（様式第９号／Format No.9）

学位論文審査の結果の要旨
Summary of Doctoral Dissertation Examination

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題　　目 Title	Modeling hydrological and sediment responses to human activities and climate variability 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-caused land degradation is a serious global environmental challenge; this is more severe specifically in the least developed countries like Ethiopia. High erosion rates and associated impacts are more visible in the Ethiopian highlands, particularly in the Upper Blue Nile basin that affects downstream countries like Sudan and Egypt as well. On the other hand, there are few efforts made on implementation of soil erosion counter measures such as soil/stone bunds and afforestation practices mainly through the involvement of the local community. Such human activities and climate variability may bring strong influence on watershed-scale hydrological and sediment responses.

Previous watershed-scale studies on hydrological and sediment responses rarely addressed the separate or combined effects of factors such as changes in land use/land cover (LULC), soil and water conservation (SWC) practices and climate variability under contrasting environments. This is profoundly due to lack of observational data such as runoff, sediment, and climate at wider spatial and longer temporal scales as well as lack of adoptable methodologies to evaluate the impacts.

On the basis of this background information, his study aimed to understand the single and combined impact of human activities (LULC changes and SWC practices) and climate variability on the spatiotemporal dynamics of hydrological and sediment responses by integrating field observations, spatial analysis, and modeling approaches. The study was conducted in three selected watersheds located in different agro-ecological environments of the Upper Blue Nile basin: Guder (highland), Aba Gerima (midland), and Debatie (lowland). The study specifically addressed the following objectives: (1) explore and evaluate LULC change, drivers and their possible implications; (2) examine hydrological responses to LULC change and climate variability and (3) examine runoff and sediment responses to SWC practices through employing alternative modeling approaches. The main results corresponding to the above three specific objectives are presented in the following subsequent sections being followed by an overall conclusion of the study.

Firstly, by integrating field observations, very high-resolution remote sensing data [0.5–3.2m], and geographic information systems, he analyzed the changes in LULC and the drivers across the three sites. The study revealed that from 1982 to 2016/17, forest land, bushland, and grazing lands respectively decreased by about 76%, 58%, and 30% in Guder; 54%, 63%, and 52% in Aba Gerima; and 69%, 45%, and 43% in Debatie. During the same period, cultivated land increased by about 38%, 97%, and 492% in

Guder, Aba Gerima, and Debatie, respectively. In contrast, between 2012 and 2017, plantation cover increased by 241% in Guder watershed, mainly at the expense of cultivated land, which in turn decreased by 32% during the corresponding period. The traditionally deleterious impacts of human activities on the environment have been recently reversed at an unprecedented rate, particularly at Guder and to a lesser extent at Aba Gerima, following the shift from the traditional annual cropping to more economically attractive tree-based farming practices such as *Acacia decurrens* plantation in Guder and khat (*Catha edulis*) cultivation in Aba Gerima. Overall, human influence on LULC has been either positive or negative depending on the study period and location of study site.

Secondly, through calibrating runoff and evapotranspriation empirical models to the local conditions of the three hydrologically-gauged watersheds, he examined the separate and combined effects of LULC change and climate variability on hydrological (annual surface runoff and evapotranspiration) responses. The observed LULC changes over the study period (1982–2016) resulted in runoff increases ranging from 4% in the midland (Kecha, Aba Gerima) to 28.7% in the highland (Kasiry, Guder) watersheds. Climate variability in terms of annual rainfall had no significant effect on estimated runoff. In contrast, evapotranspiration was affected by both LULC change and climate variability. Though climate variability increased evapotranspiration from 33.6% in the midland to 42.1% in the highland, the LULC change related to the reduction in natural vegetation had an offsetting effect, which led to overall decreases in evapotranspiration ranging from 15.8% in the highland to 32.8% in the midland. Overall, the hydrological responses in the studied sites are largely controlled by the site conditions depending on the way how the local people use and manage the land, which either mitigates or exacerbates the effects of climate variability.

Thirdly, using two alternative and widely applied approaches worldwide, he evaluated the separate and combined effects of SWC practices, LULC, and climate variability on runoff and sediment yield responses in Kecha and Laguna paired watersheds of Aba Gerima site. The paired watersheds were selected for this particular study as Kecha watershed has been under SWC program since 2011 while Laguan was not, which makes them ideal environment to address the goal of this particular study. The first (paired watershed) approach compared runoff and sediment yield data of the treated (Kecha) and untreated (Laguna) watersheds. Whereas, the second approach had compared before (baseline) and after (2011) the implementation of SWC practices, for the Kecha watershed only. The SWAT model was adopted for both treated and untreated watershed conditions. The paired watershed approach revealed that the SWC practices reduced the runoff in the treated (Kecha) watershed by about 28–36% and sediment yield by about 51–68% as compared to the untreated (Laguna) watershed. Similarly, compared with the baseline data (before 2011) in Kecha watershed, the SWC practices alone reduced the runoff and sediment yield by about 40% and 43%, respectively, which is accounting for about 65–78% of the total changes brought by LULC change, climate variability and SWC practices combined. The study also signifies a greater effect of SWC on sediment yield than on runoff by about 23–32%.

In summary, his study through integrating field observation, spatial analysis and modelling, clarified the dynamics of runoff and sediment in response to human activities and climate variability in contrasting environments of the Upper Blue Nile basin. There exists strong human influence on LULC, whose effect has been either positive or negative depending on the study period and location of study site. This observed unprecedented LULC change has brought overall direct consequences on the hydrological and sediment responses in the three sites. Whereas climate variability had exhibited positive and negative consequences on the evapotranspiration and sediment responses, respectively. The study also further revealed that implementation of SWC practices has effectively counteracted the effects of LULC change and climate variability on runoff and sediment responses. His study provided an important methodological basis for evaluating the effect of SWC practices, where particular preference can be made to the ‘before and after’ approach whenever baseline data is available. The findings of this study, therefore, provides useful information to devise future land and water management strategies for sustainable use of watershed resources in this and other basins experiencing similar impacts of human activities and climate variability. On the basis of the above background data, members of the Examining Committee unanimously voted for that the PhD thesis of Mr. Mulatu Liyew Berihun presents original research results of large importance and recommended for the award of his doctoral degree.