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SUMMARY OF DOCTORAL THESIS

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Title: Effects of land use and management practices on soil loss and soil properties in the Upper Blue Nile basin, Ethiopia
(エチオピア青ナイル川上流域における土地利用と管理策が土壌流亡および土壌特性に及ぼす影響)

Soil erosion is one of the most pressing environmental challenges in the highlands of Ethiopia where small-scale agriculture is the main source of livelihood for about 87% of country's population. Beyond soil and nutrient losses, accelerated soil erosion is causing rapid sedimentation problem that threatens the life of hydropower or irrigation reservoirs and canals in Ethiopia as well as in downstream countries such as Sudan and Egypt.

In the past few decades, huge financial and labor resources have been invested by both governmental and non-governmental organizations for the implementation of sustainable land management (SLM) practices to mitigate soil erosion in many regions of Ethiopia. The impacts of most SLM practices were better tested and well documented for the dryer areas of the northern highlands, while such relevant studies are limited for the wetter and actively eroding regions like the Upper Blue Nile basin. This is due partly to insufficient policy attention and difficulties inherent in collecting sufficient and reliable runoff, soil, and sediment data at wider spatial and temporal scales. This study was, therefore, aimed to improve our current understanding of the rates of soil loss at various spatial and temporal scales and identify SLM practices that can reduce runoff and soil loss and thereby enhance soil quality properties. The study was conducted in three contrasting agro-ecologies [i.e., Dibatie (lowland), Aba Gerima (midland), and Guder (highland) watersheds] of the Upper Blue Nile basin of Ethiopia covering the period from 2014 to 2018 and combining field survey, monitoring, and experimentation techniques. The specific objectives were to (i) better understand the variability in soil loss (sediment yield) at watershed scales with and without SLM intervention; (ii) quantify the effects of land use and management practices on runoff and soil loss (SL), and identify SLM practice/s best control soil erosion; and (iii) understand the variation in key soil properties as influenced by land use and management practices. These objectives cover chapters 2–4 of the thesis which comprises five chapters summarized as follows:

As explained by the above two paragraphs, Chapter 1 presented the introductory sections (background, problem statement, objectives, and the study area) based on the existing literatures, observed data, and facts. It provides condensed explanations of soil erosion and land degradation, and sustainable land management efforts and practices in Ethiopia.

Chapter 2 analyzed the variability of sediment yield (*SY*) in the humid tropical highland, based on discharge and sediment data monitored at the outlets of adjacent paired watersheds with (Kasiry) and without (Akusity) intervention for SLM. The measurements were done during the rainy seasons of 2014 and 2015 using gauging stations equipped with automatic flow stage sensors, manual staff gauges and a depth-integrated sediment sampler. Empirical discharge–sediment curves were created for three different parts of each rainy season to calculate *SY*. The results of the Mann-Whitney U test reveal that the daily *SY*s were significantly ($Z > -1.96$ and $P < 0.05$) higher for the watershed without SLM (Akusity) than that with SLM (Kasiry) in the two seasons. Similarly, the cumulative seasonal *SYs* for Akusity (25.7 t ha^{-1} in 2014 and 71.2 t ha^{-1} in 2015) were much higher than those observed for Kasiry (7.6 t ha^{-1} in 2014 and 27.2 t ha^{-1} in 2015). For both watersheds, however, three peak flow events accounted for a larger percentage (53% to 93%) of the seasonal *SY,* and resulted in extreme variability in daily *SY* (CV = 582% and 685% for Akusity, and CV = 313% and 586% for Kasiry during the rainy seasons of 2014 and 2015, respectively). This indicates that peak flow events are major determinants of the amount and variability of *SYs*, and thus, careful measurement of such events is crucial to better understand the dynamics of *SY* in small watersheds of tropical highland environments.

Chapter 3 examined the effects of land use and SLM practices on runoff and SL in the three agro-ecologies of the Upper Blue Nile basin. The analyses was based on runoff and sediment data collected using runoff plots (30 m × 6 m) from three land use types (cropland, grazing land, and degraded bushland) in the highland, midland, and lowland agro-ecologies of the basin. Four treatments (control, soil bund, *Fanya juu,* and soil bund reinforced with grass) for croplands, and three treatments (control, exclosure with, and without trenches) for non-croplands (grazing land, and degraded bushland) were investigated during the rainy seasons of 2015 and 2016. The results show that runoff and SL varied greatly across agro-ecologies, land use types, and SLM practices. The highest rates of both seasonal runoff (898 mm in 2016) and SL (39.67 t ha^{-1} in 2015) were observed from untreated grazing land in the midland agro-ecology, largely because of heavy grazing and intense rain events. In all agro-ecologies and land use types, both runoff and SL were significantly lower ($P < 0.05$) in plots with SLM than without, i.e., SLM practices effectively reduced runoff and SL with a relative effectiveness ranging from 11% to 68% for reducing runoff, and 38% to 94% for reducing SL, depending of land use and agro-ecology. Soil bund reinforced with grass in croplands and exclosure with trenches in non-croplands were found to be the most effective SLM practices for reducing both runoff and SL, indicating that combined structural and vegetative measures are the best way to control soil erosion and its consequences.

Chapter 4 investigated variations in soil properties among land use types and management practices. A total of 162 topsoil (0–20 cm) samples were collected and analyzed for key soil properties—texture, pH, electrical conductivity (EC), cation exchange capacity (CEC), total nitrogen (TN), soil organic carbon (SOC), available phosphorus (P_{av}), and available potassium (K_{av}). Also, 90 core samples were collected and analyzed for bulk density (BD) of topsoil. The results of one way ANOVA showed that Seven of the 11 soil properties significantly differed among the three land use types in all agro-ecologies ($P < 0.05$ to $P < 0.001$); pH, CEC, SOC, and TN values were lower in croplands than in grasslands and degraded bushlands. These imply that soil fertility under crop production has been greatly deteriorated by unsustainable cropping systems practiced over centuries. After the implementation of SLM practices, however, sensitive soil properties (BD, SOC, TN, P_{av}, and K_{av}) were markedly improved. This improvement is primarily attributed to the development of a well-established vegetation cover owing to minimum tillage and exclosures, indicating that soil degradation can best be controlled through enhancing vegetation growth and reducing soil disturbance by tillage.

Chapter 5 presented the general conclusions and recommendations based on the key findings from Chapters 2–4. Chapter 2 demonstrated that average sediment yield from the watershed with SLM intervention was 1.94 times lower than that from the watershed without; indicating that SLM interventions considerably reduced soil loss rates at watershed scales. It is also demonstrated in Chapter 3 and 4 as significantly lower runoff and SL rates, and greater values of soil quality parameters were observed in plots with SLM than without, regardless of agro-ecology and land use types. This, therefore, provides useful information that soil erosion and associated land degradation can best be controlled by implementing suitable SLM practices.

* In addition, some of the figures, etc., have been omitted.