(Form No. 14)

ABSTRACT 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 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 several SLM practices were 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 (lowland, midland, and highland) of the Upper Blue Nile basin covering the period from 2014 to 2018 and combining field survey, monitoring, and experimentation. 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 (iii) understand the variation in key soil properties as influenced by land use and management practices.

The analysis of watershed scale sediment yield (*SY*) was based on discharge and sediment data monitored during the rainy seasons of 2014 and 2015 at the outlets of adjacent paired watersheds with and without SLM intervention, in the highland agro-ecology of the basin. The effect of land use and management practices on runoff, soil loss, and soil properties was analyzed based on the 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. Runoff and soil loss rates were monitored with 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 grazing land, and degraded bushland during the rainy seasons of 2015 and 2016, whereas the variation (or change) in key soil properties — texture (proportion of clay, silt, and sand), bulk density (BD), pH, electrical conductivity (EC), cation exchange capacity (CEC), total nitrogen (TN), soil organic carbon (SOC), available phosphorus (P_{av}), and available potassium (K_{av}) — was evaluated through laboratory analysis of topsoil samples collected in 2015 and 2018.

The results of the Mann-Whitney U test revealed that sediment yield was significantly ($Z > -1.96$ and $P < 0.05$) lower for the watershed with SLM than that without, in two seasons. Also, average seasonal sediment yield from the watershed with SLM was 1.94 times lower than that from without; indicating that SLM interventions considerably reduced soil loss rates at watershed scales. Plot-scale results also showed that runoff and SL greatly varied across agro-ecologies, land use types, and SLM practices. The highest rates of both seasonal runoff (898 mm) and SL (39.67 t ha^{-1}) were

observed from untreated grazing land in the midland agro-ecology, largely because of heavy grazing and intense rain events. However, in all agro-ecologies and land use types, both runoff and SL were significantly lower ($P < 0.05$) in plots with SLM than without; SLM practices 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. The results of one way ANOVA showed that seven of the 11 studied 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 grazing lands and degraded bushlands. These imply that soil fertility under crop production has been greatly deteriorated by unsustainable cropping systems. After the implementation of SLM practices, however, sensitive soil properties (BD, SOC, TN, P_{av}, and K_{av}) were markedly improved. The greater improvement was observed in plots with greater vegetation cover (soil bund reinforced grass and exclosures) owing to the favorable natural condition maintained by fencing and minimum tillage; this suggests that soil degradation can best be controlled through enhancing vegetation growth and reducing soil disturbance by tillage. Over all, this study demonstrated that significantly lower runoff and SL rates, and greater improvement in soil quality properties can be achieved by using SLM, regardless of agro-ecology and land use types, and provides useful information that soil erosion and associated consequences can best be controlled by implementing suitable SLM practices.

Keywords: Agro-ecology, Land use, Soil erosion, SLM practices, Soil properties

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