Figure S1. Number of papers published per year, studying the relationships between soil compaction and crop yield. Searched by "soil compaction * yield" in Web of Science, from 1980 to 2021

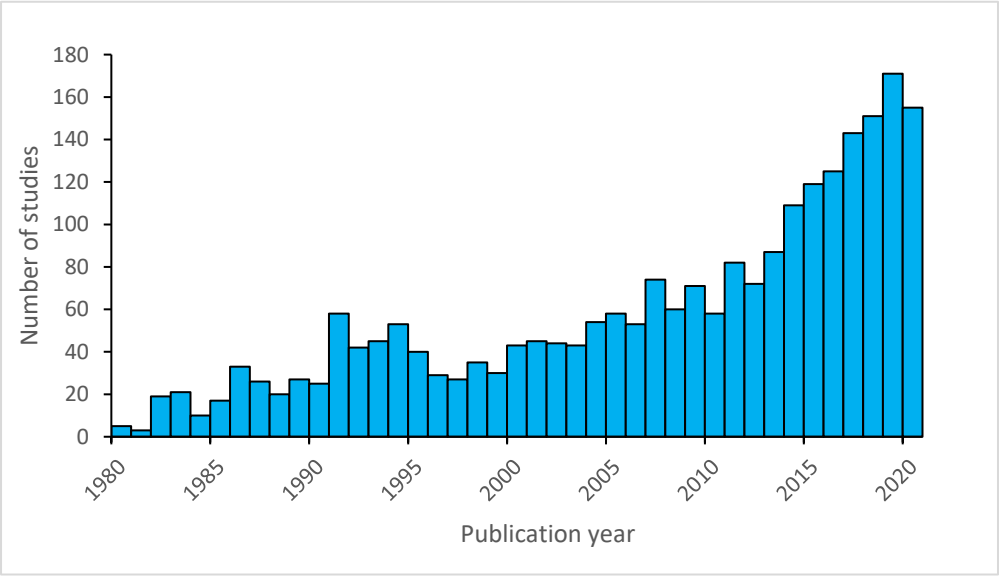


Table S1. Data and information used for this meta-analysis.

See the excel file.

Table S2. Soil compaction prevention, remediation and alleviation measures; their mechanisms and limitations.

	Measures	Description/explanation/ definition	Main limitations
Prevention	Controlled traffic	A machinery management system that confines all field vehicles to the least possible area of permanent traffic lanes [1]. Basic mechanism is to avoid irreversible plastic deformation of the soil, through minimizing the ground contact area of wheels [2].	Limitations to the adoption of controlled traffic include the high entry cost and the fact that there are often long intervals between machinery replacements on farms and the relative complexity of ensuring proper matching of axle and implement widths [1].
	No tillage	Planting crops into untilled soil, by opening a narrow slot trench or band for proper seed coverage [3]. It avoids the negative effects of conventional tillage, i.e., erosion, runoff, nutrient loss, and bulk density increases with rainfall [4]. Higher saturated and unsaturated hydraulic conductivity due to continuity of pores or flow of water through very few large pores; higher soil water storage and water use efficiency; higher SOC in surface soil [5].	Increased cost of weed control, heavier use of chemical herbicides; Elevated moisture levels in the topsoil may promote fungal diseases; yield decreases (especially in the short term).[6]
	Minimum tillage	Similar to no tillage	Lower yield; more weed control needed [6].
	Harrowing tillage	A harrow whose cutting edges are a row of concave metal discs, which may be scalloped, set at an oblique angle. It helps in breaking up clods and surface crusts, enhances soil granulation and surface uniformity and prevent weed growth and destroys already existing weeds [7].	Only the soil within the vicinity of the disc harrow action (0–20 cm) was influenced [8].

	Rotary tillage	The loosening and inverting of soil to a depth of 20–25 cm with a rotating tines or blades.	As rotary tillage only works on topsoil compaction, it can't cover crop residues at soil surface, and it even brings residues to sowing depth, thereby affecting crop emergence rate. Ploughing pan is formed because of shallow tillage, therefore decreasing soil nutrient and moisture absorption, thus, decreasing yield [9, 10].
Remediation	subsoiling	Breaking up the hardpan layer or compacted layer without turning the soil and burying fertile topsoil in the subsoil [11]. Used to shatter dense subsurface soil horizons that limit percolation of water and penetration of roots [12].	Requires a lot of power and energy; its effect tends to last only shortly if the field traffic is not controlled [12]. Excessive subsoiling may also contribute to increased subsoil compaction, as pressure from vehicle traffic may be propagated downward to depths below the tillage zone [13]. Increases the vulnerability to re-compaction by subsequent machinery traffic and grazing animals [14].
	Deep ploughing	A ploughing the soil to a depth of 40–50 cm or more [15]; To break up high density soil layers. It improves water infiltration and movement in the soil, enhances root growth and development, and ultimately increases crop production [16, 17].	Deep ploughing turns soil horizons and results in complete or semi-complete inversion of the soil profile, with subsoil horizons ending up at the soil surface and topsoil horizons buried in the deep soil [18]. It reduces diversity and number of earthworms [19]. It requires a lot of power and energy. In the long-term, it may induce deterioration of soil structure and a reduction of aggregate stability [20].
	Crop rotation	high soil disturbance to compacted top and sub-soil during mechanized harvest; biological drilling [21].	Limited by types of crops;
Alleviation	Residue returning	Increase soil organic matter, binding soil mineral particles, reducing aggregate wettability and increasing mechanical strength of soil aggregates [22, 23], therefore, neutralize the yield loss of compacted soil.	Residue cover can intercept rainfall at drought [24]; or lead to excessive soil moisture and water logging in flood [25]; and result in lower soil temperatures in cooler climates [26]. residue mixed with soil cause excess low bulk density and lead to low water/nutrient availability

Controlled irrigation	Alleviate water deficiency incurred by soil compaction; affects soils pore structure and related water infiltration capacity through altering hydraulic stresses [27, 28].	Negative effects on crop yields and soil bulk density were also detected [29, 30].
Manure application	Provide nutrient, and alleviate yield loss due to water and nutrient deficiency.	possible air pollution due to N_2O emission and water pollution due to leaching [31].

References for Table S2

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