Science Nature 2(1), pp.071-085 (2019)

e-ISSN: 2654-6264

DOI: <https://doi.org/10.30598/SNVol2Iss1pp071-085year2019>

**DEVELOPMENT OF A LAND DEGRADATION ASSESSMENT
MODEL BASED ON FIELD INDICATORS ASSESSMENT AND
PREDICTION METHODS IN WAI SARI, SUB-WATERSHED
KAIRATU DISTRICT, WESTERN SERAM REGENCY, MALUKU
PROVINCE, INDONESIA**

Silwanus M. Talakua^{1,*}, Rafael M. Osok¹

¹*Department of Soil Science, Faculty of Agriculture, Pattimura University
Jl. Ir. Martinus Putuhena, Kampus Poka, Ambon, Indonesia 97233*

Received : November 30, 2018

Revised : March 10, 2019

Published : March 11, 2019

Copyright @ All rights are reserved by S.M. Talakua and R.M. Osok

Corresponding author: *Email: silwanustalakua@yahoo.com

Abstract

The study was conducted in Wai Sari sub-watershed, Western Seram Regency Maluku to develop an accurate land degradation assessment model for tropical small islands. The Stocking's field land degradation measurement and **RUSLE** methods were applied to estimate soil loss by erosion and the results of both methods were statistically tested in order to obtain a correction factor. Field indicators and prediction data were measured on 95 slope units derived from the topographic map. The rates of soil loss were calculated according to both methods, and the results were used to classify the degree of land degradation. The results show that the degree of land degradation based on the field assessment ranges from none-slight (4.04 - 17.565 t/ha/yr) to very high (235.44 - 404.00 t/ha/yr), while the **RUSLE** method ranges from none-slight (0.04-4.59 t/ha/yr) to very high 203.90 - 518.13 t/ha/yr. However, the **RUSLE** method shows much higher in average soil loss (133.4 t/ha/yr) than the field assessment (33.9 t/ha/yr). The best regression equation of $\log D/RP = -0.594 + 1.0 \log K + 1.0 \log LS + 1.0 \log C$ or $D = 0.2547 \times R \times K \times L \times S \times C \times P$ was found to be a more suitable land degradation assessment model for a small-scale catchment area in the tropical small islands.

Keywords: Wai Sari sub watershed, land degradation, field assessment model, **RUSLE**

ARTICLES

I. Introduction

Land degradation in developing countries [1-50] has become a major concern since it has been related to environmental problems [6], food security and the productivity of agricultural land [23], and poverty [4]. According to [47], land degradation encompasses not

only soil degradation, but also vegetation degradation, forest, cropland, water resources, and biodiversity degradation of a nation. Therefore [21] stressed that the impact of land degradation is a drain on economic growth in rural areas and has an affect on national economic growth pattern.

Land degradation is a very complex phenomena as it involves a set of bio-physical and socio-economic processes and some of them occur at different spatial,

temporal, economic and cultural scales [23, 46]. Land degradation reduces the capacity of land to provide ecosystem goods and services over a period of time [25], [47], and the potential of land to support agricultural systems and their value as economic resources [37]. According to [48], the impacts of land degradation in lowering the productivity of agricultural land can be temporary or permanent. The complexity of land degradation means its definition differs from area to area, depending on the subject to be emphasized [6].

In Indonesia, soil erosion has been considered as one of the major and most widespread forms of land degradation, as a result of land use changes and human activities [36, 47]. Recent report of Ref. [47] stated that degraded land in Indonesia is 24.3 million ha in 2013, and it is caused mainly by erosion due to inappropriate land uses, and no soil and water conservation practices are applied in such areas. The extend of land degradation in Maluku is related to the deforestation activities in the past, land conversion from natural forest to agricultural and plantation areas, and the rapid expansion of agriculture and settlement area in the hilly areas in particularly in Ambon island. Study in Ref. [22] showed that soil erosion is the major factor in determining the capability of land to support agriculture development in Wai Batu Merah watershed of Ambon Island, and the environmental quality of this watershed has declined as indicated by erosion, flooding and sedimentation during the rainy season, and water deficiency during the dry season.

Many different methodologies have been used to study soil erosion and land degradation such as field measurements, mathematical models, remote sensing, environmental indicators, including the use of simple models based on indicators that synthesize complex processes. The empirical soil erosion models, such as **Universal Soil Loss Equation (USLE)** [50] and the **Revised-USLE (RUSLE)** [28] have been worldwide applied to assess soil loss by water [24, 26, 30]. In Indonesia, both models have been used to predict soil

loss from medium to large watersheds [20, 27, 29, 31-32, 39].

A number of studies have been conducted in Ambon and Seram islands using **USLE** model to estimate erosion rates from small watersheds [14, 17, 42-44], and it is very likely that the predicted soil loss from the study areas tend to be much higher than other studies in Indonesia and other regions. The study found that the high rate of soil loss is largely due to high rainfall erosivity index (R-value in **USLE**) or indicates the impact of high rainfall in the study areas. This happens, because the climate condition in the study areas is considerably different to the place where the model was originally developed.

The assessment of land degradation based on the measurement of the actual indicators in the field both qualitatively and quantitatively was discussed by Stocking [37]. Stocking introduced field indicators as pedestals, rills, gully, plant/tree root exposure, armour layers, exposure of below ground portions of fence posts and other structures, the rock exposure, tree mound, and sediment in tunnel or drains.

This study combines the Stocking's land degradation field indicators assessment and **RUSLE** method to develop a more accurate model based on the extent and amount of land degradation field indicators in a small watershed of Maluku Province. The local land conditions which are considered as the cause of land degradation including climate, soil, topography, vegetation and land use and humans influence are studied in detail. So, the results of this study will support efforts in protecting land degradation of the watershed, especially by local governments.

Wai Sari Sub watershed is part of Wai Riuapa river basin located in Kairatu Sub District, Western Seram Regency, Maluku Province in Indonesia. Wai Sari sub watershed is a source of water supply to local communities as well as irrigation water to paddy fields. Wai Sari also provides natural resource in particularly agriculture, plantations and forestry products to support

daily needs of local communities. However, some of human activities especially in the exploitation of forest resources have become the causal agents of land degradation in this watershed, as indicated by soil erosion and sedimentation during the rainy season.

II. EXPERIMENTAL METHOD

2.1. Place And Time of Places Research

The research was conducted in Wai Sari Sub watershed, Wai Riuapa river basin in Kairatu District of West Seram Regency, Maluku Province, Indonesia.

2.2. Materials and Tools

Materials and tools used in this study included a slope unit map (as the field map at scale of 1: 10,000), land degradation indicators sheet, compass, altimeter, clinometer, global position system (GPS), auger, munsell soil colour chart, roller meter, measuring stick, hoes, shovels, field knives, aquades, H_2O_2 , HCl, sample rings, plastic soil samples, calculators, and digital camera. Microsoft Office 2007, Minitab16, SPSS17, and ArcGIS10.1 were used to data processing and report writing.

2.3. Research Methods

The method used in this study was survey, and the field observation was conducted on 95 slope units showing slope steepness and flow directions derived from a topographic map. The measurement of land degradation indicators in the field was carried out on all slope units according to the field measurement method [37]. The indicators were pedestals, rills, gully, plant/tree root exposure, armour layers, exposure of below ground portions of fence posts and other structures, the rock exposure, tree mound, build up against barriers, and sediment in drains. Each indicator was identified and measured. At the same time, the soil loss prediction factors of the **RUSLE** [28] included rainfall erosivity (R), soil erodibility (K), topography (slope length and steepness) (LS), actual vegetation (C) and soil

conservation practices (P) were also measured on each slope unit.

Data processing consisted of three stages. Firstly, the calculation of soil loss (t/ha/yr) using both methods, Stocking's field measurement [37], and **RUSLE** methods which is $A = R \times K \times LS \times C \times P$ [28]. The level of land degradation was determined using the criteria of FAO in Ref. [19] ie none-slight = 0-20 t/ha/yr; moderate = 20-50 t/ha/yr; high = 50-200 t/ha/yr; very high = >200 t/ha/yr. Secondly, the results of both methods were statistically tested by using the Pre-Analysis Test included Linearity Test and Independence Test. The results was used to indicate the nonlinearity and independence between land degradation data of the field measurement and prediction. The results of the linearity model test were indicated by the value of "Deviation from Linearity ≤ 0.05 , which means that the nonlinear is significant at the 5%. The results of the independence model test were indicated by the Durbin-Watson statistical value in the model (range 1.5 – 2.5), which means that the residual is uncorrelated or the assumption of independence is satisfied at the 5% significance level. Thirdly, to apply T-different test (Paired T-test) [12] on the results of land degradation field measurements and prediction as is indicated by the P-value ≤ 0.05 . At the significance level of 5%, if the data is completely different and can be continued with the development of a more accurate model. The test of the developed-model of land degradation was carried out by linear and non-linear multiple regression-correlation analysis [5, 19], with the basic model is $Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \epsilon_i$, where Y_i = the rate of soil loss according to the field assessment method [37]; β_0 =intercept coefficient; X_{1i} - X_{5i} = land degradation factors of **RUSLE** prediction method [28] namely rainfall erosivity, soil erodibility, topography (slope length and steepness) vegetation and conservation measures; β_1 - β_5 = regression coefficient for X_1 - X_5 factors; ϵ_i = error. All data were analyzed using the MS Exel 2007, SPSS17 and Minitab16 programs.

III. RESULTS AND DISCUSSION

3.1. Land Degradation by Field Assessment

Method [37]

The result of the study as presented in **Fig. 1** and **Fig. 2** shows that the actual field phenomenas or land degradation field indicators in the Wai Sari Sub-watershed are pedestals, plant/tree root exposure to identify sheet erosion, rill indicator as rill erosion, gully indicator as gully erosion. According to the calculation of soil loss rates, the level of land degradation can be classified as follows: none to slight degradation level (soil loss 4.04 - 17.56 t/ha/yr) covers the area of 220.75 ha or 66.24%, with field indicators are pedestal (average height = 2.00 cm); trees/plant root exposure (1.91cm); rills (average depth 2.70cm), and soil bulk density (average 1.12 g/cm³). The occurrence of pedestal, roots exposed and rill indicators is predicted longer than 24.7 years with the average soil loss is 0.76 mm/yr (lower than other levels of land degradation)

The moderate degradation level (20.06 - 43.76 t/ha/yr) covers the area of 57.57 ha or 17.29%, with field indicators are pedestal (average height = 2.04 cm), trees/plant root exposure (2.62 cm), rill (average depth = 9.05 cm), and soil bulk density (average 1.08 g/cm³). The formation of pedestal, plant roots exposure and rill indicators is predicted about 16.9 years with the average of soil loss of 2.60 mm/yr (higher than the slight degradation level, but lower than high and very high land degradation levels).

The high degradation level (51.91- 194.21 t/ha/yr) covers the area of 50.14 ha or 15.04%, with field indicators are pedestal (average height=1.92cm), trees/plant root exposure (2.16 cm), rills (average depth=18.14cm), gully (average depth=62.09cm), and soil bulk density (average 1.10 g/cm³). The pedestal, plant roots exposure, rills and gully have been formed within 9.1 years, resulting in an average degradation due to soil loss of 9.01 mm/yr (higher than slight and moderate degradation levels).

The level of very high degradation (235.44- 404.00 t/ha/yr) covers the area of 4.76 ha or 1.43% of the total study area. The field indicators are pedestal (average height 1.95cm), trees/plantexposed root (1.05 cm), and soil bulk density (average 1.10 g/cm³). The occurrence of pedestal and trees/plant root exposure is predicted less than 0.75 yr with the average of soil loss is 29.20 mm/yr (higher than other land degradation levels in the study area).

Figure 1. The level of land degradation based on Field Indicators Assessment [37] in Wai Sari Sub Watershed.

Figure 2. Map of land degradation level based on Field Indicators Assessment [37] in Wai Sari Sub Watershed.

The study found that at the slightly degradation level, vegetation conditions are generally still in good

condition, especially the density of higher and lower vegetation, and the vegetation stratification is relatively well-formed. In this condition, vegetation canopy protects soil surface from the direct impact of rainfall, and reduces the destructive energy of droplets on the ground surface by intercepting the falling rainfall. Vegetation also minimizes the rate and volume of surface flow by holding some of the water for its own use, creating surface roughness and increasing infiltration, and prevents the formation of crust on the surface [8]. The effect of vegetation canopy and ground covers in reducing soil erosion varies with upper cover (aerial cover) and ground cover (contact cover) [9, 43], and structure of vegetation stratification [3]. However, in many areas, the type of land uses presents the effects of plants, vegetation and soil cover on soil loss within a catchment [45]. In addition, the existence of biomass of living plants and litter plays a role in reducing erosion by capturing the energy of raindrops, ground cover can also reduce the rate of water, and the volume of surface runoff and soil loss, while plant roots will physically stabilize the soil and increase resistance to erosion.

In contrast, at the high to very high degradation levels, the condition of vegetation shows loss of native vegetation, and change in both the density (the upper and lower vegetation) and stratification of vegetation due to various human activities such as deforestation, land-use conversion from forest to agriculture, plantations and settlement. Under a such condition, the high erosivity energy of rainfall cannot be properly intercepted by vegetation canopy, so the soil surface is opened to direct impact of raindrops. The field indicators found at this degradation level are pedestal, plant/root exposure, rill and gully with higher depth and their formation are relatively recent compared to other levels of degradation.

Although degradation processes may occur without human interference [37], however, according to [18] the land degradation is commonly accelerated by human intervention in the environment. Similarly, as reported by [16] that soil erosion is a function of land use, and loss of

vegetation cover will increase erosion from none to moderate erosion. According to [45] the conversion of forest into agricultural land will increase erosion by changing in vegetation cover and land processing, while on the agricultural lands, the increasing of soil erosion is due to the repeated of soil treatment and removal of vegetation cover on soil surface. Therefore, change in land use from natural forest to perennial crops/plantations, annual crops and bare soil will increase land degradation from slight to high levels [37]. Moreover, according to [41] deforestation is the cause for the increase in surface flow and erosion rates in a watershed. According to Hopley (1999) quoted by Ref. [13] that loss of vegetation due to deforestation, agricultural practices, land preparation for settlements, burning of forests and grasslands is considered to be a causal agent of erosion in Balikpapan East Kalimantan.

Loss of forest trees and the increasing of shrubs and *imperata cylindrica* areas will increase the rates of surface flow and soil erosion. According to Ref. [11] loss of vegetation and humus on the plantation areas has created serious erosion problems. The results of study in Lampung Province in Ref. [35] concluded that changes in land use from forests to annual crops led to increased erosion. Intensive infrastructure development such as settlements is considered to be one of the human activities that cause land degradation [34]. Loss of ground cover will also accelerate the formation of sheet erosion, rill and gully erosion (Field, 1997) quoted by Ref. [34].

3.2. Results of Prediction of Land Degradation by the RUSLE Method [28]

The levels and amount of land degradation based on the RUSLE soil loss predicted method [28] as shown in Fig. 3 are none to slight degradation, soil loss is 0.04-4.59 t/ha/yr covering the area of 143.5 ha or 43.05%. This degradation level is generally found on slopes with low LS-factor values (flat to almost flat slope steepness, 0-6%) and on land uses with high C-factor values such as cultivated field, mixed garden, settlements and *imperata*

cylindrica areas. This degradation level also occurs on slopes with high LS-factor values (slope steepness 20-70%) and on secondary forest with very low C-factor values.

At the moderate degradation level, soil loss is 41.60-48.33 t/ha/yr covering the area of 9.33 ha or 2.99%. This degradation level occurs in soils with slightly high K-factor values (Dystrudepts) and slopes with medium LS-factor values (gently to moderately slope steepness, 8-16%) and shrub and mixed garden land uses.

At the high degradation level, soil loss is 60.80-192.80 t/ha/yr covering the area of 0.04 ha or 0.003%, which generally occurs on slopes with high LS-factor values (moderately to very steep slope steepness, 15-85%) and low K-factor values. The land uses are shrub, cultivated field, mixed garden, clove and coconut gardens.

At the very high degradation level, soil loss is 203.90-518.13 t/ha/yr covering the area of 93.67 ha or 28.12% of the total study area. This degradation level, occurs in soil with slightly high K-factor values (Dystrudepts) and high LS-factor values (moderately steep - very steep, 30-85%). The land uses are shrub, cultivated field, mixed garden, clove and coconut gardens, and *imperata cylindrica* areas.

Figure 3. Level and extent of land degradation based on Predicted Method (RUSLE) [28] in Wai Sari Sub Watershed.

The study shows that at the slight degradation level, although the slope condition is steep to very steep, the vegetation cover of secondary forest is sufficient enough

to reduce the impacts of slope steepness by protecting soil surface from raindrops and runoff.

According to [28], soil loss per unit area generally increases along with the increasing of slope length and steepness. In the other words, soil loss can be decreased by reducing slope length and steepness. Soils with flat or almost flat slopes are usually stable and have very low soil loss. However, the rate of soil loss will be rapidly increasing once the slope steepness increases to 2% or 5%, as stated by [1] that on a slope of 10%, erosion will increase to eight times higher, and soil erosion will continue to increase on steeper slopes. The study in Lampung by [35] indicated that land cover especially with dense canopy such as natural forest has lower soil loss compared to the plantation. Similar study in Thailand, as reported by [49] that land degradation due to erosion on forest is lower than field cultivation.

The high to very high degradation levels occurred in the study area show that slope, soil properties, land uses are considered to be the major factors influencing soil erosion at this levels. The condition of slope and soil erodibility factors in the study area indicate high susceptibility of soil to erosion, transportability of sediment and the amount and rate of flow on the surface as slope steepness is dominated by steep to very steep slopes, and soil is dominated by medium to slightly high erodibility factors. According to [28], soil loss per unit area generally increases with the increasing of slope length and steepness, and the high value of soil erodibility factor increase the erosion rate of the study area. The impacts of land uses on erosion is also significant at this levels due to low vegetative covers (both vegetation canopy and ground covers), so the vegetative covers are not sufficient enough to protect soil surface from detachment and sediment transport by surface flow. Hopley in 1999 quoted by Ref. [13] stated that loss of vegetation caused by deforestation, agricultural practices, land preparation for settlements, burning of forests and grasslands is considered as a major factor determining the erosion problems in Balikpapan East Kalimantan.

Brandt in 1988 cited by Ref. [11] stated that the ability of ground cover to protect soil surface from raindrops to erode is greater than higher trees, because the raindrops are collected before dripping from the leaves and hit the ground surface with greater power.

3.3. Development of Land Degradation Assessment Model

The results of Linearity Pre-analysis Test show no linear relationship between the level of land degradation assessment based on field indicators and **RUSLE** prediction method at the 95% confidence level as indicated by Sig. of Deviation from Linearity = 0.000 * (<0.05). However, they are independent to each other at a 95% confidence level according to the Independence Pre-analysis Test and is indicated by the Durbin-Watson statistical value of 1,718 (range 1.5 - 2, 5). While the results of Independent Samples T-test analysis show that there is no different in land degradation levels resulting from the field indicators assessment and the **RUSLE** methods at the 95% confidence level, as indicated by a Sig.2-tailed value of 0.000 * (<0.05).

This study also shows that the average annual soil loss predicted by **RUSLE** method is higher (133.4 t/ha/yr) than field indicators measurement (33.9 t/ha/yr) as depicted in **Fig. 4 to Fig. 11**. This implies that the rate of predicted soil loss tends to be over estimated for Wai Sari sub watershed and in consequently it provides a higher land degradation levels compared with the actual field measurement in the study area. Therefore, the field indicators measurement is considered to be a more acceptable method in assessing land degradation levels based on soil loss in a small watershed in the tropic, as they represent the actual erosion phenomena in the field.

Figure 4. Root exposure in cultivated field. Land degradation by field indicators assessment = 23.60 t/ha/yr. Land degradation based on predicted soil loss (**RUSLE**) = 344.43 t/ha/yr (*over estimated*)

Figure 5. Pedestal in cultivated field. Land degradation by field indicators assessment = 33.67 t/ha/yr. Land degradation based on the predicted soil loss (**RUSLE**) = 248.53 t/ha/yr (*over estimated*)

Figure 6. Pedestal in coconut garden. Land degradation by field indicators assessment = 7.87 t/ha/yr. Land degradation based on the predicted soil loss (**RUSLE**) = 190.80 t/ha/yr (*over estimated*)

Figure 7. Root exposure in coconut garden. Land degradation by field indicators assessment = 7.21 t/ha/yr. Land degradation based on the predicted soil loss (**RUSLE**) = 190.80 t/ha/yr (*over estimated*)

Figure 8. Root exposure in mixed garden. Land degradation by field indicators assessment = 9.25 ton/ha/thn. Land degradation based on the predicted soil loss (**RUSLE**) = 85.59 t/ha/yr (*over estimated*)

Figure 9. Rill in mixed garden. Land degradation by field indicators assessment = 47.20 t/ha/yr. Land degradation based on the predicted soil loss (**RUSLE**) = 85.59 t/ha/yr (*over estimated*)

The development of land degradation assessment model based on the results of field measurements shows the best regression equation as follow:

$\log D / RP = -0.594 + 1.0 \log K + 1.0 \log LS + 1.0 \log C$, or $D = 0.2547 \times R \times K \times LS \times C \times P$, with a P value of 0.000 * (<0.05) at 95% confidence level, and D is the amount of land degradation in a slope unit (t/ha/yr), R is the rainfall erosivity (ton.m/ha/cm-rain), 0,2547 is the correction factor to **RUSLE** model, K is the soil erodibility value of a slope unit, LS is the index of topographic factors (slope length and steepness values), C is the value of plant or vegetation index factors, P is the value of soil conservation index factors. By integrating the 0,2547-correcting factor into the **RUSLE**, the predicted soil loss in the study area can be reduced to almost 26% compared to the original model (**RUSLE**).

According to Ref. [37], the application of a model from one place to very different conditions of soil, climate, slope and land use may lead to greater uncertainties associated with estimates of average annual soil loss. Therefore, it is important to obtain suitable local data that can suit for the study area particularly climate, soil type, topography, and land uses, and output of the model should be validated using measured field data. Further, Ref. [37] stated that erosion factors of the original empirical equation are rated on a numeric scale and the combined effects of multiple factors of rainfall, slope, soil type, land uses and vegetation cover

determines the average of annual soil loss. So, the equation does not express an actual measurement of the land degradation in the field, but provides the potential land degradation based on the predicted annual soil loss in a study area. The study in Ref. [10, 15, 40] showed that the assessment of land degradation due to erosion can be measured by using field indicators proposed by Ref. [37]. While according to Ref. [7], the accuracy of actual land degradation indicators at the farmer's land level is required in development and improvement methods for soil and water conservation planning at the catchment scale in the highlands of East Africa. In addition, the field assessment techniques have considerably advantages compared to standard experimental approaches in measuring soil loss and soil quality changes, because, their results express the actual processes and evidences that occur in the field, but can not be created in the laboratory. The field assessment techniques also allow the involvement of farmers and local communities, so they can improve their perspective and accept the technology [38].

This study has developed a land degradation assessment model based on the actual field data measurement, and the model is suitable for small watersheds in small islands of Maluku Province.

4.1. Conclusions

1. The level of land degradation based on field assessment methods [37] are none-slight degradation (4.04 - 17.565 t/ha/yr) covering 220.75 ha or 66.24%, moderate degradation (20.06 - 43.76 t/ha/yr) covering 57.57 ha or 17.29%, high degradation (51.91 - 194.21 t/ha/yr) of 50.14 ha or 15.04 % and degradation is very high 235.44 - 404.00 t/ha/yr covering an area of 4.76 ha or 1.43% of the total study area. The field indicators of land degradation found in the Wae Sari Sub-watershed are pedestal and trees/plant roots exposure to identify sheet erosion, and rill (indicators of rill erosion) and gully (indicator of gully erosion).

2. The results of land degradation level based on the **RUSLE** soil loss predicted method [20] are none-slight of land degradation of 0.04-4.59 t/ha/yr with an area of 143.5 ha or 43.05%, moderate level 41.60-48.33 t/ha/yr, with an area of 9.33 ha or 2.99%, high level of 60.80-192.80 t/ha/yr covering an area of 0.04 ha or 0.003%, and very high level between 203.90-518.13 t/ha/yr covering an area of 93.67 ha or 28.12% of the total study.
3. The development of land degradation assessment model based on the field assessment provides the best regression equation as: $\log D / RP = -0.594 + 1.0 \log K + 1.0 \log LS + 1.0 \log C$ or $D = 0.2547 \times R_x \times K_x \times L_{S_x} \times C_{xP}$. This model can reduce the rate of soil loss by erosion till almost 26% compared to the original model (**RUSLE**), and therefore, it has been considered as the suitable model for assessing land degradation of small catchment areas in small islands of Maluku.

4.2. Suggestion

The present model, $D = 0.2547 \times R_x \times K_x \times L_{S_x} \times C_{xP}$ is still needed to be tested at other small watersheds in Maluku, so the accuracy of the model can be improved and it will be more adaptable to Maluku condition.

Acknowledgement

1. We are grateful to thank the Ministry of Research, Technology and Higher Education of Republic of Indonesia in providing the research fund.
2. We would like to thank Prof. Michael A. Stocking, MPhil., PhD at the University of East Anglia, Norwich, UK who provided the form of land degradation methods based on field indicators assessment.
3. We also thank Luohui Liang, Managing Coordinator for People, Land Management and Environmental Change (**UNU/PLEC**) in Tokyo-Japan, who sent the book of Land degradation-guidelines for field assessment.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

- [1] Anthony F.J. 2001. Soil Erosion and Conservation. Seafriends Marine Conservation and Education Centre. 7 Goat Island Rd. Leigh R.D.5. New Zealand. ISSN 1177-4983 <<http://www.seafriends.org.nz/enviro/soil/erosion.htm>>.
- [2] Arsyad. S. 2006. Konservasi Tanah Dan Air. Departemen Tanah Fakultas Pertanian IPB. IPB Press. Bogor.
- [3] Asdak. C. 2002. Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gadjadara University Press.
- [4] Barbier, E.B and Jacob P. Hochard, 2016. Does Land Degradation Increase Poverty in Developing Countries? PLOS ONE | DOI:10.1371/journal.pone.0152973 May 11, 1-12.
- [5] Draper. N.R. dan H. Smith. 1992. Terjemahan Analisis Regresi Terapan. P.T. Gramedia Pustaka Utama. Jakarta.
- [6] Erlewein A and Antje Hecheltjen, 2018. Land Degradation Neutrality – a New Impetus for Addressing the Degradation of Land And Soils. RURAL 21, 33 - 37.
- [7] EORAH. 2005. Tools for catchment level soil and water conservation planning in the East African Highlands (Draft). Tool for participatory soil and water conservation mapping Tool for financial analysis of soil and water conservation measures. Development of an improved method for soil and water conservation planning at catchment scale in the East African highlands (EROAHI) EROAHI Report 4. ISSN 1566-7197
- [8] FAO. 1999a. Methods and Materials in Soil Conservation A Manual. Miscellaneous Reports/Guides/Manuals/Filmstrips-Soil. Land and Water Publication Series. Land and Water Development

- Devison. <[ftp://ftp.fao.org/agl/agll/docs/mmsoilc.pdf](http://ftp.fao.org/agl/agll/docs/mmsoilc.pdf)>
- [9] FAO. 1999b. Land and Crop Management in the Hilly Terrains of Central America : Lessons Learned and Farmer to Farmer Transfer of Technologies. FAO Soil Bulletin 76e. Land and Water Publication Series. Land and Water Development Devison. <[ftp://ftp.fao.org/agl/agll/docs/sb76e.pdf](http://ftp.fao.org/agl/agll/docs/sb76e.pdf)>
- [10] FAO. 2003. Data Sets, Indicators and Methods To Assess Land Degradation In Drylands. World Soil Resources Reports No. 100. Rome.
- [11] FAO dan CIFOR. 2005. Hutan dan Banjir. Tenggelam Dalam Suatu Fiksi Atau Berkembang Dalam Fakta. RAP Publication 2005/3. Forest Perspective 2. Food and Agriculture Organization - Centre of International Forestry Research. <www.cifor.cgiar.org/publications/pdf_files/Books/BCIFOR0502.pdf>
- [12] Johnson R.A and Douri K. Bhattacharyya. 1996. Statistics-Principles and Methods. University of Wisconsin at Madison. Third Edition. John Willey and Sons. Inc New York-Chichester-Brisbane-Toronto-Singapore.
- [13] Kelompok Kerja Erosi dan Sedimentasi. 2002. Kajian Erosi dan Sedimentasi Pada DAS Teluk Balikpapan Kalimantan Timur. TE-02/13-I CRC/URI CRMP Proyek Pesisir Kaltim Balikpapan Jl. R.E. Martadinata No.3 RT.28 RW.10 Kelurahan Mekarsari Balikpapan 76121, Indonesia. <www.crc.uri.edu/download/TE-02_13-I_Kajian_Erosi_Teluk_BPN.pdf>-2744k>
- [14] Maasily, A., 2017. Purposed Land Uses Based On Land Capability and Environmental Quality Of the Wae Ela Watershed, Negeri Lima, The Regency Of Central Maluku, Maluku. Thesis, University of Pattimura
- [15] Maitima J.M and Jennifer M. Olson. 2001. Guide to Field Methods for Comparative Site Analysis. for the Land Use Change, Impacts and Dynamics Project The Land Use Change, Impacts and Dynamics Project Working Paper Number: 15. LUCID Project International Livestock Research Institute P.O. Box 30709 Nairobi, Kenya.
- [16] Majule A.E. 2003. Impact of Land Use/Land Cover Changes on Soil Degradation and Biodiversity on the Slopes of Mount Kilimanjaro. Tanzania. Land Use Change Impact and Dynamics Working Paper Series Number 26. Institute of Resource Assessment University of Dar es Salaam. P.O. Box 35097. Dar es Salaam. Tanzania.
- [17] Manuputty, M.P.F., 2017. Evaluation of the Environmental Quality and Carrying Capability of Wae Batu Merah Watershed Ambon. Tesis, University of Pattimura
- [18] Mohawesh Y, A. Taimeh, And F. Ziadat. 2015. Effects of land use changes and soil conservation intervention on soil properties as indicators for land degradation under a Mediterranean climate Solid Earth, 6, 857–868, 2015 www.solid-earth.net/6/857/2015/doi:10.5194/se-6-857-2015 © Author(s) 2015. CC Attribution 3.0 License.
- [19] Morrison D.F. 1976 Multivariate Statistical Methods. Second Edition. Mc.Graw-Hill Book Company. New York St. Louis San Francisco Auckland Düsseldorf Johannesburg Kuala Lumpur London Mexico Montreal New Delhi Panama Paris São Paulo Singapore Sydney Tokyo Toronto.
- [20] Nugraheni, A., Sobriyah and Susilowati, 2013. Perbandingan Hasil Prediksi Laju Erosi Dengan Metode Usle, Musle, Rusle Di DAS Keduang. e-Jurnal MATRIKS TEKNIK SIPIL/September 2013/318.
- [21] Olson, J. and L. Berry, -. Land Degradation In Java, Indonesia: Its Extent And Impact. Global Mechanism with support from the World Bank, Jakarta.
- [22] Osok, R.M. Osok, S.M. Talakua, D. Supriadi, 2018. Determination Of Land Capability Class and Land Rehabilitation Planning At Wai Batu Merah

- Watershed In Ambon City, Maluku Province. *AGROLOGIA*, Vol. 7, No. 1, 32-41.
- [23] Peprah, K., 2015. Land degradation is indicative: proxies of forest land degradation in Ghana. *Journal Of Degraded And Mining Lands Management* Issn: 2339 - 076x, Volume 3, Number 1, 477-489. DOI:10.15243/jdmlm.2015.031.477
- [24] Pham, T.G., J. Degener, and M. Kappas, 2018. Integrated Universal Soil Loss Equation (**USLE**) and Geographical Information System (**GIS**) For Soil Erosion Estimation In A Sap Basin: Central Vietnam. *International Soil and Water Conservation Research*, Volume 6, Issue 2, June 2018, Pages 99-110.
- [25] Ponce-Hernandez. 2004. Assessing Carbon Stock and Modelling Win-Win Scenarios of Carbon Sequestration through Land Use Changes. *Land and Water Development Devision*. FAO.
- [26] Prasannakumar, H., J. Vijith, Abinod, N., 2012. Estimation of soil erosion risk within a small mountainous watershed in Karala India using **RUSLE** and **GIS** Technology. *Geoscience Frontier* 3(2), 209-215.
- [27] Purwaamijaya, I.M., 2018. Multi Criteria Evaluation For Universal Soil Loss Equation Based On Geographic Information System. The 4th International Seminar of Mathematics, Science and Computer Science Education IOP Publishing IOP Conf. Series: Journal of Physics: Conf. Series 1013 (2018), 012153, doi:10.1088/1742-6596/1013/1/012153
- [28] Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K, and Yoder, D.C., Coordinators. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Soil Loss Equation (**RUSLE**). U.S.Department of Agriculture, Agriculture Handbook No. 703, 404 pp.<http://www.ott.wrcc.osmre.gov/library/hbmanual/rusle/ah_703.pdf>.
- [29] Roni, A, T. Masunaga, 2013. Assessment erosion 3D hazard with **USLE** and **Surfer** tools: a case study of Sumani watershed in West Sumatra, Indonesia. *Journal of Tropical Soil*, 18 (1), 82-92.
- [30] Rubianca, B., B. Jackson, D. Maxwell and K. Norton, 2018. A review of the (Revised) Universal Soil Loss Equation (**RUSLE**): with a view to increasing its global applicability and improving soil loss estimates. *Hydrol. Earth Syst. Sci.*, 22, 6059–6086, 2018 <https://doi.org/10.5194/hess-22-6059-2018>.
- [31] Santoro, A.A., A.L. Nugraha, A.P.Wijaya, 2014. Analisis Ancaman Bencana Erosi Pada Kawasan DAS Beringin Kota Semarang Menggunakan Sistem Informasi Geografis. *Jurnal Geodesi Undip* Vol. 3, No. 4, 60-68.
- [32] Saptari, A.Y., A. Supriadi, K. Wikantika, S. Darmawan, 2015. Remote Sensing Analysis In **RUSLE** Erosion Estimation. *Indonesian Journal of Geospatial* Vol. 4 No.1, 2015, 34-45
- [33] Senjobi, B.A., O. T. Ande, A. O. Ogunkunle, 2013. Land Degradation Assessment Under Different Uses: Implications On Soil Productivity And Food Security. *Agronomski Glasnik* 1/2013, 3-22.
- [34] Sherbinin. 2002. Guide to Land-Use and Land-Cover Change (**LUCC**) Center for International Earth Science Information Network (**CIESIN**) Columbia University Palisades, NY, USA. **A collaborative effort of SEDAC and the IGBP/IHDP LUCC Project**. <<http://sedac.ciesin.columbia.edu/notices.html>>.
- [35] Sihite. J. 2001. Evaluasi Dampak Erosi Tanah Model Pendekatan Ekonomi Lingkungan dalam Perlindungan DAS : Kasus Sub-DAS Besai – DAS Tulang Bawang, Lampung. Disertasi Doktor Program Pascasarjana Institut Pertanian Bogor. ICRAF SE-Asia Southeast Asian Regional Research Programme PO Box 161 Bogor 16001 Indonesia. <<http://www.worldagroforestry.org/sea/Publications/files/workingpaper/WP0029-04.PDF>>.

- [36] Sitorus, S.R.P and A.E. Pravitasari, 2017. Land Degradation and Land slide in Indonesia. Sumatra Journal of Disaster, Geography and Geography Education. ISSN:2580-4030(Print) 2580-1775 (Online) Vol.1, No. 2, 61-71), <http://sjdgge.ppj.unp.ac.id>
- [37] Stocking. M and Niamh Murnaghan, 2000. Land Degradation Guidelines For Field Assessment. Overseas Development Group University of East Anglia Norwich, UK Co-operating Institutions : United Nations Environment Programme (UNEP), United Nations University (UNU). People, Land Management and Environmental Change Project (PLEC)-Japan.
- [38] Stocking, Hilde Helleman, Roger White. 2005. Renewable Natural Resources Management for Mountain Communities. International Centre for Integrated Mountain Development Kathmandu, Nepal.
- [39] Sumbang, B., U. Numiaty, S. Arif, 2014. GIS-Based Soil erosion modelling for assessing land suitability in the urban watershed of Tallo river South Sulawesi, Indonesia. Modern Applied Science, 8 (4), 50-60.
- [40] SWALIM. 2007. Field Survey Manual Landform-Soil-Soil Erosion-Landuse-Land Cover. Prepared as support material for field data collection Project Report No. L- 01 January 2007. Somalia Water and Land Information Management Kalson Towers, 3rd Floor, Parklands, P.O. Box 30470, Nairobi.
- [41] Symeonakis. E, S. Koukoulas, A. Calvo-Cases, E. Arnau-Rosalen and I. Makris. 2004. A Landuse Change and Land Degradation Study In Spain and Greece Using Remote Sensing and GIS. Departamento de Geografía, Universidad de Valencia, Av. Blasco Ibáñez 28, Valencia 46010, Spain - Dept. of Geography, University of the Aegean, Mytilene 81100, Greece.
- <<http://www.isprs.org/istanbul2004/comm7/papers/110.pdf>>
- [42] Tahir M.P., 2011. Analysis The Rate Of Critical Land And Recommendation Of Land Utilization In Wae Ruhu Catchment Area, Ambon. Thesis, University of Pattimura.
- [43] Talakua, S.M and R.M. Osok, 2018. The Effect of Land Use Factors on Soil Degradation of Mixed Garden in District Of Kairatu West Seram Regency Maluku Province. AGROLOGIA, Vol 7. No 1, 9-16.
- [44] Talakua, S.M and R.M. Osok, 2018. Establishment of Innovative Patterns of Land Conservation of Four Watersheds to Support Reservoirs as Flood and Sediment Barriers in Ambon City. Paper presented at Nasional Seminar, Faculty of Agriculture, University of Mataram. Lombok, 27 Januari, 2018.
- [45] Tefera Bezuyayehu, Gezahegn Ayele, Yigezu Atnafe, M.A. Jabbar and Paulos Dubale. 2002. Nature and causes of land degradation in the Oromiya Region: A review Socio-economics and Policy Research Working Paper 36. International Livestock Research Institute P.O. Box 30709, Nairobi, Kenya <<http://www.ilri.org/InfoServ/Webpub/Fulldocs/WP36/land.htm>>
- [46] Tesfa, A, Shigdaf Mekuriaw, 2014. The Effect of Land Degradation on Farm Size Dynamics and Crop-Livestock Farming System in Ethiopia: A Review. Open Journal of Soil Science, 2014, 4, 1-5 (<http://www.scirp.org/journal/ojss>).
- [47] UNCCD and The Ministry of Environment and Forestry, 2015. Indonesia - Land Degradation Neutrality National Report. The Ministry of Environment and Forestry, Jakarta.
- [48] UNEP. 1992. Desertification, land degradation [definitions]. Desertification Control Bulletin 21.
- [49] Vitiyakon P. 2001. The Role of Trees in Countering Land Degradation in Cultivated Fields in Northeast Thailand. Southeast Asian Studies. Vol. 39. No. 3.

Department of Land Resources and Environment.
Faculty of Agriculture. Khon Kaen University.
Khon Kaen 40002. Thailand. <www.cseas.kyoto-u.ac.jp/seas/39/3/390305.pdf>.

- [50] Wischmeier, W.H., and D.D. Smith. 1978.
Predicting rainfall erosion losses: A guide to
conservation planning. U.S. Dep. Agric., Agric.
Handb. No. 537.

*Corresponding Author Brief CV

Dr. Ir. Silwanus Matheus Talakua, MP was born in Ambon, Maluku Province on January 3rd, 1965. He got his Bachelor of Agriculture (S1) from Pattimura University in 1991 with specialist in Soil Sciences/Soil and Water Conservation. In 1999 he completed his Master Degree Program (S2) at Padjadjaran University in Bandung with the main specification in Soil science, Land Reclamation and Rehabilitation. In 2009, he finished his Doctor (S3) degree at Padjadjaran University with specification in Soil Science, Land Degradation and Rehabilitation. Since 1993, he is working at the Soil Science and Agroecotechnology Study Program, Faculty of Agriculture, Pattimura University teaching Soil Physics, Basic Soil Science, Hydrology, Soil and Water Conservation, Geodesy and Cartography, Degradation and Land Rehabilitation. He is also teaching Soil Physics, Land Resource Conservation, Land Rehabilitation, Land Use Planning, and Statistical Analysis at Land Management Study Program, Postgraduate Program, Pattimura University. The researches that he had done were the Study of Soil Degradation Through Estimation of Potential Erosion by the **USLE** method in the Wai Ruhu Watershed at Sirimau Sub District Ambon (1991), Determination of Erosion Hazard Levels in the Wai Lela Watershed at Ambon Bay Baguala Sub District Ambon City (1999), Analysis of Some Physical Properties of Soil, Land Use and Properties of Soil Profiles on Infiltration Processes in Wae Tonahitu Watershed at Ambon Bay Baguala Sub District, Ambon City (2002), Evaluation of Soil Degradation and Control Effort in the Wai Riuapa Watershed at Kairatu Sub District of Maluku Province (2006), Inventory of Sago Potential and Sago Mapping in Bula Sub District East Seram District (2009), Sago Development Survey in South Buru District (2009), Effects of Land Use on Soil Degradation Due to Erosion in Kairatu Sub District at West Seram District of Maluku Province (2009), Identification of watershed characteristics in Wai Batu Merah Watershed at Ambon City of Maluku Province (2012). The Effect of Land Use Extent and Vegetation Density on Soil Degradation in Mixed Plantation and Shifting Cultivation in Kairatu District, West Seram Regency, which was published in the Agrinimal Journal. Faculty of Agriculture Pattimura University, Vol. 3, No. 1 (2013). ISSN: 2088-3609. Evaluation of Land Capability and Landuse Planning in the Wai Tina Watershed, South Buru Regency, Maluku Province, which was published in the Agrologia Journal of the Agriculture Faculty Pattimura University Vol. 3, No. 1 (2014). ISSN: 2301-7287. Water Efficiency on Irrigation System in Way Bini of Waeapo Sub District, Buru District of Maluku Province, which was published in the Agrologia Journal of Agriculture Faculty Pattimura University Vol. 5, No. 2 (2016). The Effects of Land Use Factors on Soil Degradation at Mixed Plantation in the Sub District of Kairatu, West Seram District, Maluku Province, published in the Agrologia Journal of the Agriculture Faculty Pattimura University Vol. 7, No. 1 (2018). Determination of Land Capability Class and Land Rehabilitation Planning at Wai Batu Merah Watershed in Ambon City, Maluku Province, which was published in the Agrologia Journal Vol. 7, No. 1 (2018). Dr. Talakua was also a speaker at several scientific meetings such as Annual Scientific Meeting (**PIT**) XXVIII – Indonesian Hydraulic Engineering Expert Association

(**HATHI**) (2011). "The Role of Integrated Watershed Management in Regional Development" at the Meeting for the Watershed Management of Integrated Wae Apu Watershed in Buru Regency (2011). Soil from the Side of Empowerment, Conservation. General Meeting of GPM Male Pastors in Maluku Province (2011). The Importance of Integration in Watershed Management at the Coordination Meeting on the Planning of the Integrated Management of the Wae Manumbai Watershed in Aru Islands Regency (2012). "Maluku in the Aspect of Disaster Presenters Papers on Activities for Dissemination of Disaster Risk Reduction in Ambon City for Elementary, Junior High School, Senior High School Teachers in Ambon City in collaboration with Ambon City Government cq Ambon City Regional Disaster Management Agency with Hope World Wide Indonesia (2013). As Oral Presenter in National Joint Conference Unpatti-Unpad. Sustainable Development For Archipelago Region in Pattimura University (2017). Determination of Innovative Patterns of Land Conservation at Wai Batu Merah, Wai Tomu, Wai Batu Gajah, and Wai Batu Gantung to Support Flood and Sediment Barriers at the National Seminar for the 51st Anniversary of the Faculty of Agriculture, Mataram University in Lombok at Nusa Tenggara Barat Province (2018). He attended the International Seminar on Sago and Spices For Food Security. Sail Banda (Small Island for Our Future) (Ambon, 2010), Disaster Risk Reduction Training Program at Yogyakarta (2014), Training Data Analysis Experimental Design 2 Factors With Minitab 17 Program (2016), Basic training on ArcGIS by the Center For The Development Of Spatial Data (PPIDS) of Pattimura University (Ambon, 2018), International Seminar Sago feed The World (Ambon, 2018). He has published two books: 1."Sago, Hope and Challenges" First Edition on November 2010. Publisher: PT Bumi Aksara Jl. Sawo Raya No.18. Jakarta-13220 ISBN 978-979-010-518-8., and 2. Land Degradation, Method of Analysis and Its Application on Land Use on 2016, Publisher : Plantaxia Publisher Yogyakarta. ISSN: 978-602-6912-13-8. Dr. Talakua was a Secretary of the soil physics and mechanics devision of The Indonesian Soil Science Association (**HITI**) branch Maluku and Irian Jaya (1993-1996), and a member of the Indonesian Soil Science Association (**HITI**) (Deputy Chairman of the HITI KOMDA Maluku), the secretary of the Watershed Forum of Maluku Province, a member of the Water Resources Council of Maluku Province, a member of Regional Spatial Planning Coordination Team (**BKPRD**) of Ambon City, and a member of the Resources Management Coordination Team of Ambon-Seram River Region of Maluku Province.

E-ISSN: 2654-6264