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SUMMARY OF DOCTORAL THESIS

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Title: Impact of soil and water conservation interventions on runoff response under contrasting agro-ecologies of Upper Blue Nile basin, Ethiopia

（エチオピア青ナイル川上流域の対照的な農業生態系における土壌・水保全策が流出応答に及ぼす影響）

Ethiopia is, often described as the water tower of East Africa, and the rainfall-runoff processes on the mountainous slopes are the source of the surface water, the potential of surface water which is estimated to be around 110 billion m^3 a^{-1}, with unequal distributions over the country. Soil erosion by water is the most serious threat in Ethiopian highlands, thereby degrading land and causing socio-economic problems. In response, various governmental and non-governmental land management interventions have been implemented since the 1970s, and great efforts have been undertaken to conserve soil and water resources through various types of land management technologies (e.g., soil bund, *fanya juu*, stone-faced, soil bund combined with biological measures, short trenches, cut-off drains, check dams, hillside terraces, area closures). Despite all those efforts sustainability of the development work is always in question, and their response to decrease the existing runoff and soil erosion amount has not been evaluated, particularly in the Upper Blue Nile basin (UBNB) of Ethiopia.

The spatial runoff response of the UBNB is the combination of many complex hydrological processes, depending on the watershed characteristics (e.g. land management practice, land cover, soil and rainfall). These spatial difference will have a paramount effect on runoff response and yield impacting the efficiency of land management practice. For these reasons; adequate understanding of the runoff response in contrasting agroecology (high, mid and low in both elevation and rainfall) to various soil and water conservation (SWC) practices in UBNB is crucial to develop sustainable water resources management strategies in the region. The overall objective of this study is therefore, to demonstrate and analyzing spatial runoff responses to different SWC measures at various land use and slope classes and thereby, to contribute to better water resources management for Upper Blue Nile basin of Ethiopia. More specific objectives include: (1) to analyze the spatial variability of rainfall-runoff relationship and its controlling factors (2) to determine the ability of different SWC practices to reduce runoff and improve soil moisture availability in typical agro-ecology systems (3) to determine CN values for various SWC practices and test to what extent the effect of SWC practices can be captured with the most commonly used CN runoff estimation method (4) to analyze the hydrological responses of paired watersheds under existing SWC practices, and (5) to investigate the effects of SWC measures on runoff under various management scenarios for better planning and management of water resources under the conditions of Upper blue Nile Basin; Ethiopia. This study comprises five chapters described as follows:

Chapter 1 presents the introductory section of this study. It sets out an overview of the background for the study, focusing on water resource potentials, soil erosion problem, runoff response factors, model application, principles of soil and water conservation, the country's experience in SWC activities, Subsequently, it presents the research gaps, study objectives and organization of the thesis.

Chapter 2 investigates efficiency of soil and water conservation practices in different agro-ecological environments of Ethiopia's Upper Blue Nile basin. The analysis is based on runoff plots from three sites each representing a different agro-ecological environment in Ethiopia's Upper Blue Nile basin. The plots at each site represented common land use types (cultivated vs. non-agricultural land uses) and slopes (gentle and steep). Seasonal runoff from control plots in the highlands ranged between 214 and 560 mm, versus 253 to 475 mm at midlands and 119 to 200 mm at lowlands. The three SWC techniques (soil bund, *fanya juu*, soil bund combined with biological measures) applied in cultivated land increased runoff conservation efficiency by 32 to 51%, depending on the site. At the moist subtropical site in a highland region, SWC increased soil moisture enough to potentially cause waterlogging. Soil bunds combined with Vetiveria zizanioides grass in cultivated land and short trenches in grassland conserved the most runoff (51 and 55%, respectively). Runoff responses showed high spatial variation within and between land use types, causing high variation in SWC efficiency. Our results highlight the need to understand the role of the agro-ecological environment in the success of SWC measures to control runoff and hydrological dynamics. This understanding will support policy development to promote the adoption of suitable techniques that can be tested at other locations with similar soil, climatic, and topographic conditions.

Chapter 3 analyzes the runoff response to SWC measures in a tropical humid Ethiopian highlands. The analysis is based on daily rainfall and runoff depth from 18 runoff plots (30 m long × 6 m wide) representing the five main land use types with various SWC practices and two slope classes (gentle and steep). The effect of SWC practices on runoff response and experimentally derived and tested the validity of the runoff curve number (CN) model parameter. The CN values were derived using the lognormal geometric mean CN procedure. Runoff was significantly less from plots with SWC measures where an average reduction of 44% and 65% were observed in cultivated and non-agricultural lands, respectively. Runoff on plots representing non-agricultural land was relatively accurately predicted with the derived CN method, but predictions were less accurate for plots treated with a SWC practice. The results indicate that predicting the effect of SWC practices on runoff requires parameterization with separate sets of CN value for each SWC practice.

Chapter 4 quantify and investigate the impact of soil and water management interventions on watershed runoff response in a tropical humid highland of Ethiopia. Firstly, a paired-watershed approach was employed. Secondly, a calibrated curve number hydrological modelling was applied for the Kasiry watershed alone. The paired-watershed approach showed a distinct runoff response between the two watersheds (kasiry and Akusity) however the effect of SWC measures was not clearly discerned being masked by other factors. On the other hand, the model predicts that, under the current SWC coverage at Kasiry, the seasonal runoff yield is being reduced by 5.2%. However, runoff yields from Kasiry watershed could be decreased by as much as 34% if soil bunds were installed on cultivated land and trenches were installed on grazing and plantation lands. The results on the magnitude of runoff reduction under optimal combinations of soil and water measures and land use are crucial in selection and promotion of valid management practices that are suited to particular biophysical niches in the tropical humid highland of Ethiopia.

Chapter 5 provides a general synthesis of the whole thesis, including conclusions, policy implications and avenues for further research. The findings of this study provided an overview of the hydrological dynamics and effectiveness of SWC practices to reduce runoff under the common agro-ecology systems and contributed a solid basis for selecting event runoff CNs for different land uses and vegetation types in Ethiopia's UBNB. In addition, it also explains the effects of SWC practice on hydrological responses of watersheds.

The responses of runoff, runoff coefficient and runoff conservation efficiency to SWC practices were highly variable both within and between agro-ecology systems. This high variation was attributed to a combination of several factors: the type of soil (permeability), land use, soil water availability, the response of runoff to rainfall, and the prevailing climatic conditions (precipitation and potential evapotranspiration). Our finding allows managers towards the optimal choice of soil and water conservation measures under specific site conditions instead of making blanket recommendations for all systems. Furthermore, model parameters (CN) derived from our local studies has been found to be more reliable than taken from other secondary sources. Thus, this finding capitalize modelling exercise on the effects of SWC practices on runoff requires parameterization with separate sets of CN value for each SWC practice. To explore policy options for upscaling sustainable land management activities, it is important to understand the factors that affect runoff responses, the potential of SWC interventions in reducing runoff in the watershed system, and prioritize land uses for interventions based on their potential runoff yield. Future hydrological studies should consider time series data of runoff responses and its relationship with sustainability land management interventions.