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Long-term impacts of inter-cropping and reduced tillage on ecosystem services in dryland agriculture

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We assess the long-term environmental impacts and delivery of several ecosystem services of crop diversification (inter-crop with legumes/cereal) in two rainfed almond (*Prunus dulcis* Mill.) orchards under semiarid Mediterranean conditions. In addition, the effect of the intensity of tillage practices (conventional tillage vs. reduced tillage) in the almond monocultures was also tested. The study was carried out in two farms located in the province of Murcia (South East Spain) and the experimental design consisted of nine plots (49 m long and 7 m wide) in a randomized-block design, with three replicates for each treatment: inter-crop, (IRT), monoculture under conventional tillage (MCT), and monoculture under reduced tillage (MRT). Each plot comprised five almond trees: the three central trees were used for soil measurements and the other two trees constituted guard rows (a buffer zone to avoid edge effects). The conventional tillage consists in a chisel plowing to 15 cm depth using a cultivator between three and five times a year while the reduced tillage treatments (MRT and IRT) implies ploughing only twice a year (autumn and spring), to control weeds. The tillage affects the whole plot area, including the area around the trunk base. In the monoculture, weeds are the only vegetation present between the rows. The inter-crop consists of a mix (3:1) of common vetch (*Vicia sativa* L.) and common oat (*Avena sativa* L.), sown annually during early autumn at 150 kg seeds ha⁻¹ and mowed in May. After manually mowing, it is incorporated into the soil using a cultivator.

During ten years (2009-2018) the effects of crop diversification and reduced tillage on a range of soil quality indicators (including soil physical, chemical and biological properties) were monitored allowing the evaluation of different support, regulating and provisioning ecosystem services (e.g. carbon sequestration, water availability, crop yield).

An improvement in soil quality with the inter-crop management (IRT) was detected after three years from its implementation, after which it was maintained or slightly increased for ten years. When comparing the inter-cropping system with the monoculture one, an improvement in soil quality indicators for regulating and supporting ecosystem services was observed at the plow layer (e.g., soil bulk density decrease, as well as increases in soil water retention capacity, plant water availability, infiltration capacity, fertility, microbial activity, and OC stabilized in aggregates). During the first seven years of inter-cropping implementation, an average reduction of about 30% in the

crop yield (provisioning ecosystem service) in the inter-crop treatment respect to the monoculture was observed. However, those differences decreased, or even were reversed after eight years, suggesting that the observed positive effect on crop production with inter-crops does not occur at the same time than the improvement on soil quality but several years after that. All together, these results highlight the potential of inter-cropping in woody crops as a good option to be adopted by farmers and for climate change mitigation and adaptation.