Jakarta.

[3] Aprisal, Bujang Rusman and Darmawan. 2017. The optimization of land use in the Batang Masang watershed to reduce the rate of surface flow, erosion, and sediment. (Case studies, Batang Masang watershed in Agam district, West Sumatra). Procceding National Conference, University of Riau.

[4] Flood and Sediment Control of Kuranji river, Padang City, Public Works Departement. 2015 (in Indonesia: Upaya Pengendalian Banjir dan Sedimen Batang Kuranji di Kota Padang). http://pu.go.id/berita/10072/Upaya Pengendalian Banjir dan Sedimen Batang Kuranji di Kota Padang, accessed Januari 2, 2017.

[5] Guidelines for Soil Quality Assessment in Conservation Planning. 2001. Natural Resources Conservation Services. Soil Quality Institute USDA.

[6] Partoyo. 2005. Analysis of Soil Quality Index for Agriculture in Samas Beaches (in Indonesia: Analisis Indeks Kualitas Tanah Pertanian di Lahan Pasir Pantai Samas) Jogyakarta. Journal of Ilmu Pertanian Vol. 12 (2) : 140 – 151.

[7] Andrew SS, JP Mitchell, R Mancinelli, DL Karlen, TK Hartz, WR Howarth, GS Pettygrove, KM Scow, and DS Munk. 2002. On-farm Assessment of Soil Quality in California's Central Valley. Agron. J.94: 12-23.

[8] Arsyad, S. 2010. Soil and Water Conservation (in Indonesia: Konservasi Tanah dan Air) IPB Press. Dargama, Bogor.

[9] Supriyadi, Sumarno, Sri Hartati, Cristiningsih. Assessment the Sustainability of Watershed with Soil Quality Based on Soil Physical Properties of Various Type Agroforestry. Procceding of the National Seminar on Land of Suboptimal, Palembang 26-27 September 2014 ISBN : 979-587-529-9.

[10] Purkait, B. 2010. The Use of Grain Size Distribution Patterns to Elucidate Aeolian Processes on a Transverse Dune of Thar Desert, India. Earth Surface Processes Landforms. 35 : 525-530.

[11] Istijono.B. 2006. Watershed Conservation and Economic Analysis (in Indonesia: Konservasi Daerah Aliran Sungai dan Pendapatan Petani : Studi Tentang Integrasi Pengelolaan Daerah Aliran Sungai (Case study: Sumani River Basin, Solok District/Solok City, West Sumatera). Dissertation of PPs. Andalas University.

[12] Hardjowigeno. 2007. Soil Sciences (in Indonesia: Ilmu Tanah). PT. Mediyatama Sarana Perkasa. Jakarta.

[13] Seybold, C.A., Mausbach, M.J., Karlen, D.L., and Rogers, H.H. 1998. Quantification of Soil Quality. p. 387 – 404. In : R. Lal, J. M Kimble, R.F. Follett, and B.A. Stewart (eds.) Soil Processes and The Carbon Cycle. CRC Press, Boca Raton.