**Supplementary Methods:**

**Study System:**

The study was carried out from 2014 to 2020 at the at the United States Department of Agriculture Conservation District Farm in northeastern Montana (48°33′ N, 104°50′ W, elevation 589 m) in the northern Great Plains of the United States of America (see Lenssen *et al.* 2012 and Jabro *et al.* 2021 for site descriptions). Dryland cropping systems in the northern Great Plains region are dominated by small grains, such as winter, spring and durum wheat, planted in rotation with fallow, but rotational crops such as pulses (e.g., peas, lentils), oilseed (flax, sunflower and canola) and forages have been increasing in acreage over the last few decades (Long *et al.* 2016). There are multiple shortcomings with the traditional crop-fallow system including increased soil erosion, saline seep formation, and reduced soil water holding capacity (Hansen *et al.* 2016). While continuous cropping typically reduces soil water availability in semi-arid cropping systems compared to crop-fallow, annualized crop yields are typically greater in continuously cropped systems (Sainju *et al.* 2021). Thus, replacing fallow with alternative crop rotations has great potential in the region.

**Crop planting, harvest and management:**

All crops were planted in April to early May using a custom built no-till research drill with double shoot Barton single disk openers on 20.3 cm row spacing (Jabro *et al.* 2021). Durum ‘Grenora’ was planted at 67 kg ha-1. Camelina ‘Suneson’, carinata ‘A110’, and the 10-species cover crop mix were planted at 9.0, 7.3, and 26.9 kg ha-1 respectively. Seeding densities were based on recommendations from the developers of the varieties used for each oilseed crop, Montana State University for camelina (Suneson) and Agrisoma Biosciences for carinata (A110). Fertilizer was banded at planting 5 cm below and 5 cm to the side of seeds at rates of 56 and 45 kg ha-1 monoammonium phosphate and potassium chloride, respectively (details in Jabro et al. 2021). Preplant and post-harvest applications of glyphosate herbicide at 3.36 kg a.i. ha–1 were used to control weeds (Jabro *et al.* 2021). Additionally, durum received an in-crop application of 0.68 kg a.i. ha–1bromoxynil and 0.09 kg a.i ha–1fenoxaprop herbicides, and camelina and carinata received 9.0 kg a.i. ha–1 ethylﬂuralin in late fall preceding spring planting (Jabro et al. 2021). Cover crop plots did not receive any herbicide application after planting. Camelina and carinata were harvested with a Kincaid 8XP research combine (manufactured in Haven, KS, USA) in July-August. The cover crop mix was swathed for forage at pea bloom in mid-July. Following forage harvest, the cover crop was allowed to regrow unharvested and was terminated each year with a killing frost.

Crops included in the cover crop mix (Table S1) were selected to include multiple functional groups and species commonly recommended as cover crops in the region (see the following link: [Cover Crop Chart : USDA ARS](https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/docs/cover-crop-chart/)) (Liebig *et al.* 2013). Plants in the Brassicaceae were included to represent one of these functional groups, the cool season broadleaves. Radish and turnip are common components of cover crop mixes because their taproots can reduce soil compaction (Jabro et al., 2021). Additional functional groups included cool- and warm-season legumes, warm-season grasses and non-legume broadleaf species. Cool-season grasses were intentionally omitted from the cover crop mix, since plots were rotated with durum wheat, which represented this in functional group in alternate years. Cover crop mix seeding rates were based on 10% of monoculture recommended seeding rates for a given species, with the sum equaling 26.9 kg/ha for the ten species. For example, flax was 6% of the cc mix, i.e. 1.6 kg/ha, with a monoculture recommended planting rate of 16 kg/ha.

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