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学位論文審査の結果の要旨

Summary of Doctoral Dissertation Examination

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題　　目 Title	Spatio temporal modeling of gully erosion in the Upper Blue Nile basin, Ethiopia

審査結果の要旨（２，０００字以内）／Summary of Doctoral Dissertation Examination (Within 1200 words)

Soil erosion remains a significant global challenge, leading to serious environmental issues both on and off-site. The Ethiopian highlands, particularly in the Upper Blue Nile (UBN) basin, are highly affected by water erosion, impacting not only Ethiopia but also downstream countries like Sudan and Egypt. Gully erosion in this basin varies in space and time, influenced by factors such as topography, soil, climate, and human activities.

Prior research on gully erosion modeling often overlooked small-scale watersheds in tropical humid and sub-humid climates, and inadequately considered all potential controlling factors across different agro-ecological environments. To address these gaps, the present study aimed to evaluate gully erosion dynamics under various climate and human activity scenarios in three paired watersheds across different agro-ecological environments in the UBN basin. The study employed field observations, high-resolution remote sensing data, and modeling tools. Specifically, two main objectives were pursued: (1) modeling the spatial distribution of gully erosion susceptibility and its controlling factors and (2) simulating the separate and combined impacts of rainfall, land use, and management on gully erosion.

Firstly, he integrated detailed field investigations with high-resolution remote sensing products to assess gully erosion susceptibility and identify its controlling factors using a machine learning model in six watersheds across three agro-ecological environments of the basin. To achieve this, he employed a Random Forest (RF) algorithm and extracted 20 conditioning factors with eight different pixel resolutions ranging from 0.5 to 30 m. The training and validating datasets were divided into 70% to 30% ratio while statistical analyzes were conducted before and after running the model to assess whether there are variables with collinearity problems and assess the statistical relationships among factors, respectively. The study results showed that outstanding performance of the model found when the finest-resolution datasets were used to predict gully erosion susceptibility.

Regardless of the watershed treatment conditions and agro-ecological settings, elevation, height above nearest drainage, runoff curve number, distance from streams, drainage density, soil type, and land use/land cover were the most important factors influencing the spatial distribution of gullies in the study watersheds. As a result, he identified that the most susceptible lands to gully erosion that need priority for land management activities were low-lying grazing, bushland, and cultivated lands with sensitive soil of high runoff-generation capacity located within short horizontal and vertical distances from drainage networks.

Therefore, basin- and watershed-scale gully management strategies need to consider the relative importance and interaction of the above controlling factors, including the previously unaccounted runoff curve number-II, and should give priority to the most susceptible areas.

Secondly, he investigated the impact of changes in rainfall, land use/land cover (LULC), and land use management (LUM) practices on gully erosion in two midland watersheds (treated Kecha and untreated Laguna) by employing the LANDPLANER model. The study simulated gully erosion under past (in 2005), present (in 2021), and three potential future curve number conditions, each time under four rainfall scenarios (10, 30, 60, and 100 mm) using the dynamic erosion index (e), static topographic (esp), and erosion channel ($esp\_channel$) thresholds. The best predictions of gullies identified through true positive rates (TPR) and true negative rates (TNR) were achieved considering $esp\_channel > 1$ for Kecha (TPR = 0.667 and TNR = 0.544) and $e > 0.1$ for 60 mm of rainfall in Laguna (TPR = 0.769 and TNR = 0.516). The results showed that the 10 mm rainfall has insignificant erosion-triggering potential while the 60 and 100 mm rainfall scenarios have 4–5 and 10–17 times, respectively, higher impact than the 30 mm rainfall scenario. The LULC change in the untreated Laguna watershed increased the impact of rainfall on gully initiation by only 0–2% (between 2005 and 2021) whereas the combination of LULC and LUM significantly reduced the impact of rainfall in the treated Kecha watershed by 64–79%. Similarly, the gully initiation area in the treated Kecha was reduced by 28% (from 33% in 2005 to 5% in 2021) due to changes in LULC and LUM practices, whereas the untreated Laguna showed little increment by only 1% (from 42% in 2005 to 43% in 2021) due to LULC change. In addition, the future predicted alternative land use planning options showed that gully initiation areas in untreated Laguna could be reduced by 1% with only LULC conversion; 39% when only LUM practices were implemented; and 37% when both were combined. Overall, the results indicate that rainfall has a significant impact and LUM practices outweigh the impact of LULC on gully erosion in the studied paired watersheds.

In summary, Mr. Tadesual Asamin Setargie conducted a comprehensive study on gully erosion in the UBN basin, Ethiopia, using field observations, remote sensing, and modeling tools. His research revealed the spatio-temporal dynamics of gully erosion in diverse agro-ecological environments. Key findings include the significant influence of pixel resolution on gully erosion prediction and the crucial impact of changes in rainfall and land use management (LUM) practices. LUM practices had a more significant effect on gully initiation and development than land use and land cover (LULC) changes. The thesis's significance lies in its potential to improve spatio-temporal modeling and management of gully erosion in the UBN basin and similar areas. The work also contributes valuable concepts and methods to machine learning-based gully erosion assessments, especially regarding the importance of runoff curve number-II. Moreover, the research evaluated the separate and combined impacts of rainfall, LULC, and LUM practices on gully erosion. The Examining Committee unanimously voted to award Mr. Tadesual Asamin Setargie's Ph.D. degree due to the importance and originality of his research, which represents a valuable contribution to the field of gully erosion studies and is highly recommended for recognition and publication.