COMPUTATIONAL MODEL FOR SOIL EROSION IN HILLY AREAS

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Abstract

Tangub City has a total land area of about 16, 572 hectares in which 60% is hilly and highly elevated associated with clean top forest of some part which make it more vulnerable to high soil erosion. This study aims to make computational model of soil erosion in hilly areas of Tangub City. The study utilized the existing model from the NETLOGO entitled erosion. The model represents a graphical presentation of soil erosion as influenced by the following model parameters: rainfall, terrain-smoothness, soil hardiness, hilly and bumpiness. The study made use of a two-factorial experimental design with Factor A: Rainfall and Factor B: Terrain Smoothness with three levels of each factor. The study shows that rainfall and terrain smoothness both have significant impacts on duration to soil erosion. Rainfall appears to have more impact on soil erosion than terrain smoothness. Its potential disastrous impact becomes even more lethal when taken in combination with terrain smoothness. The study concludes that the impact of rainfall to soil erosion can be diminished when the terrain is highly vegetated or non-smooth. Planting trees as mitigation measure for soil erosion is a significant means to stop further damage to the soil. The effect of planting trees on terrain smoothness is about 80.98% while its mitigating impact on rain is .08% only.

Keywords: *soil erosion, computational model, hilly areas*

1.0 Introduction

The most active agent of soil erosion in the Philippines is water. The climatic condition in the City of Tangub has an average of 183 mm of rainfall more or less evenly distributed throughout the year and Jasaan Clay Loam soil type. Jasaan Clay Loam soil series is derived from igneous rocks such as basalt and andesite. This ranges from gently sloping to hilly and mountainous areas. The elevation reaches to a height of about 3,500 feet. The native vegetation consists of secondary forest and cogon, which are found in the upper section and steeper slopes. With this vegetation, during heavy rains more clay sediments deposited in Panguil bay that affects the organisms living in it. It shallows the deep of the bay which causes it to increase in size to widen. The high elevated area of the City was observed less of vegetation which causes severe soil erosion due to clean top forest. Trees and other vegetative growth in the forest functions as a soil water reservoir and decrease the pressure of surface water run-off. Lack of trees in elevated area of the city promotes more soil particles eroded due to no binding effects in roots of trees and pressure of surface water run-off cannot be prevented. This study aims to make computational model of soil erosion in hilly Areas of Tangub City.

Tangub City is found at the southern curve of the D-shaped province of Misamis Occidental. It is bounded by Mt. Malindang in the north, Ozamiz City in the east, Panguil Bay in the south and the municipality of Bonifacio in the west. Sheltered by the mighty Mt. Malindang Range and embraced by the placid Panguil Bay. Tangub City is composed of fifty-five barangays spread over a land area of 16,572 hectares. The topography is approximately 40% plain area. Tangub city is ideal for agriculture. Basically the city has more than 60% of the land devoted to farming. Main products along the coast of Panguil Bay and 60% rolling and hilly, gradually rising to the Mt. Malindang National Forest Reservation are coconut, corn and banana. Fishing is another source of livelihood of the people.

Intensive agriculture, deforestation, climate change and urbanization are amongst the human activities which stimulates soil erosion. According to (WWF 2016), the effects of soil erosion go beyond the loss of fertile land. It has led to increase pollution and sedimentation in streams and rivers, clogging these waterways and causing declines in fish and other species. And degraded lands are also often less able to hold onto water, which can worsen flooding. Sustainable land use can help to reduce the impacts of agriculture and livestock, preventing soil degradation and erosion and the loss of valuable land to desertification. Agricultural management practices like slash and burn (Kaingin system) is a common practice used by the farmers in clearing the land in high elevated area and uncontrolled illegal logging is severe. Cultivating the soil removes the protective covering which makes soil prone to erosion. During tilling, the soil is detached from its binding form which causes easily detachment during rainfall. In addition, the clay type soil has a low infiltration and permeability of water which causes high water run-off in the surface due to microscopic soil pores. This is the reason why during heavy rain, large clay sediments are deposited in the lower part of the city and large volume of water are expectedly flooded if heavy rainfalls occur in hilly area. Diminishing sediment deposited by water during rainfall is one of the important details that will be given much attention to improve the productivity of Panguil bay and prevent changes of soil profile of the lower area affected by erosion.

Soil erosion can change productivity of soil in the lower part due to most of the eroded soil from the upper part is the top soil which is infertile. Healthy soil is a primary concern of farmers and the global community whose livelihoods depend on a well-managed agriculture that starts with the dirt beneath our feet. While there are many challenges in maintaining fertile and less erosion, this computational model will help to identify the rate of soil erosion which can be used as soil conservation tools and preventive measures of soil erosion on the upper part of the city.

2.0 Model Definition

The study utilized an existing model from the NETLOGO models library entitled: Soil Erosion authored by Uri Wilensky (2007). The model depicts a graphical presentation of soil erosion as influenced by the following model parameters:

1. Land topography (hilly or not hilly)
2. Bumpiness (bumpy or not)
3. Terrain smoothness (range 1 for very rugged to 30 extremely smooth)
4. Rainfall (how much rain falls: 0.10 means each patch has a 10% chance of being rained each step)
5. Soil hardness (how resistant to erosion the soil is; higher values will cause the soil to be harder. A value of 1.0 means that the soil will not erode at all).

Seed data for running the model were then obtained for the specific location of the hilly portion of Tangub City. Tangub City is located in Mindanao in the province of Misamis Occidental and covers an area of 16,572 hectares. The topography is approximately 40% plain along the coast of Panguil Bay and 60% rolling and hilly, gradually rising to the Mt. Malindang National Forest Reservation area.

The climate condition of the city has the average of 183 mm of rainfall more or less evenly distributed throughout the year which translates into probabilities ranging from low to high chance of patch rained in the model. The soil type is Jasaan Clay Loam. The model diagram is shown below;

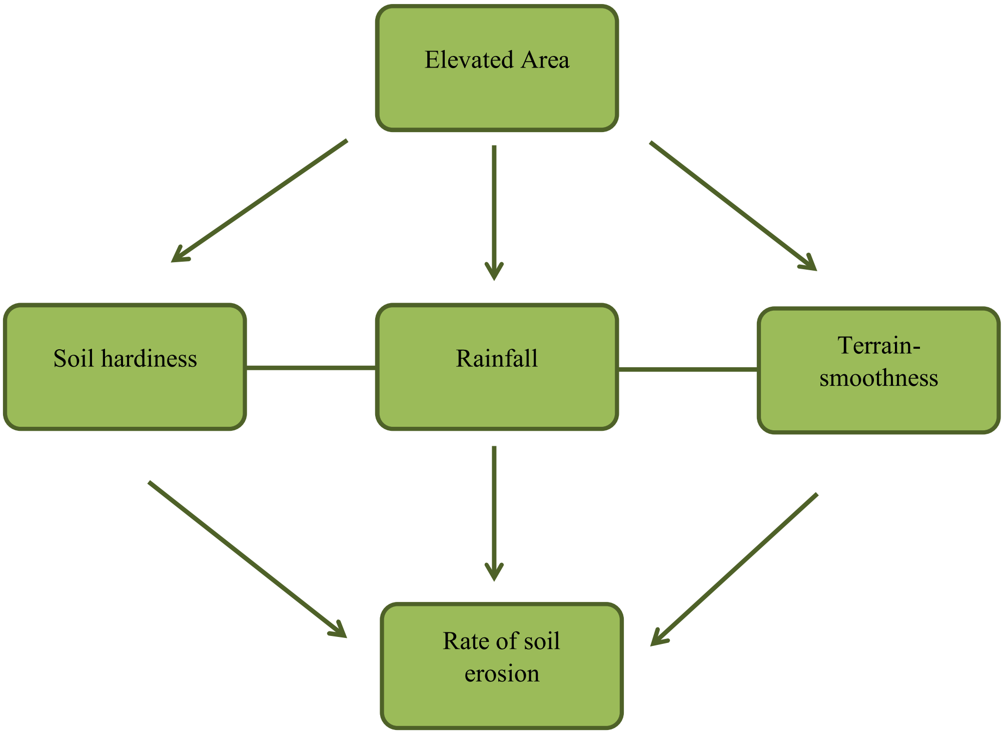

Figure 1. Model diagram of the study

The greater the intensity and duration of a rainfall, the higher potential rate of soil erosion. The soil aggregates can be break through the impact of raindrops on the soil which can disperse the aggregate material. The finer aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop and run-off water; the large amount and high pressure of water run-off can carry even the large particles of soil or even stone. Soil movement by rainfall is usually the greatest and most noticeable cause of soil erosion. Soil hardiness is the ability of soils to resist erosion, based on the physical characteristics of each soil. Soil texture and structure are the principal characteristics affecting hardiness. Soil with high organic matter and permeability of water also influence the soil to resist erosion. Generally, soils with faster infiltration rates higher levels of organic matter and improved soil structure have a greater resistance to erosion.

Tillage and cropping practices will reduce soil organic matter levels, which can cause poor soil structure, or result into soil compaction, contribute to increase soil erodability. By such practices, farmers tilled the field by clearing vegetation. Clearing vegetation removes the protection of plants and roots needed to lock soil in place. Basically, the more exposed or heavily tilled a soil is, the more likely it is to erode during rain or windstorms.When the topsoil is eroded from an area which loses its most nutrient-rich layer, therefore soil quality is reduced.

The risk of erosion is higher when the steepness of the slope of the terrain is longer and smooth. Due to a greater accumulation and increased velocity of water run-off which permits carrying large amount of soil particles.

3.0 Research Design and Methods

The study made use of a two-factorial experimental design with Factor A: Rainfall and Factor B: Terrain Smoothness. Medium (0.16 to 0.30) and High (0.31 to 0.50). Factor A has three levels , namely, Low (.15 below), Factor B also has three levels, namely, Low (1-10), Medium(11-20) and High (21-30). Factor A was chosen as a factor to account for the highly variable rainfall pattern observed in the last decade. For instance, in 2013, the highest amount of rainfall was observed over the last 50 years in the City. Factor B was chosen because of the uncertainties in the actual terrain smoothness in the hilly portions of Tangub City. While some parts of the hills are bare and smooth, other parts are still covered with sufficient vegetation. Five(5) replicates were made for each of the 3 x 3 possible combinations of the treatment levels of the two factors. The data were then subjected to a two-way analysis of variance with interaction analysis.

4.0 Results and Discussion

Table 1 shows the mean hours to erosion observed for each combination cells of the treatment factors.

Table 1. Table of Means. Hours to erosion

	Rainfall		
Terrain-smoothness	Low (0.01-.15)	Medium (.16-.30)	High (.31-.50)
Low (1-10)	3378.8	1598.8	1097
Medium (11-20)	3277.4	1614.8	1077.6
High (21-30)	3173.6	1615.4	1061

Table 2 shows the analysis of variance table for the various hours to erosion noted.

Table 2.Two-way ANOVA. Analysis of Variance for hours to erosion.

Source	DF	SS	MS	F	P
Terrain	2	42211	21106	6.36	0.004
Rainfall	2	39204110	19602055	5905.26	0.000
Interaction	4	68368	17092	5.15	0.002
Error	36	119499	3319		
Total	44	39434188			

Table 2 shows the mean squares computed for the main and interaction effects. Tabular values indicate that both main effects, namely; rainfall and terrain smoothness have significant impacts on hours to erosion as indicated by the large f-values of 6.36 and 5905.26 respectively exceeding the required values for significance beyond the 0.01 probability levels. Of the two significant main effects, rainfall appears to have a thousand times more impact on soil erosion than terrain smoothness. With respect to the phenomenon of soil erosion, it may be inferred that rainfall is a more potent environmental parameter that one needs to pay a greater attention. Its potential disastrous impact becomes even more lethal when taken in combination with terrain smoothness. The interaction effect is found to be likewise significant beyond the 0.01 probability level (f=5.15). The reduction in the f-value for the interaction effect is due to the decrease in soil erosion when the terrain is highly vegetated or non-smooth. According to the study of Romkens et al. (2010) results showed that soil erosion is very evident in hilly area than in smooth terrain area. Planting trees as mitigation measure for soil erosion is a significant means to halt further damage to the soil. In fact, the effect of planting trees on terrain smoothness is about MS(Int)/MS(Terrain) = 80.98% while its mitigating impact on rain is MS(Int)/MS(Rain)=0.08% only.

According to Gillaspy (2016), the best way to prevent soil erosion is to increase vegetation. Plants and trees grow above the surface, protecting soil from erosion, and their roots meander down through the soil and become like bars in a prison, locking the soil particles in place, making it hard for them to escape and be carried away by water.

Figures 2 to 10 show some examples of the simulations performed to obtain Tables 1 and 2.

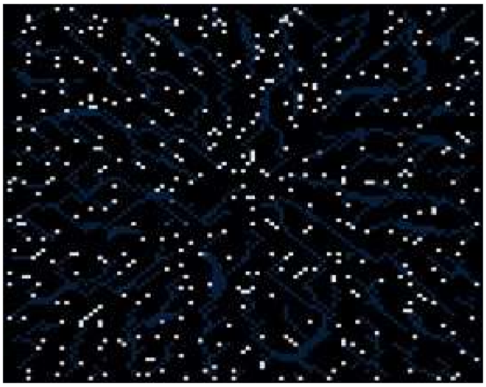

Figure 2: Sample Simulation for Low Rainfall, Low Terrain-smoothness Combination

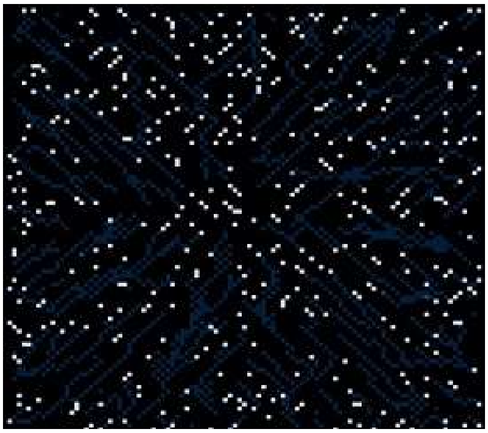

Figure 3: Sample Simulation for Low Rainfall, Medium Terrain-smoothness Combination

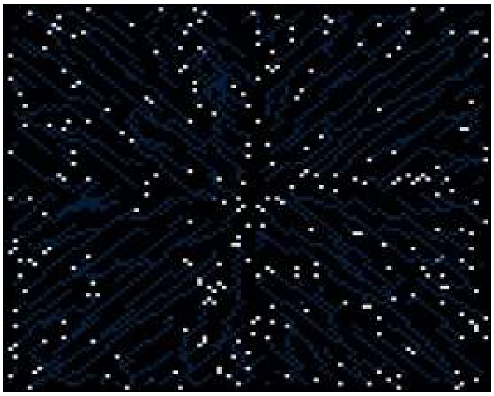

Figure 4: Sample Simulation for Low Rainfall, High Terrain-smoothness Combination

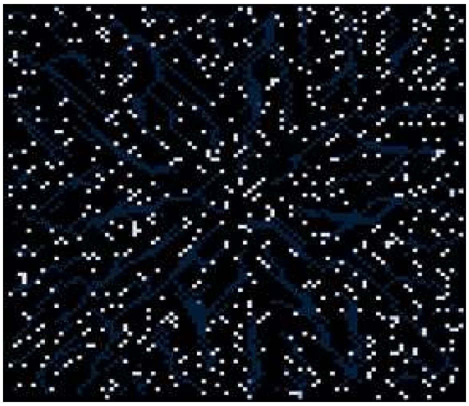

Figure 5: Sample Simulation for Medium Rainfall, Low Terrain smoothness Combination

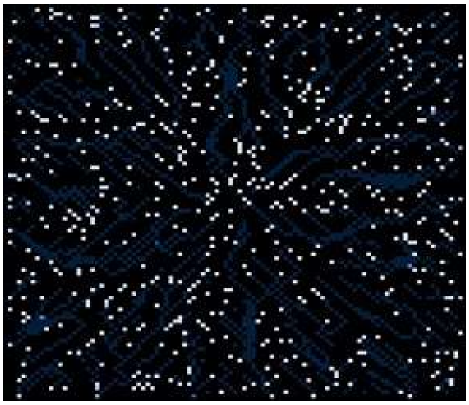

Figure 6: Sample Simulation for Medium Rainfall, Medium Terrain-smoothness Combination

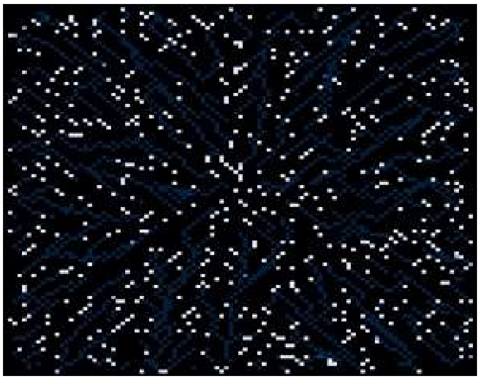

Figure 7: Sample Simulation for Medium Rainfall, High Terrain-smoothness Combination

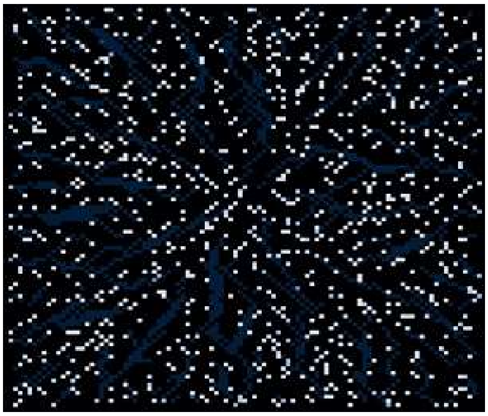

Figure 8: Sample Simulation for High Rainfall, Low Terrain-smoothness Combination

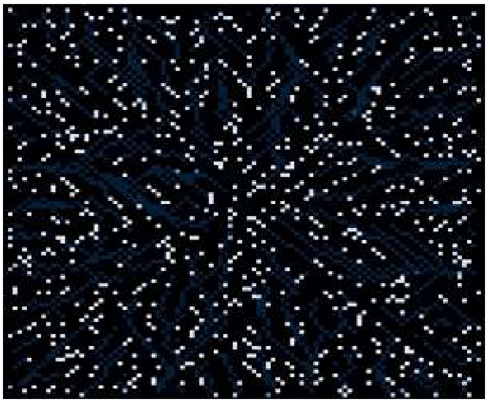

Figure 9: Sample Simulation for High Rainfall, Medium Terrain-smoothness Combination

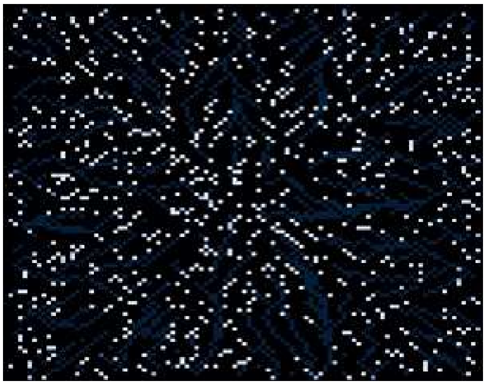

Figure 10: Sample Simulation for High Rainfall, Medium Terrain-smoothness Combination

5.0 Conclusion

The study shows that rainfall and terrain smoothness both have significant impacts on duration topsoil erosion. Of the two significant main effects, rainfall appears to have more impact on soil erosion than terrain smoothness. Its potential disastrous impact becomes even more lethal when taken in combination with terrain smoothness. The study conclude that the impact of rainfall to soil erosion can be diminished when the terrain is highly vegetated or non-smooth. In most studies, results showed that soil erosion is very evident in hilly area than in smooth terrain area. Planting trees as mitigation measure for soil erosion is a significant means to halt further damage to the soil. In fact, the effect of planting trees on terrain smoothness is about 80.98% while its mitigating impact on rain is 0.08% only.

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