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12.3 Arable farming

| Based on the collated evidence, what is the current assessment of the effectiveness of interventions on arable farming systems for enhancing soil fertility? | |
|--|--|
| Beneficial | <ul style="list-style-type: none"> • Amend the soil using a mix of organic and inorganic amendments • Grow cover crops when the field is empty • Use crop rotation |
| Likely to be beneficial | <ul style="list-style-type: none"> • Amend the soil with formulated chemical compounds • Grow cover crops beneath the main crop (living mulches) or between crop rows |
| Trade-off between benefit and harms | <ul style="list-style-type: none"> • Add mulch to crops • Amend the soil with fresh plant material or crop remains • Amend the soil with manures and agricultural composts • Amend the soil with municipal wastes or their composts • Incorporate leys into crop rotation • Retain crop residues |
| Unknown effectiveness (limited evidence) | <ul style="list-style-type: none"> • Amend the soil with bacteria or fungi • Amend the soil with composts not otherwise specified • Amend the soil with crops grown as green manures • Amend the soil with non-chemical minerals and mineral wastes • Amend the soil with organic processing wastes or their composts • Encourage foraging waterfowl • Use alley cropping |

Beneficial

● Amend the soil using a mix of organic and inorganic amendments

- *Biodiversity*: Five controlled trials from China and India (four also randomized and replicated), and one study from Japan found higher microbial biomass and activity in soils with a mix of manure and inorganic fertilizers. Manure alone also increased microbial biomass. One trial found increased microbial diversity.
- *Erosion*: One controlled, replicated trial from India found that mixed amendments were more effective at reducing the size of cracks in dry soil than inorganic fertilizers alone or no fertilizer.
- *Soil organic carbon loss*: Four controlled, randomized, replicated trials and one controlled trial all from China and India found more organic carbon in soils with mixed fertilizers. Manure alone also increased organic carbon. One trial also found more carbon in soil amended with inorganic fertilizers and lime.
- *Soil organic matter loss*: Three randomized, replicated trials from China and India (two also controlled), found more nutrients in soils with manure and inorganic fertilizers. One controlled, randomized, replicated trial from China found inconsistent effects of using mixed manure and inorganic fertilizers.
- *Yield*: Two randomized, replicated trials from China (one also controlled) found increased maize or rice and wheat yields in soils with mixed manure and inorganic fertilizer amendments. One study found lower yields of rice and wheat under mixed fertilizers.
- *Soil types covered*: clay, clay-loam, sandy loam, silt clay-loam, silty loam.
- *Assessment*: beneficial (effectiveness 69%; certainty 64%; harms 15%).

<http://www.conservationevidence.com/actions/902>

● Grow cover crops when the field is empty

- *Biodiversity*: One controlled, randomized, replicated experiment in Martinique found that growing cover crops resulted in more diverse nematode communities. One replicated trial from the USA found

greater microbial biomass under ryegrass compared to a ryegrass/vetch cover crop mix.

- *Soil structure*: Three randomized, replicated studies from Denmark, Turkey and the UK found that growing cover crops improved soil structure and nutrient retention. One trial found higher soil porosity, interconnectivity and one lower resistance in soil under cover crops, and one found reduced nitrate leaching.
- *Soil organic carbon*: One replicated study from Denmark and one review based mainly in Japan found increased soil carbon levels under cover crops. One study also found soil carbon levels increased further when legumes were included in cover crops.
- *Soil organic matter*: Two controlled, randomized, replicated studies from Australia and the USA found increased carbon and nitrogen levels under cover crops, with one showing that they increased regardless of whether those crops were legumes or not. Two studies from Europe (including one controlled, replicated trial) found no marked effect on soil organic matter levels.
- *Yield*: One replicated trial from the USA found higher tomato yield from soils which had been under a ryegrass cover crop.
- *Soil types covered*: clay, loam, sandy clay, sandy loam, silty clay, silty loam.
- *Assessment*: beneficial (effectiveness 75%; certainty 67%; harms 16%).

<http://www.conservationevidence.com/actions/898>

● Use crop rotation

- *Biodiversity*: Three randomized, replicated trials from Canada and Zambia measured the effect of including legumes in crop rotations and found the number of microbes and diversity of different soil animals increased.
- *Erosion*: One randomized, replicated trial from Canada found that including forage crops in crop rotations reduced rainwater runoff and soil loss, and one replicated trial from Syria showed that including legumes in rotation increased water infiltration (movement of water into the soil).

- *Soil organic carbon*: Three studies from Australia, Canada, and Denmark (including one controlled replicated trial and one replicated site comparison study), found increased soil organic carbon under crop rotation, particularly when some legumes were included.
- *Soil organic matter*: Two of four replicated trials from Canada and Syria (one also controlled and randomized) found increased soil organic matter, particularly when legumes were included in the rotation. One study found lower soil organic matter levels when longer crop rotations were used. One randomized, replicated study found no effect on soil particle size.
- *Soil types covered*: clay, clay-loam, fine clay, loam, loam/silt loam, sandy clay, sandy loam, silty loam.
- *Assessment*: beneficial (effectiveness 66%; certainty 75%; harms 8%).

<http://www.conservationevidence.com/actions/857>

Likely to be beneficial

● Amend the soil with formulated chemical compounds

- *Nutrient loss*: Three of five replicated trials from New Zealand and the UK measured the effect of applying nitrification inhibitors to the soil and three found reduced nitrate losses and nitrous oxide emissions, although one of these found that the method of application influenced its effect. One trial found no effect on nitrate loss. One trial found reduced nutrient and soil loss when aluminium sulphate was applied to the soil.
- *Soil organic matter*: Four of five studies (including two controlled, randomised and replicated and one randomised and replicated) in Australia, China, India, Syria and the UK testing the effects of adding chemical compounds to the soil showed an increase in soil organic matter or carbon when nitrogen or phosphorus fertilizer was applied. One site comparison study showed that a slow-release fertilizer resulted in higher nutrient retention. One study found higher carbon levels when NPK fertilizers were applied with straw, than when applied alone, and one replicated study from France found higher soil carbon when manure rather than chemical compounds were applied.

- *Yield*: One replicated experiment from India showed that maize and wheat yield increased with increased fertilizer application.
- *Soil types covered*: clay, fine loamy, gravelly sandy loam, loam, sandy loam, silty, silty clay, silt-loam.
- *Assessment*: likely to be beneficial (effectiveness 64%; certainty 46%; harms 19%).

<http://www.conservativevidence.com/actions/909>

● **Grow cover crops beneath the main crop (living mulches) or between crop rows**

- *Biodiversity*: One randomized, replicated study from Spain found that cover crops increased bacterial numbers and activity.
- *Erosion*: Two studies from France and the USA showed reduced erosion under cover crops. One controlled study showed that soil stability was highest under a grass cover, and one randomized replicated study found that cover crops reduced soil loss.
- *Soil organic matter*: Two controlled trials from India and South Africa (one also randomized and replicated) found that soil organic matter increased under cover crops, and one trial from Germany found no effect on soil organic matter levels.
- *Soil types covered*: gravelly sandy loam, sandy loam, sandy, silty loam.
- *Assessment*: likely to be beneficial (effectiveness 65%; certainty 54%; harms 19%).

<http://www.conservativevidence.com/actions/897>

Trade-off between benefit and harms

● **Add mulch to crops**

- *Biodiversity*: Three replicated trials from Canada, Poland and Spain (including one also controlled, one also randomised and one also controlled and randomised) showed that adding mulch to crops (whether shredded paper, municipal compost or straw) increased soil animal and fungal numbers, diversity and activity. Of these, one trial also showed that mulch improved soil structure and increased soil organic matter.

- *Nutrient loss*: One replicated study from Nigeria found higher nutrient levels in continually cropped soil.
- *Erosion*: Five studies from India, France, Nigeria and the UK (including one controlled, randomised, replicated trial, one randomised, replicated trial, two replicated (one also controlled), and one controlled trial) found that mulches increased soil stability, and reduced soil erosion and runoff. One trial found that some mulches are more effective than others.
- *Drought*: Two replicated trials from India found that adding mulch to crops increased soil moisture.
- *Yield*: Two replicated trials from India found that yields increased when either a live mulch or vegetation barrier combined with mulch was used.
- *Soil types covered*: clay, fine loam, gravelly sandy loam, sandy, sandy clay, sandy loam, sandy silt-loam, silty, silty loam.
- *Assessment: trade-offs between benefit and harms* (effectiveness 60%; certainty 64%; harms 23%).

<http://www.conservationevidence.com/actions/887>

● Amend the soil with fresh plant material or crop remains

- *Biodiversity*: One randomized, replicated experiment from Belgium found increased microbial biomass when crop remains and straw were added.
- *Compaction*: One before-and-after trial from the UK found that incorporating straw residues by discing (reduced tillage) did not improve anaerobic soils (low oxygen levels) in compacted soils.
- *Erosion*: Two randomized, replicated studies from Canada and India measured the effect of incorporating straw on erosion. One found straw addition reduced soil loss, and one found mixed effects depending on soil type.
- *Nutrient loss*: Two replicated studies from Belgium and the UK (one also controlled and one also randomized) reported higher soil nitrogen levels when compost or straw was applied, but mixed results when processed wastes were added.

- *Soil organic carbon*: Three randomized, replicated studies (two also controlled) from China and India, and one controlled before-and-after site comparison study from Denmark found higher carbon levels when plant material was added. One found higher carbon levels when straw was applied along with NPK fertilizers. One also found larger soil aggregates.
- *Soil types covered*: clay, clay-loam, loam/sandy loam, loamy sand, sandy, sandy clay-loam, sandy loam, silt-loam, silty, silty clay.
- *Assessment: trade-offs between benefit and harms* (effectiveness 53%; certainty 53%; harms 34%).

<http://www.conservativevidence.com/actions/910>

● Amend the soil with manures and agricultural composts

- *Biodiversity loss*: Three controlled, replicated studies from the UK and USA found higher microbial biomass when manure or compost was applied, and higher microbial respiration when poultry manure was applied.
- *Erosion*: One controlled, randomized, replicated study from India found lower soil loss and water runoff with manure application in combination with other treatments.
- *Nutrient management*: Two randomized, replicated studies from Canada and the UK (one also controlled) found lower nitrate loss or larger soil aggregates (which hold more nutrients) when manure was applied, compared to broiler (poultry) litter, slurry or synthetic fertilizers. One study found that treatment in winter was more effective than in autumn and that farmyard manure was more effective than broiler (poultry) litter or slurry in reducing nutrient loss. One controlled, replicated study from Spain found higher nitrate leaching.
- *Soil organic carbon*: Three studies (including two controlled, replicated studies and a review) from India, Japan and the UK found higher carbon levels when manures were applied.
- *Soil organic matter*: One controlled, randomized, replicated study from Turkey found higher organic matter, larger soil aggregations

and a positive effect on soil physical properties when manure and compost were applied. One study from Germany found no effect of manure on organic matter levels.

- *Yield*: Four controlled, replicated studies (including four also randomized) from India, Spain and Turkey found higher crop yields when manures or compost were applied. One study found higher yields when manure were applied in combination with cover crops.
- *Soil types covered*: clay-loam, loam, loamy, sandy loam, sandy clay-loam, silty loam, sandy silt-loam.
- *Assessment: trade-offs between benefit and harms* (effectiveness 70%; certainty 59%; harms 26%).

<http://www.conservationevidence.com/actions/911>

● Amend the soil with municipal wastes or their composts

- *Erosion*: Two controlled, replicated trials in Spain and the UK measured the effect of adding wastes to the soil. One trial found that adding municipal compost to semi-arid soils greatly reduced soil loss and water runoff. One found mixed results of adding composts and wastes.
- *Soil types covered*: coarse loamy, sandy loam.
- *Assessment: trade-offs between benefit and harms* (effectiveness 45%; certainty 44%; harms 54%).

<http://www.conservationevidence.com/actions/890>

● Incorporate leys into crop rotation

- *Nutrient loss*: One replicated study from Denmark showed that reducing the extent of grass pasture in leys reduced the undesirable uptake of nitrogen by grasses, therefore requiring lower rates of fertilizer for subsequent crops.
- *Soil types covered*: sandy loam.
- *Assessment: trade-offs between benefit and harms* (effectiveness 46%; certainty 45%; harms 36%).

<http://www.conservationevidence.com/actions/900>

● Retain crop residues

- *Biodiversity*: One replicated study from Mexico found higher microbial biomass when crop residues were retained.
- *Erosion*: One review found reduced water runoff, increased water storage and reduced soil erosion. One replicated site comparison from Canada found mixed effects on soil physical properties, including penetration resistance and the size of soil aggregates. One replicated study from the USA found that tillage can have mixed results on soil erosion when crop remains are removed.
- *Soil organic matter*: One randomized, replicated trial from Australia found higher soil organic carbon and nitrogen when residues were retained, but only when fertilizer was also applied.
- *Yield*: One randomized, replicated trial from Australia found higher yields when residues were retained in combination with fertilizer application and no-tillage.
- *Soil types covered*: clay, loam, sandy loam, silt-loam.
- *Assessment*: trade-offs between benefit and harms (effectiveness 63%; certainty 54%; harms 29%).

<http://www.conservationevidence.com/actions/907>

Unknown effectiveness (limited evidence)

● Amend the soil with bacteria or fungi

- *Biodiversity*: One randomised, replicated trial from India showed that adding soil bacteria and arbuscular mycorrhizal fungi resulted in higher microbial diversity.
- *Soil organic matter*: One controlled, randomised, replicated trial from Turkey found increased soil organic matter content in soil under mycorrhizal-inoculated compost applications.
- *Yield*: Two randomised, replicated trials (including one also controlled) from India and Turkey found higher crop yields.
- *Soil types covered*: clay-loam, sandy loam.
- *Assessment*: unknown effectiveness (effectiveness 40%; certainty 31%; harms 17%).

<http://www.conservationevidence.com/actions/888>

● Amend the soil with composts not otherwise specified

- *Soil organic matter*: One controlled, randomised, replicated trial in Italy found that applying a high rate of compost increased soil organic matter levels, microbial biomass and fruit yield.
- *Soil types covered*: silty clay.
- *Assessment: unknown effectiveness* (effectiveness 54%; certainty 29%; harms 19%).

<http://www.conservationevidence.com/actions/889>

● Amend the soil with crops grown as green manures

- *Soil organic matter*: Two controlled, randomized, replicated studies from India and Pakistan found higher soil organic carbon, and one found increased grain yields when green manures were grown.
- *Soil types covered*: clay-loam.
- *Assessment: unknown effectiveness* (effectiveness 53%; certainty 36%; harms 16%).

<http://www.conservationevidence.com/actions/908>

● Amend the soil with non-chemical minerals and mineral wastes

- *Nutrient loss*: Two replicated studies from Australia and New Zealand measured the effects of adding minerals and mineral wastes to the soil. Both found reduced nutrient loss and one study found reduced erosion.
- *Soil types covered*: sandy clay, silt-loam.
- *Assessment: unknown effectiveness* (effectiveness 35%; certainty 37%; harms 23%).

<http://www.conservationevidence.com/actions/892>

● Amend the soil with organic processing wastes or their composts

- *Nutrient loss*: Two controlled, replicated trials from Spain and the UK (one also randomized) measured the effect of adding composts to soil. One trial found applying high rates of cotton gin compost and poultry manure improved soil structure and reduced soil loss, but

increased nutrient loss. One trial found improved nutrient retention and increased barley *Hordeum vulgare* yield when molasses were added.

- *Soil types covered*: sandy clay, sandy loam, silty clay.
- *Assessment: unknown effectiveness* (effectiveness 58%; certainty 35%; harms 20%).

<http://www.conservationevidence.com/actions/891>

● Encourage foraging waterfowl

- *Soil organic matter*: One controlled, replicated experiment from the USA found increased straw decomposition when ducks were allowed to forage.
- *Soil types covered*: silty clay.
- *Assessment: unknown effectiveness* (effectiveness 14%; certainty 34%; harms 20%).

<http://www.conservationevidence.com/actions/711>

● Use alley cropping

- *Biodiversity*: A controlled, randomized, replicated study from Canada found that intercropping with trees resulted in a higher diversity of arbuscular mycorrhizal fungi.
- *Soil types covered*: sandy loam.
- *Assessment: unknown effectiveness* (effectiveness 36%; certainty 23%; harms 19%).

<http://www.conservationevidence.com/actions/903>