MICROBIOLOGICAL AND MINERALOGICAL APPROACHES FOR ASSESSING AND IMPROVING SOIL QUALITY OF SALINATED AND POLLUTED AGRICULTURAL FIELDS INUNDATED BY THE 26 DECEMBER 2004 TSUNAMI IN BANDA ACEH, SUMATRA ISLAND, INDONESIA

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Abstract. At 1.5 years and 3.5 years after the 26 December 2004 tsunami disaster, soil samples (10-20 cm) were taken from four adjacent sites located in the agricultural area of Banda Aceh, Sumatra Island, Indonesia in order to investigate the impact of seawater flooding. The tsunami disaster deposited sediments containing extremely high concentrations of salts and heavy metals. The salt contents (detected as B, Na, Ca, Mg, and Cl), as well as the salinity levels (detected by electrical conductivity, EC) in tsunami-impacted soils still remained significantly increased compared to non-impacted soils, even after 1.5 and 3.5 years of intrinsic bioremediation. Heavy metals such as Pb, Cd, Zn, Cu, Ni, Co, Fe and Cr were significantly higher in impacted soils than in non-impacted soils in 2006, and they remained relatively increased in 2008, except for Cd and Pb which were significantly reduced. Tsunami-impacted soils also had higher levels of exchangeable sodium percentage (ESP: 18%), sodium adsorption ratio (SAR: 0.6-0.9) and swelling factor (0.3) than did tsunami-unimpacted soils (ESP: 1.2-2.7%, SAR: 0.1, swelling factor: 0.03-0.04), indicating that seawater flooding greatly affects soil physical properties. Furthermore, the tsunami disaster has led to an increase in macronutrients, such as N, P, K, and S, as well as to an increase in soil organic C content and C/N ratio. The tsunami-impacted soils, as assessed by FTIR analysis, contained greater amounts of hydrophilic than hydrophobic organic compounds. The mean pH of soils in tsunami-impacted soils was 7.4 (in 2006) and 7.1 (in 2008), while in non-impacted soils the pH was 5.1 (in 2006) and 5.5 (in 2008). The soil mineral composition, as assessed by XRD analysis, revealed that the tsunami-impacted soils contained the major minerals (quartz, plagioclase and goethite), minor minerals (hornblende and lepidocrocite) and clay minerals (kaolinite, smectite and illite). Non-impacted soils contained major minerals (quartz, plagioclase, goethite and hornblende), minor minerals (lepidocrocite and cristobalite) and clay minerals (kaolinite and smectite). Changes in the physicochemical and

mineralogical soil properties were reflected in changes in the microbial populations and their activities. T-RFLP analyses of the communities in tsunami-impacted soils, transitional soils that were flooded for a short time, and unimpacted soils indicated that the communities of tsunami-impacted soils differed from those of the other soils. Likewise, the basal CO_2 respiration was higher and the fluorescein diacetate (FDA) hydrolytic activity was lower in tsunami-impacted soils. The 16S rRNA pyrosequencing analysis revealed that the changes in the composition of bacterial groups were more pronounced in tsunami-impacted soils that could be attributed to the abundance of a few operational taxonomic units (OTUs). Thus, the tsunami disaster had potentially negative impacts, such as salt and heavy metal pollution, as well as potentially positive impacts, such as increases in major macronutrient contents and clay mineral composition, on agricultural soils. In addition, these results indicate that major changes in the physicochemical and mineralogical properties of agricultural soils following the tsunami disaster have lasting impacts on the microbial communities of these soils.

Key Words: Heavy metals, Salinity, ESP, SAR, Swelling factor, FTIR, XRD, T-RFLP, FDA, 16S rRNA pyrosequencing, OTU.