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SUMMARY OF DOCTORAL THESIS

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Title: Role of soil microbes from remnant Church Forest to assist seedling establishment of native tree species in a degraded land

（劣化地での在来樹種の実生定着における遺された「教会の森」由来の土壌微生物の役割）

Land degradation is the top global concern identified in the 2015 Status of the World's Soil Resources report. In Ethiopia, due to its prolonged and unsustainable agricultural history, land degradation has been causing the most severe problem on agricultural production and other ecosystem services. On the other hand, there have been efforts made on countermeasures that include afforestation, and establishment of exclosures (protecting human and animal interference) implemented in different parts of the country. Though such efforts (i.e., exclosures) have improved soil fertilities and vegetation covers, achieving restored ecosystem function and diversity through the establishment of native tree species has proved a challenging task due to the slow nature of the process and poor availability of beneficial soil microbes in the degraded lands. Whereas small patches of natural forest called "Church Forests", which constitute the last remnants of the original forest cover in Ethiopia, having been conserved for more than a century. These Church Forests, on top of their social and spiritual values, they are foci of biodiversity being used for seed sources and germplasm conservation sites for native fauna and flora.

However, scientific information on key ecological indicators of land degradation or afforestation such as soil organic carbon (SOC), total nitrogen (TN) stocks are scarce to prioritize and design evidence-based land management interventions. Moreover, there is lack of studies characterizing the role of microbial communities or evaluating the inoculum potential and the effects of microbes from Church Forests on the early stages of native trees establishment in degraded lands.

Thus, the overall objective of this research is to contribute for the assisted-restoration of native trees in degraded lands through using Church Forest soils as a source of native microbes. The specific objectives were to: 1) prioritize severely degraded areas for management intervention through assessing SOC and TN stocks in different land uses and topographic positions found in three agro-ecosystems of the Upper Blue Nile basin; 2) to clarify the soil microbial potential of Church Forest soil and its effect on seedling growth of selected native trees species under glasshouse conditions and 3) to evaluate the role of Church Forest soil in assisting the seedling establishment of a selected native tree under a degraded land field conditions. This thesis consists of five chapters as described below:

Chapter 1 explains the introduction section of the study. It presents the study background, problem statement, objectives and description of the study area. Moreover, it provides an overview of land degradation and deforestation, ecological restoration efforts, the seedling establishment in degraded lands based on literature review. It then describes the aim of this study and the overall structure of the thesis.

Chapter 2 presents the SOC and TN stocks in different land uses, topographic positions of the three selected watersheds found across three agro-ecosystems of the Upper Blue Nile basin. The studied watersheds; namely, Guder, Aba Gerima and Dibatie represent the highland, midland and lowland agro-ecosystems of the basin, respectively. A total of 352 soil samples taken from 4–land uses, 3–topographic positions and 3–soil depths in the three watersheds were analyzed for SOC and TN. I found that land use, topographic positions, agro-ecosystems and their interactions have a significant influence in both stocks. Not surprisingly, the cropland located in the upper topographic position was found the most degraded land use type, likely due to higher erosion rate. However, unlike the normal assumption, plantations exhibited lower SOC and TN stocks due to poor undergrowth and overexploitation for charcoal and firewood production including the roots. Specifically, among the three watersheds, Aba Gerima was found under a severely degraded situation owing to prolonged cultivation and unsustainable human activities, thus revealing the need for immediate land management interventions.

Chapter 3 clarifies the microbial potential of soils from Church Forest in Aba Gerima and its effect on seedling establishment of *Olea europaea* and *Albizia gummifera* native tree species under glasshouse conditions. The results showed significantly higher plant height, root collar diameter, shoot and total biomass for seedlings grown in non-sterilized (with microbes) forest soils than those grown in sterilized (without microbes) soil. Furthermore, the relative abundance of *Acidobacteria, Actinobacteria, and Nitrospirae* was significantly correlated with non-sterilized forest soil bacterial community (r^2 = 0.6–0.8, $p < 0.001$). The favorable soil pH environment of the forest soils was found to affect the abundance of the bacterial community in the Church Forest soils. Overall, seedlings grown in Church Forest soils showed better performance and survival rate, because of higher soil microbial abundance and diversity, than those grown in the soil from degraded land. This effect was more noticeable on the performance of *Olea* seedlings grown in the soil from *Croton macrostachyus*. This suggests that soil from remnant Church Forests, particularly soil from beneath *Croton macrostachyus*, can serve as a good inoculum source for native tree seedling growth and survival in degraded lands.

Chapter 4 evaluated the role of Church Forest soil in assisting seedlings of *Olea europaea* establishment under a degraded land condition in Aba Gerima watershed. Plots assisted with intact Church Forest (n=3) soil and without (n=3) were arranged in randomized block design with three replicates. In each plot, 16– *Olea* seedlings were planted in 1m x 1m spacing in July 2018. Monitoring for growth-related parameters was conducted on a monthly time basis. The results showed that *Olea* seedlings assisted with soil from Church Forest had higher growth and survival than seedlings without Church Forest soil. The height of assisted seedlings with a mean value of 85.7 (±5.3) cm compared to 74.5 (±2.3) cm in non-assisted ones. Significantly higher mortality of non-assisted seedlings was observed particularly during the months of 3–6 starting from the planting date. The survival was 89% and 77% for assisted and non-assisted seedlings, respectively. The results of this study confirm that Church Forest soils can assist seedlings establishment of native tree species in degraded lands.

Chapter 5 provides a general synthesis of the whole thesis based on the key findings of Chapters 2-4. These findings confirm that Church Forest soils are endowed with beneficial native microbes (mainly bacteria and fungi), which can serve as a source for native soil inoculum. Use of this inoculum source can facilitate native trees seedlings establishment, growth and survival in degraded lands restoration.