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Impact of Climate Change on Soil Erosion

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Abstract

Global warming is expected to result in a more vigorous hydrological cycle, including total rainfall and more frequent high-intensity rainfall events, which affect soil erosion and cause a threat to agricultural land sustainability and productivity, particularly in tropical and subtropical regions. This study aims to determine the effects of climate change on soil erosion in Taiwan. This experiment assesses the risk of soil erosion in Taiwan over 2 – 200 years. To determine the predictor of soil erosion risk, the study used USPED. Result showed there was an increase in sediment yield because of soil erosion. Hence, targeting conservation practices to erosion-prone areas, expanding conservation coverage, and adapting agronomic practices may be necessary to prevent excessive soil erosion under climate change scenarios that include intensified precipitation.

Keywords: Climate Change; Rainfall Intensity; Soil Erosion

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INTRODUCTION

Global warming is expected to lead to a more vigorous hydrological cycle, including total rainfall and frequent high-intensity rainfall events (Nearing, Pruski, and Neal, 2014). Climate changes in temperature and precipitation patterns will affect plant biomass production, infiltration rate, soil moisture, land use, and crop management, affecting runoff and soil erosion (Li and Fang, 2016). Parroisen et al. (2014) stated that Global climate and land use changes could strongly affect soil erosion and the capability of soils to sustain agriculture and, in turn, affect regional or global food security. According to Zhang and Nearing (2005), the potential for global climate changes to increase the risk of soil erosion is clear, but the actual damage is not.

Soil erosion is a worldwide challenge and becomes a significant threat to the sustainability and productivity of agriculture, especially in tropical and subtropical regions. Research by Kumar and Pani (2012) showed that a considerable share of fertile land has gone out of plow because of long and continuous fluvial erosion. As a result, crop productivity has declined in villager severely affected by land degradation. Moreover, due to this menace, the water table has also gone down further retarding the development of irrigation facilities. In addition, erosion also contributed to the poor health of livestock due to a lack of pasture grass to feed on, loss of grazing land, and poor bush regrowth (Ighodaro, Lategan, and Yusuf, 2013).

Given this potential, climate change can increase the rate of soil erosion, and it has associated negative effects. Thus modeling soil erosion rates for the future is a critical step to assess the potential future agriculture and environmental issues because the modeling climate change scenario can analyze the soil erosion risk. Research by Correa et al. (2015) showed that in annual terms, there was a significant trend of decreasing rainfall erosivity and increasing the concentration of rainfall simulated based on A1Bclimate change scenario. Because the A1B scenario affects rainfall erosivity mainly during the rainy season, this causes a risk to environmental sustainability and future agricultural activities. In addition, modeling soil erosion can determine soil sustainability. Research by Parroissen et al. (2015) showed that the median simulated soil erosion rate for the current period was 3.5 t/ha/year, and the soil life expectancy was 273 years, showing low sustainability of soils. For the future period with the same land use distribution, the median simulated soil erosion rate was 4.2 t/ha/year, and the soil life expectancy was 249 years. Among the scenarios tested, instituting a mandatory grass cover in vineyards seems to be an efficient means of significantly improving soil sustainability by decreasing soil erosion rates and increasing soil life expectancies.

This knowledge is essential to know the potential risks of soil erosion in a changing climate to inform farmers in agricultural management decisions. Based on previous study, since rainfall characteristics are essential for agricultural management to reduce the amount of soil erosion thus, reviewing and updating the rainfall characteristics for future climate scenarios is necessary. Therefore, this paper aims to determine the impacts of climate changes on soil erosion in Taiwan using USPED and Arcgis 10.2 software with one scenario from 2 – 200 years .

RESEARCH METHOD

This experiment assesses the risk of soil erosion in Taiwan over 2 – 200 years. The data used in this study were rainfall data. This experiment uses the ArcGIS 10.2 software, which aims to determine the prediction of erosion and deposition due to the amount of rainfall. Therefore, to determine the predictor of soil erosion risk, the study used USPED. USPED (Unit Stream Power-based Erosion Deposition) method is a simple model that predicts the spatial distribution of erosion and deposition rate for steady state land flows under uniform over rainfall conditions for limited case transport capacity of erosion processes. The application of the long-term constant R factor is another simplification. The R factor needs to be somewhat modified when calculating annual erosions for various years based on actual yearly rainfall

RESULT AND DISCUSSION

Climate change is expected to lead to increased intensity and high frequency of rainfall, especially where the average annual rainfall is also expected to increase. In addition, because the rainfall amount and intensities are the most influencing factors, changes in rainfall in total rainfall, intensity, and temporal distribution are estimated to impact soil erosion directly. Our study has found the different soil erosion distributions caused by climate change. The impact of climate change on soil erosion is shown in Figure 1. Our study has found the different soil erosion distributions from Figure 1 – 7 caused by climate change The impact of climate change on soil erosion from 2 years to 5 years increased by 29%. For 10, 25, 50, 100, and 200 years, soil erosion increased by 46%, 65%, 78%, 89%, and 100%.

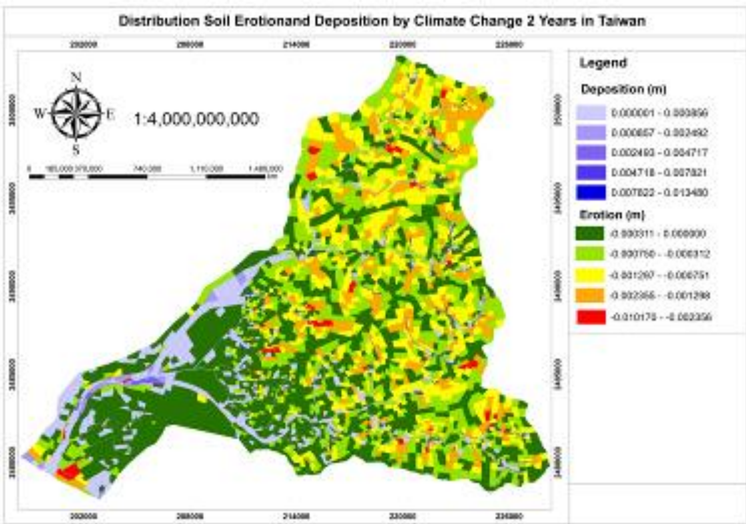

Figure 1. Distribution Soil Erotion and Deposition by Climate Change 2 Years in Taiwan

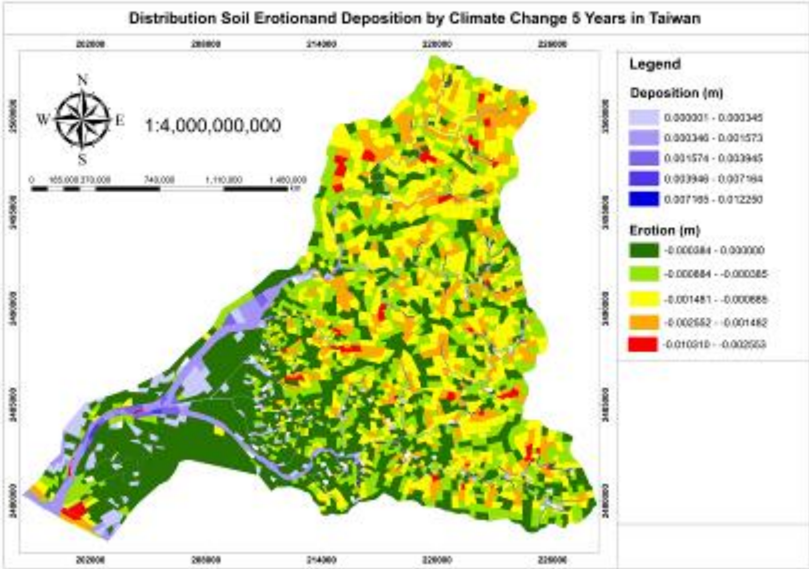

Figure 2. Distribution Soil Erotion and Deposition by Climate Change 5 Years in Taiwan

Zhang et al. (2012) suggested that projected mean annual runoff and soil loss increased significantly, ranging from 79% to 92% and 127% to 157%, respectively, relative to 1970 to 1999. These results suggest that erosion can be expected to increase when precipitation increases are significant. Where precipitation decreases occur, the results may be more complex due mainly to interactions of plant biomass, runoff, and erosion, and either increases or decreases in overall erosion may be expected (Pruski & Nearing, 2002).

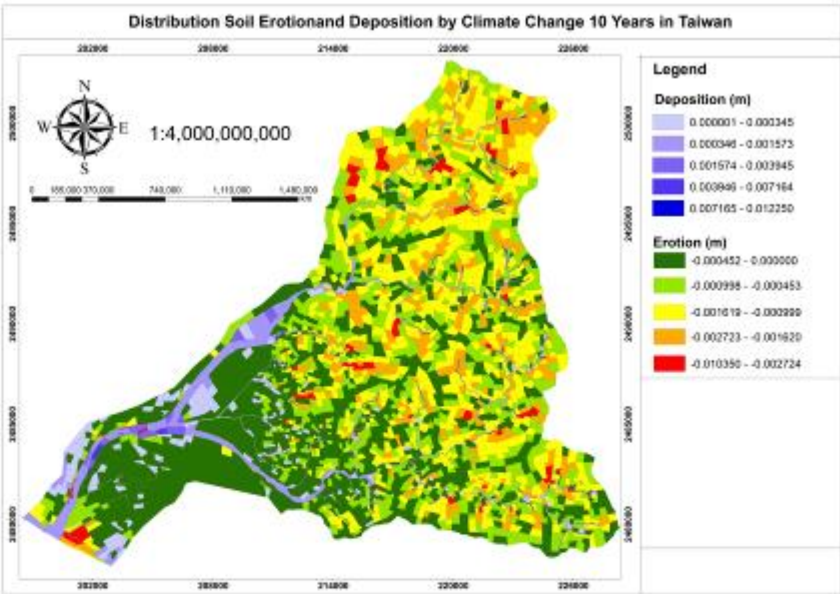

Figure 3. Distribution Soil Erosion and Deposition by Climate Change 10 Years in Taiwan

In addition, from figure 1 – 7 showed the deposition was decreased for periods 2, 5, 10, 25, 50, 100, and 200. It showed there was an increase in sediment yield because of soil erosion. This result was confirmed by Garbrecht et al. (2014) stated that the climate change scenarios of increased precipitation intensity lead to an exponential increase in soil erosion, runoff, and watershed sediment yield. Lu et al. (2013) showed that every 1% change in precipitation has resulted in a 1.3% change in water discharge and a 2% change in sediment loads supported it. In addition, every 1% change in water discharge caused by precipitation has led to a 1.6% change in sediment loads. However, the same percentage of water discharge change caused mainly by humans would only result in a 0.9% change in sediment loads. Giang, Giang, and Toshiki (2016) also stated that under the impact of climate change, it is very likely that the soil erosion rate in the downstream area will increase at a higher rate than in its upstream area due to a more significant increase in precipitation.

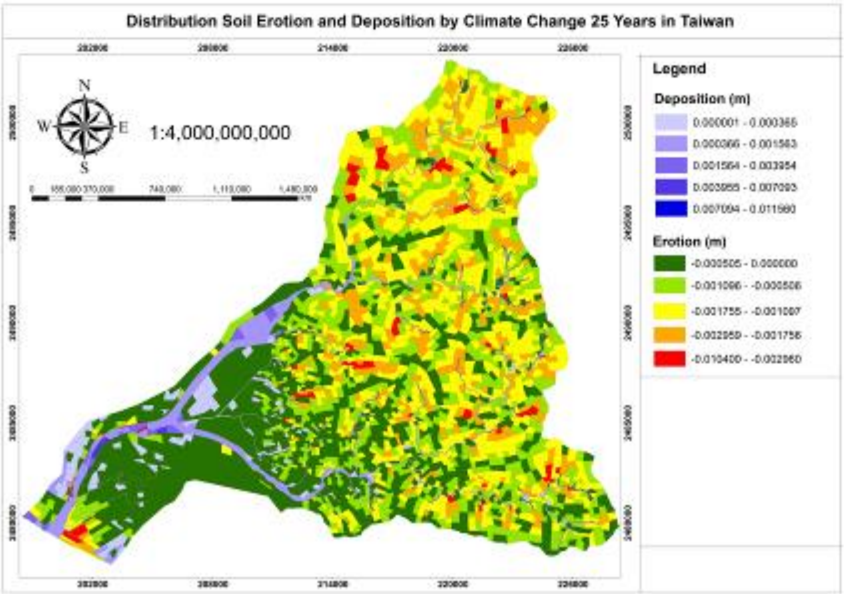

Figure 4. Distribution Soil Erotion and Deposition by Climate Change 25 Years in Taiwan

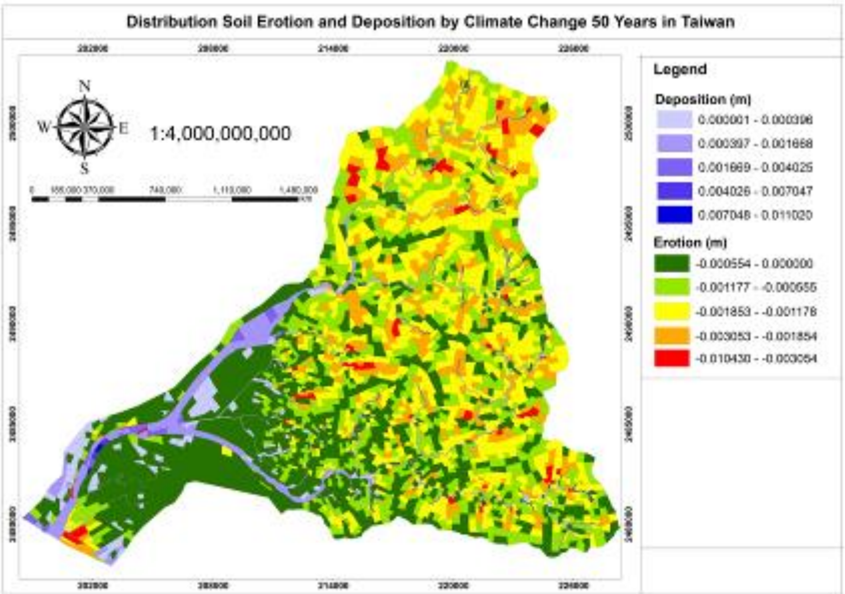

Figure 5. Distribution Soil Erotion and Deposition by Climate Change 50 Years in Taiwan

Berdasarkan penjabaran tersebut, estimasi resiko terjadinya erosi tanah dengan menggunakan model empiris telah lama menjadi topik penelitian dengan tujuan untuk menetapkan rencana pengelolaan DAS (Arrebei et al., 2020). Hal ini juga dikarenakan pemanasan global yang terjadi dalam beberapa decade terakhir dengan meningkatnya frekuensi persitowa cuaca ekstrem (Chen et al., 2022). Hasil penelitian Liu et al (2007), menunjukkan bahwa perkiraan erosi dengan menggunakan metode USPED adalah alat yang efektif untuk mengukur tingkat erosi.

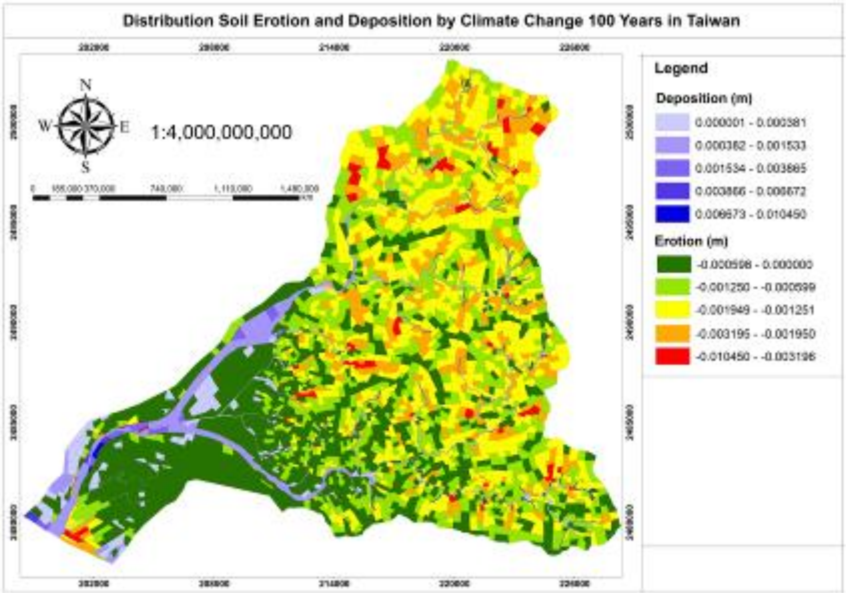

Figure 6. Distribution Soil Erotion and Deposition by Climate Change 100 Years in Taiwan

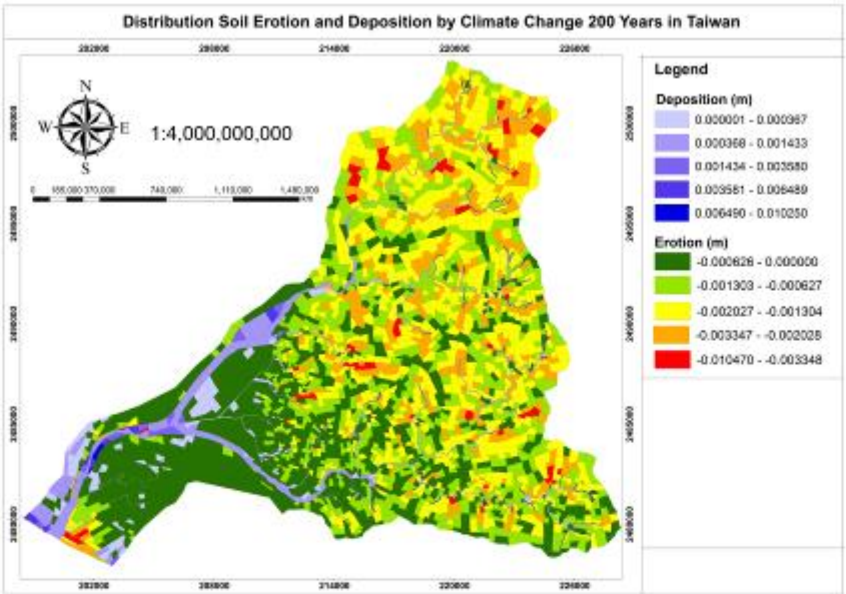

Figure 7. Distribution Soil Erotion and Deposition by Climate Change 200 Years in Taiwan

Higher rainfall intensity means stronger erosivity of a single event, significantly influencing water erosion processes and mechanics. Thus, if the rainfall duration is long enough or the rainfall amount is significant enough, more soil particles will likely be eroded by saturation excess runoff because of the kinetic energy provided. In addition, soil loss tends to be higher in soil that is shallow or without vegetation cover (Li and Fang, 2016). Thus, targeting conservation practices to erosion-prone areas, expanding conservation coverage, and adapting agronomic practices may be necessary to prevent excessive soil erosion under climate change scenarios that include intensified precipitation. Moreover, rangeland management policies and practices should consider these changes, runoff risks, and soil erosion (Zhang et al., 2012). Thereby emphasizing current conservation practices and future practices designed with today's practice standards are necessary.

CONCLUSION

Global warming is expected to lead to a more vigorous hydrological cycle, including total rainfall and more frequent high-intensity rainfall events that affect soil erosion and threaten sustainability and productivity for agricultural land, especially in tropical and sub-tropical regions. Thus modeling soil erosion rates for the future is a critical step in assessing future agriculture and environmental issues because the modeling climate change scenario can analyze the soil erosion risk. Our research found that the impact of climate change on soil erosion from 2 years to 5 years increased by 29%. For 10, 25, 50, 100 and 200 years, soil erosion increased by 46%, 65%, 78%, 89%, and 100%, respectively. In addition, the deposition was decreased for periods 2, 5, 10, 25, 50, 100, and 200. It showed there was an increase in sediment yield because of soil erosion. Hence, targeting conservation practices to erosion-prone areas, expanding conservation coverage, and adapting agronomic practices may be necessary to prevent excessive soil erosion under climate change scenarios that include intensified precipitation.

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