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EFFECTIVENESS OF SOIL CONSERVATION TO EROSION CONTROL ON SEVERAL LAND USE TYPES

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The erosion plot method for direct evaluation in agriculture became necessary to (1) quantify soil erosion on cocoa, areca and oil palm, (2) determine the most effective soil conservation, and (3) calculate nutrient content in sediment. The experiment was treated with three conservation practices and the conventional treatment as control in a completely randomised block design. The results showed for the areca land use, that soil conservation with ridges + maize produced the lowest erosion (1.68 t/ha). For cocoa land use, the ridges + groundnut treatment produced the lowest erosion (8.2 t/ha). For oil palm land use, the cover crop of *Mucuna bracteata* had lowest erosion yield (12.2 t/ha). Soil conservation techniques significantly affected the levels of organic C and available P under the cocoa land use, where ridges + maize have the lowest content of organic C and available P in soil sediment (1.03% and 0.69 ppm). Soil conservation at areca land use also has a significant effect on the levels of organic C and available N, but it did not affect significantly the levels of available P and exchangeable K sediments, where ridges + groundnut have lowest organic C and available N in sediment (1.4% and 0.18%). Furthermore, soil conservation on the land use of oil palm showed a significant effect on the levels of available P, but did not significantly affect the levels of organic C, available N and exchangeable K sediments. Soil conservation with cover crops *Mucuna bracteata* showed the lowest available P in sediments (0.86 ppm).

Key words: land use, nutrient, sediment, soil erosion, soil conservation

The loss of soil from land surfaces by erosion is widespread globally and adversely affects the productivity of all natural ecosystems and agricultural ecosystem (Pimentel 2006). Loss of soil through erosion also brings with it nutrients contained in the soil. Nutrients loss due to surface runoff and soil erosion carried away from agricultural land is the main cause of soil degradation of agriculture land (Bertol *et al*. 2003). Nitrogen, phosphorus, organic carbon, potassium, calcium, magnesium and sodium are the main nutrients carried by overland flow and soil erosion (Hidayat *et al*. 2012).

Krueng Sieumpo watershed is the sub-watershed of Krueng Peusangan Watershed in Aceh Province, Indonesia, which was categorised as a critical area under unappropriate land management. In needs rehabilitation (Fitri 2011). The farmers in this area still do not use their land in accordance with land capability and land suitability. No conservation techniques are implemented, the cropping patterns and farming practices are inappropriate (Satriawan *et*

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al. 2014). Oil palm (*Elaeis guineensis* Jacq.), areca (*Areca catechu* L.) and cocoa (*Theobrema cacao* L.) are major crops in Kreueng Sieumpo watershed, which spread more dominant on land with slopes between 9% – and 45%. The land area for oil palm plantations in Krueng Sieumpo watershed has increased rapidly, with 4,644 ha of cultivation under 5 years since 2008 (IICB 2013). But today, oil palm cultivation is limited to marginal areas such as hilly sloping lands where they comprise about 60% of the marginal land areas (Satriawan & Fuady 2012). Similarly to oil palm, Cocoa is one of the major export commodities in Indonesia.The area under cocoa plantation in Bireuen District in 2012 is 6,023 ha and it still continues to grow with an average productivity of 0.63 t/ha (IICB 2013). Areca is also the main crop of traditional plantation with 7,782 ha of cultivation area and the productivity of 1.5 t/ha of dry beans. As a result of land use patterns, the predicted rate of soil erosion on cultivated land reaches from 54.6 to 1,007.6 t/ha/year (Satriawan & Harahap 2013), is still higher than the tolerable erosion in this region ranging from 25.1 to 40 t/ha/year (Fitri 2010).

The aims of soil conservation for growing more production can be achieved by using land in accordance with its capabilities, to apply measures to restore the productivity of the soil where it has been damaged and to prevent further damage from taking place, and to combine sound methods of soil management with other methods and inputs of modern agriculture to obtain satisfactory production on sustainable basis (Hudson 1993).

Numerous studies have evaluated the environmental pollution by nutrients currently used in agriculture (Sharpley & Smith 1990; Pratap Narain *et al*. 1998; Thomas *et al*. 1999; Jae-Young Cho & Kwang-Wan Han 2002; Zuazo *et al*. 2011). The erosion plot method for direct evaluation in the field is the most effective to quantify water erosion (Sanchez *et al*. 2002). Therefore, it became necessary to quantify soil erosion more extensively, with the aim of providing a tool for planning soil conservation strategies for many land use types on watershed basis. The objectives of this study were to determine: (1) the rate of runoff and erosion on each types of land use, (2) nutrient contents in eroded soil, and (3) the most effective soil conservation.

MATERIAL AND METHODS

Study Area

The study experimental plot used to measure the overland flow, sediment and nutrient loss was located at Krueng Sieumpo watershed (5°4′37.65″

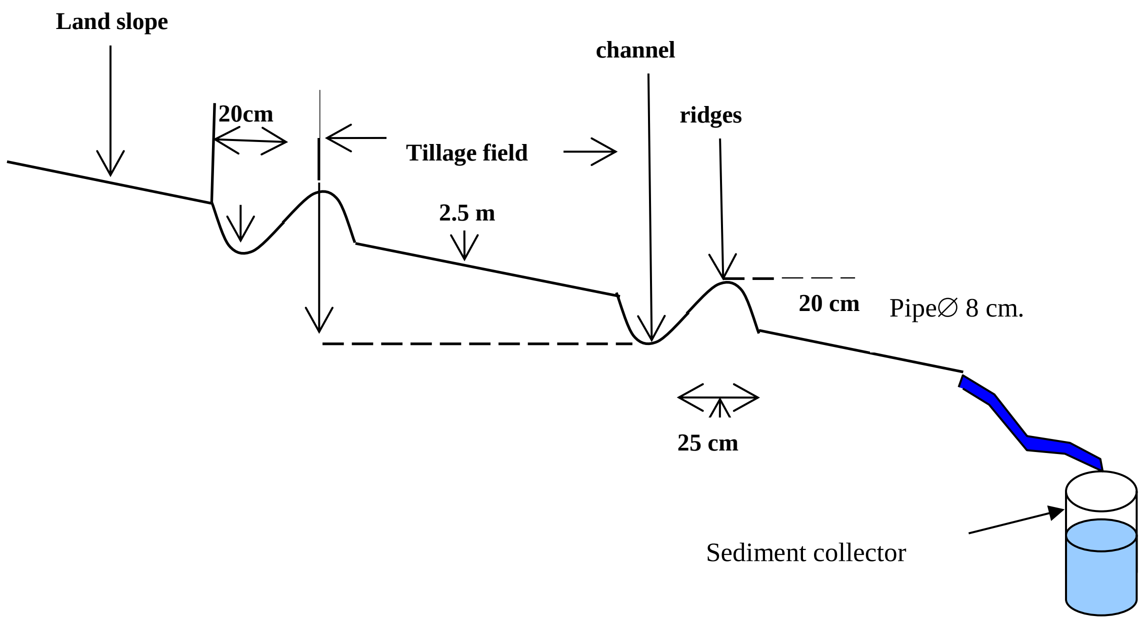

Figure 1. Sketch the ridges and sediment collector at the experimental plots


Figure 2. Plot of experiment on cocoa


Figure 3. Plot of experiment on areca


Figure 4. Plot of experiment on oil palm

N and 96°45′44.91″ E). Three crops were tested: areca, cocoa and oil palm a specific soil conservation techniques. The experiment lasted for one year (June 2013 – July 2014). The area was cultivated with 2 years old oil palm trees, 5 years old areca trees and 3 years old Cocoa. Average annual rainfall in this area was 1.818 mm, and the daily mean air temperature was 27.6°C. The soil of the experimental area is classified as Typic Paleudults (USDA Soil Taxonomy), which has sandy clay in the topsoil (0–15 cm depth).

Experimental Design

The field experiment layout has a completely randomised block design with three replicas. Four treatments were tested for each land use (three conservation practices and the conventional treatment as control). The conservation practices were not the same for each land use type. For areca trees it was: (1) control (no soil conservation); (2) ridges + green beans; (3) ridges + groundnut; (4) ridges + maize. For cocoa (1) control (no soil conservation); (2) ridges + green beans; (3) ridges + groundnut; (4) ridges + maize. For oil palm (1) control (no soil conservation); (2) green beans; (3) *Mucuna bracteata*; (4) sediment trap + maize.

The erosion plots were located on the hill slopes of 25% (15°) inclination, with an acreage of 20 m^2 (4 × 5 m) in cocoa and areca area (Figures 2 and 3), and 80 m^2 (4 × 20 m) in oil palm area (Figure 4). Each erosion plot consisted of a galvanised enclosure, drawer collector, sediment and runoff collector (Θ 0.6 m, 0.8 m high). The application rate of chemical fertiliser during the study was (150 kg N/ha, 100 kg P/ha, and 75 kg K/ha) for each treatment.

Ridges are constructed of two pieces with 20 cm high and 25 cm width (Figure 1). Measurement of runoff and erosion was conducted for each rainfall event during the period of the experiment. Erosion measurements involved the measurement of the runoff volume and the measurement of eroded soil. The weight of soil sediment was measured by filtering the water samples using filter paper. The soil left on the filter paper was dried in an oven at 60°C until the sediment weight became constant. The amount of sediment (E) is calculated using the following equation:

$$E = \frac{C_{ap}\, x V_{ap}\ x 10^{-3}}{A}$$

where:
E – is the eroded soil [t/ha],
C_{ap} – is the concentration of sediment load [kg/m^3],
V_{ap} – is the volume of runoff [m^3],

A – is the wide of area [ha],
10^{-3} – is unit conversion kg to ton.

Sediment analysis conducted to measure the content of organic C (C_{tot}) (Walkley-Blackmethod), total Nitrogen (N_{tot}) (Kjeldahl method), P_2O_5 available (Bray-1 method) and K_2O (extraction with 1N NH_4OAc pH 7.0). The yield of organic C, available N, available P and exchangeable K carried by runoff was calculated by the equation:

$$X = Y x E$$

where:
X – is the total nutrient loss (organic C, available N, available P and exchangeable K) [kg/ha],
Y – is the concentration of organic C [%], total nitrogen [%], available P [µg/g] and exchangeable K [cmol/kg] in sediment,
E – is the total of eroded soil [t/ha].

The amount of runoff and erosion and the data nutrient loss obtained from erosion sediment was subjected to ANOVA procedure, and means separation test was done by protected Least Significant Difference (*LSD*) test at 5% level of significance.

RESULTS AND DISCUSSION

Runoff and Soil Erosion

Soil conservation techniques tested on the three investigated land use types had small effect on the runoff, but they had significant effects soil erosion rate (Table 1).

Table 1 presents all runoff events monitored during the experiment. The runoff fluxes from tested treatments ranged from 210.18 to 243.22 m³/ha for cocoa land use, 207 to 243m³/ha for areca land use, 199.50 to 238.95 m³/ha for oil palm treatment. For cocoa land use, the soil conservation with ridges + groundnut consistently produced the lowest erosion as compared to three other methods (8.20 t/ha) and as compared to the control treatment, the erosion under ridges + groundnut decreased by 79.61%. Then, on the areca land use, the implementation of ridges maize treatment shows a high ability for controlling the erosion (4.64 t/ha), slightly better than ridges + green beans treatment, but it is much more effective than groundnut + ridges and control, decrease by 76.47%. While at oil palm land use, the *Mucuna bracteata* treatment was most effectively controlling the erosion (12.20 t/ha), followed by ridges + maize treatment (12.33 t/ha). Two other treatments (green beans and control) resulted in greater erosion. As compared to the control treatment, the erosion under *Mucuna bracteata* decreased by 34.61%.

The results showed that the intercropping combined with ridges is quite effective to reduce erosion and runoff at cocoa and areca land use. Ridges modified the soil surface to become more rugged and served as a water collector. Similarly, a denser plant cover and stratified canopy on intercropping systems reduced the rain erosivity through intercep-

T a b l e 1

Runoff and soil erosion on three types of land use

Land use							
Treatment	Cocoa		Areca		Treatments	Oil Palm	
	Runoff [m³/ha]	Erosion [t/ha]	Runoff [m³/ha]	Erosion [t/ha]		Runoff [m³/ha]	Erosion [t/ha]
Ridges + green beans	243.22	17.86[b]	243.00	6.99[b]	Green beans	200.18	18.66[b]
Ridges + maize	231.79	27.39[c]	224.00	4.64[a]	*Mucuna bracteata*	199.50	12.20[a]
Ridges + groundnut	210.18	8.20[a]	207.00	13.23[c]	Maize + sediment trap	221.11	12.33[a]
Control	227.52	40.22[d]	215.20	19.72[d]	Control	238.95	17.97[b]
$LSD_{0.05}$	–	2.75	–	1.43	$LSD_{0.05}$	–	1.85

In the same column, values with different indices are significantly different from one another at the *LSD* test at $P \leq 0.05$

tion, and increase of infiltration due to the diversity of plant root systems. Intercropping system also reduces the susceptibility for erosion through its extensive root system, which helps to hold soil in place. In contrary the runoff and erosion at control treatment were lower as compared to ridges + maize and ridges + green beans treatment. At the control treatment, runoff during rain has no barrier, so that the movement of runoff could transport soil particles. The results of this study are consistent with the study of Noeralam *et al*. (2003) who reported that the application of ridges with canal effectively reduced the overland flow/runoff by 50.8%. Similarly, Fuady and Satriawan (2011) report 63.5% reduction and erosion to 67.5% (both in the period of vegetative and generative). Moreover, the results indicated that the beneficial in controlling soil erosion, similar to other previous studies by Gomez *et al*. (2009) who reported using cover crop with barley, reduced the soil losses to 0.8 t/ha/year and the average annual runoff coefficient to 1.2%, that indicated the use of a cover crop can be a simple, feasible soil and water conservation practice.

In the application of soil conservation in oil palm land use, treatment of *Mucuna bracteata*, maize + sediment trap among oil palm trees shows significantly different erosion between control and green beans treatment. The use of cover crops such as *Mucuna bracteata* can reduce the rate of runoff and erosion through the increased volume of water infil-

T a b l e 2

Nutrient content of sediments as a result of the application of soil conservation techniques on Cocoa land use

Treatment	Parameter							
	Organic C		N_{tot}		P_{av}		K_{exc}	
	[%]	[kg/ha]	[%]	[kg/ha]	[µg/g]	[kg/ha]	[cmol/kg]	[kg/ha]
Ridges + ground nut	1.46^{b}	119.33^{a}	0.17^{a}	13.17^{a}	2.94^{b}	0.03^{a}	0.95	0.07^{a}
Ridges + maize	1.03^{a}	283.75^{a}	0.12^{a}	31.90^{b}	0.69^{a}	0.02^{a}	0.80	0.22^{b}
Ridges + green beans	2.11^{b}	376.87^{ab}	0.19^{a}	34.62^{b}	3.73^{c}	0.07^{ab}	0.83	0.15^{ab}
Control	1.76^{b}	710.49^{b}	0.16^{a}	64.30^{c}	2.28^{b}	0.15^{b}	0.92	0.37^{c}
$LSD_{0.05}$	0.72	241.00	0.09	16.65	0.68	0.08	–	0.13

In the same column, values with different indices are significantly different from one another at the *LSD* test at $P \leq 0.05$

T a b l e 3

Nutrient content of sediments as a result of the application of soil conservation techniques on areca land use

Treatment	Parameter							
	Organic C		N_{tot}		P_{av}		K_{exc}	
	[%]	[kg/ha]	[%]	[kg/ha]	[µg/g]	[kg/ha]	[cmol/kg]	[kg/ha]
Ridges + ground nut	1.40^{a}	185.98^{a}	0.18^{a}	23.87^{b}	2.35	0.031^{a}	0.84	0.112^{ab}
Ridges + maize	1.80^{a}	83.49^{a}	0.34^{b}	15.93^{a}	2.10	0.010^{a}	1.00	0.046^{a}
Ridges + green beans	1.83^{a}	127.32^{a}	0.23^{a}	15.67^{a}	3.68	0.026^{a}	0.91	0.063^{ab}
Control	3.86^{b}	757.73^{b}	0.41^{b}	80.65^{c}	1.24	0.025^{a}	0.95	0.188^{b}
$LSD_{0.05}$	0.78	121.00	0.10	6.71	–	0.03	–	0.06

In the same column, values with different indices are significantly different from one another at the *LSD* test at $P \leq 0.05$

tration, the improvement of soil physical properties and reduction of high rainfall impact. High rainfall cause intensive detachment of soil particles, so the soil becomes easily eroded, but alley cropping, fertilisation and mulching can reduce soil erosion to tolerable level (Noer 2011). Probable mechanisms for the greater sediment reduction in this study are linked with changes in flow dynamics through at least three processes. First, the vegetative barrier and ridges may intercept concentrated flow by decreasing velocity and dispersing runoff; second, increased ponding may promote deposition of sediment; third, the ponding may absorb runoff energy that would cause soil detachment and transport and thus reduce the erosion and transport capacity.

Nutrient Loss

Soil conservation also affects the nutrient loss together with the sediment. Tables 2, 3 and 4 show for each land use different effects of soil conservation on the levels of organic C, total N, available P and exchangeable K. Soil conservation techniques can reduce the erosion rates as well as the amount of organic C and nutrients carried by runoff.

Cocoa

Soil conservation techniques have significantly affected the levels of organic C and available P for the cocoa land use but the levels of total N and exchangeable K did not differ. Ridges + maize treatment showed lowest content of organic C and available P in soil sediment (1.03% and 0.69 μg/g) (Table 2). But in contrast to the total weight of nutrients [kg/ha], all parameters showed a difference to the control treatment.

The nutrient content in sediment is shows linear correlation with the amount of eroded soil. In this study the lowest erosion was recorded for ridges + groundnut treatment. These results indicate that the characteristics of the plant such as the type of plants, roots, and the period of growth has effect on erosion. Maize is most effective to prevent loss of nutrients through intensive nutrient absorption mechanism by roots, thus means selectivity of erosion by the maize is better than the other plants. In addition, ridges helps to inhibit surface flow and supports the deposition of particles carried by runoff.

Areca

Soil conservation on areca land use has also significant effect on the levels of organic C and N_{tot}, but it did not significantly affect the levels of available P and exchangeable K sediments. In fact, ridges + groundnut treatment containing of organic C and N_{tot} lowest in sediment (1.40% and 0.18%). Total nutrient losses along the sediments also show different results for particular treatments. Losses of organic C and N_{tot} were significantly higher for the control treatment than other treatments (Table 3).

Sediment in the treatment of groundnut + ridges has lowest nutrient levels except for P, while the highest levels were found for the control treatment and ridges + maize treatment. This result is in contrast with the experiment on land use of cocoa, where maize selectively prevents nutrient loss.

Table 4

Nutrient content of sediments as a result of the application of soil conservation techniques on Oil Palm land use

Treatment	Parameter							
	Organic C		N_{tot}		P_{av}		K_{exc}	
	[%]	[kg/ha]	[%]	[kg/ha]	[μg/g]	[kg/ha]	[cmol/kg]	[kg/ha]
Green beans	1.55	285.48^{a}	0.19	35.77^{a}	3.86^{b}	0.07^{b}	0.35	0.18^{b}
Mucuna bracteata	1.80	220.34^{a}	0.24	29.72^{a}	0.86^{a}	0.01^{a}	0.50	0.11^{a}
Maize + Sediment trap	1.14	138.89^{a}	0.19	22.77^{a}	1.28^{a}	0.02^{a}	0.38	0.12^{b}
Control	2.62	470.20^{a}	0.17	30.39^{a}	2.40^{a}	0.04^{ab}	0.34	0.16^{b}
$LSD_{0.05}$	–	341.00	–	–	1.81	0.029	–	0.04

In the same column, values with different indices are significantly different from one another at the *LSD* test at $P \leq 0.05$

The loss of soil nutrient from control treatment was caused by the soil aggregates easily broken down, and consequently the finer particles could be transported by runoff. This is the major factor in land degradation, reducing the productivity and soil nutrients, such as soil organic carbon (Fenton *et al*. 2005), phosphorus and nitrogen (Jokela & Casler 2011).

Oil Palm

Soil conservation on land use of oil palm also showing a significant effect on the levels of P available, but it did not significantly affect the levels of organic C, N_{tot} and exchangeable K sediments. Soil conservation with cover crops *Mucuna bracteata* contains P available lowest in sediments (0.86 µg/g) (Table 4).

In general, the yield of organic C and N_{tot} carried out by erosion is much greater than the amount of P and K. This suggests that the loss of organic matter due to erosion is a more serious problem because it accelerates land degradation and decline soil fertility. Amount of organic C and N_{tot} in sediment indicates the magnitude of the potential loss of nutrients by erosion. This is understandable because the properties of nitrogen are very susceptible to leaching, being more mobile than phosphate. Therefore, soil conservation which also serves to maintain soil organic matter content is a must, so that the level of organic matter in the soil is one indicator of the sustainability of land resources (Wolf & Snyder 2003).

CONCLUSIONS

Results from this study show that ridges + ground nut most effectively reduces erosion on the land use of cocoa, ridges + maize effectively reduce erosion on the areca land use, and *Mucuna bracteata* is more effective in the oil palm land use. Ridges + maize effectively reduce the nutrient loss (organic-C, N_{tot}, av-P and exc-K) on the land use of cocoa, ridges+ground nut also effectively reduce the nutrient loss (organic-C, N_{tot}, av-P and exc-K) on areca land use, and *Mucuna bracteata* effectively to decrease the loss of av-P in the oil palm land use. The plant and ridges, in combination can improve the conservation effectiveness of soil conservation approach, and they may be a practical and economical alternative to technical conservation structures (such as terraces).

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REFERENCES

BERTOL, I.B. – MELLO, E.L. – GUADAGNIN, J.C. – ZAPAROLLI, A.L.V. – CARRAFA, M.R. 2003.Nutrient losses by water erosion.In *Scientia Agricola*, vol. *60*, p. 581–586.

INDONESIA INVESTMENT COORDINATING BOARD. 2013. Komoditas Unggulan Daerah. Retrieved December 15 from PubMed database on the world wide web: http://regionalinvestment.bkpm.go.id/newsipid/id/commodityarea.php?ia=11&ic=2580

FENTON, T.E. – KAZEMI, M. – LAUTERBACH-BARRETT, M.A. 2005. Erosional impact on organic matter content and productivity of selected Iowa soils. In *Soil and Tillage Research*, vol. *81*, pp. 163–171.

FITRI, R. 2010. Planning of farming system based on Areca catechu L for sustainable agricultural development in South Peusangan District of Aceh Province. In *Proceedings of the National Seminar and Annual Meeting of the Dean of Agricultural Sciences BKS – PTN West Regional 2010*. Faculty of Agriculture, University of Bengkulu. ISBN 979-602-96609-8-2. p 548.

FUADY, Z. – SATRIAWAN, H. 2011. Application of the mound to against the surface flow rate and erosion. In *Proceedings of the National Seminar in Precision Farming*. Post Graduate Forum, North Sumatera Utara University, Medan. Indonesia. ISBN 979-458-591-2. pp 489–495.

GOMEZ, J.A. – SOBRINO, T.A. – GIRALDEZ, J.V. – FERERES, E. 2009. Soil management effects on runoff, erosion and soil properties in a olive grove of Southern Spain. In *Soil & Tillage Research*, vol. *102*, no. 1, pp. 5–13.

HIDAYAT, Y.– MURTILAKSONO, K. – SINUKABAN, N. 2012.Characterization of surface runoff, soil erosion and nutrient loss on forest-agriculture landscape. In *Journal of Tropical Soils,* vol.*17,* no. 3, pp. 259–266.DOI: 10.5400/jts.2012.17.3.259.

HUDSON, N.W. 1993. *Field measurement of soil erosion and runoff.* FAO soil bulletin 68. Food and Agricultural Organization of the United Nation, Rome. pp. 139.

JAE-YOUNG CHO – KWANG-WAN HAN, 2002.Nutrient losses from a paddy field plot in Central Corea. In *Water, Air, and Soil Pollution,* vol.*134*, pp. 215–228.

JOKELA, W. – CASLER, M.D. 2011. Transport of phosphorus and nitrogen in surface runoff in a corn silage system: Paired watershed methodology and calibration period results. In *Canadian Journal of Soil Science*, vol. *91*, pp. 479–491. DOI:10.4141/CJSS09095.

NOER, H. 2011. Optimizing utilization of water resources through improved planting pattern and repair cultivation techniques in farming systems. In *Indonesian Journal of Agricultural Economics*,vol. *2*, no. 2, p.169–182.

NOERALAM, A.S. – ARSYAD, S.– ISWANDI, A. 2003. Control Techniques of Surface Flow on sloping dry land farming. In *Jurnal Tanah dan Lingkungan*, vol. *5*, no. 1, pp. 13–16.

PIMENTEL, D. 2006. Soil erosion: A food and environmental threat. In *Environment, Development and Sustainability,* vol. *8,* pp. 119–137. DOI 10.1007/s10668-1262-8.

PRATAP NARAIN – SINGH, R.K. – SINDHWAL, N.S. – JOSHIE, P. 1998. Agroforestry for soil and water conservation in the western Himalayan Valley region of India. In *Agroforesty System,* vol. *39*, pp. 175–189.

SANCHEZ, M.M. – SORIANO, M. – DELGADO, G. – DELGADO, R. 2002. Soil quality in mediterranian mountain environments: Effects of land use change. In *Soil Science Society of American Journal,* vol. *66*, pp. 948–958.

SATRIAWAN, H. – FUADY, Z. 2012. Referral Land Use For Agricultural Development in Peusangan Selatan Sub-district. In *Proceedings of the National Seminar and Annual Meeting of the Dean of Agricultural Sciences BKS – PTN West Regional 2012*. Faculty of Agriculture University of Sumatera Utara. ISBN 979-458-597-1. pp 497.

SATRIAWAN, H. – E.M. HARAHAP. 2013. Study of soil erosion in KruengSieumpo Watershed Aceh. In *Proceedings of the National Seminar on Community-Based Watershed Managemen*t Towards Sustainable Aceh Forest, Banda Aceh. ISBN 978-979-8278-89-1. p. 171–180

SATRIAWAN, H. – HARAHAP, E.M. – RAHMAWATY, – KARIM, A. 2014.Land capability evaluation for agriculture in Krueng Sieumpo watershed, Aceh. In *Academic Research International*, vol. *5*, no. 3, pp. 55–63.

SHARPLEY, A.N. – SMITH, J. 1990.Soil erosion on agricultural land. In BOARDMAN, I.D. –FOSTER, L. –DEARING, J.A. (Eds.) *Phosphorus Transport in Agricultural Runoff : The Role of Soil Erosion*. John Wiley & Sons, pp. 351–366.

THOMAS, A.D. –WALSH, R.P.D. –SHAKESBY, R.A. 1999. Nutrient losses in eroded sediment after fire in eucalyptus and pine forests in the wet Mediterranean environment of northern Portugal. In *Catena,* vol. *36*, pp. 283–302.

WOLF, B. –SNYDER, G.H. *Sustainable Soils. The Place of Organic Matter in Sustainability Soils and Their Productivity.* New York : Food Product Press. 2003. pp. 352.

ZUAZO, D.V.H. – MARTÍNEZ, A.R. – RUIZ, J.A. 2004. Nutrient losses by runoff and sediment from thetaluses of orchard terraces. In *Water, Air, and Soil Pollution*, vol. *153*, no. 1–4, pp. 355–373. DOI:10.1023/B:WATE.0000019956.17314.88.

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