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Temperate cropland agroforestry can increase nutrient response efficiency while sustaining productivity

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Cropland monocultures (CM) are highly productive but use high amounts of fertilizers, especially nitrogen (N). This is problematic because it results in waterway pollution, accumulation in ecosystems and gaseous losses. More sustainable agricultural alternatives need to secure food production and improve soil functions such as soil nutrient cycling and water purification. This may be achieved by more efficient use of plant-available soil nutrients, for which nutrient response efficiency (=biomass production per plant-available soil nutrient) is a suitable indicator. We hypothesized that cropland agroforestry (CAF, i.e. alley cropping of fertilized crops and unfertilized trees) is a more sustainable management alternative compared to CM. Our objective was to evaluate productivity, nutrient availability, and nutrient response efficiency of these two management systems. At three sites of CMs with adjacent CAF in central and eastern Germany, we measured productivity (annual harvestable above-ground biomass) and the plant-available soil nutrients, N, P and K, during the growing season of 2016. We calculated nutrient response efficiencies for N, P and K and assessed the relationships of biomass production and nutrient response efficiency. For CAF, area-weighted means of tree strips and crop strips were used. Productivity (3.7 - 14.9 x 103 g DM m^{-2} yr^{-1}) was not consistently higher in either one of the management systems and plant-available N (0.00 - 0.13 g N m^{-2} d^{-1}) did not differ between management systems. Plant-available P (5.4 - 12.9 g P m^{-2}) was lower in CAF at two sites and plant-available K (9.4 – 16.8 g K m^{-2}) was lower in CAF at one site compared to CM, but these plant-available soil nutrients did not differ between the crop strip of CAF and the crops in CM. Nutrient response efficiencies of N, P and K did not differ between management systems at two sites. However, at one site nutrient response efficiencies of N, P and K were higher in CAF compared to CM. The observed relationships of productivity and nutrient response efficiency with plant-available soil nutrients revealed that for N, P and K, a plateau of high productivity was reached across management systems. As a consequence, levels of nutrient response efficiencies were below the optimum peak. Our results demonstrated that CAF can use plant-available soil nutrients more efficiently than CM. We suggest that 1) CAF improves soil nutrient cycling, and b) reduction in amount of fertilization in both CAF and CM will further increase nutrient response efficiency while maintaining biomass production.