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Temperate agroforestry can increase soil functions compared to monocultures

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Soils provide essential ecosystem services, or soil functions, such as food production, water purification and nutrient cycling. These services are often of low value in conventional agriculture with monoculture systems but can be enhanced by agroforestry through plant interactions. In temperate alley-cropping agroforestry, rows of fast-growing trees alternate with rows of crops or grass, which may render competition or facilitation. For instance, crop growth close to the trees may be affected by shading, but tree roots below the crops can acquire deep-soil water and nutrients, which may reduce nutrient leaching. Adoptation of alley-cropping agroforestry into policy requires holistic assessment of the ecological advantages as well as productivity and economic sustainability. Our objective was to compare soil ecological and economic functions between monoculture and alley-cropping agroforestry systems. We hypothesized that agroforestry will have higher soil ecological and economic functions than monoculture. At four cropland sites and two grassland sites of Germany, with monoculture and adjacent agroforestry at each site, we measured two to seven indicators to represent each of the following six soil functions: biomass production, carbon sequestration, habitat for biological activity, filtering and storage of water, storage and recycling of nutrients, and plant health. Additionally, for cropland systems, we assessed economic functions such as profitability and risk. Our findings show that soil functions in cropland agroforestry did not differ (i.e. storage and recycling of nutrients, filtering and storage of water, or habitat for biological activity; $P > 0.05$) or were higher (i.e. production of biomass, carbon sequestration, and plant health; $P < 0.02$) than in cropland monocultures. Soil functions of grassland agroforestry did not differ from those of grassland monocultures. Cropland agroforestry yielded higher net benefits, although it presented a higher risk for farmers than cropland monocultures. Our results indicated that diminished soil ecological functions in conventional cropland monocultures can be mitigated by agroforestry. While risk is a strong driver of farmers' decision whether or not to implement cropland agroforestry, this land use has the potential to reduce external costs by enhancing carbon sequestration and improving plant health. One promising option to foster cropland agroforestry adoption is a well-designed public payment for environmental services that compensate for risk or lower profit from environmentally friendly land management.