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Limited effect of organic matter on soil available water capacity

B. Minasny & A. B. Mcbratney

Sydney Institute of Agriculture, The University of Sydney, 1 Central Avenue, 2015 Eveleigh, New South Wales Australia

Summary

Soil water-holding capacity is an important component of the water and energy balances of the terrestrial biosphere. It controls the rate of evapotranspiration, and is a key to crop production. It is widely accepted that the available water capacity in soil can be improved by increasing organic matter content. However, the increase in amount of water that is available to plants with an increase in organic matter is still uncertain and may be overestimated. To clarify this issue, we carried out a meta-analysis from 60 published studies and analysed large databases (more than 50 000 measurements globally) to seek relations between organic carbon (OC) and water content at saturation, field capacity, wilting point and available water capacity. We show that the increase in organic carbon in soil has a small effect on soil water content. A 1% mass increase in soil OC (or 10 g C kg^{-1} soil mineral), on average, increases water content at saturation, field capacity, wilting point and available water capacity by: 2.95, 1.61, 0.17 and 1.16 mm H_2O 100 mm soil^{-1}, respectively. The increase is larger in sandy soils, followed by loams and is least in clays. Overall the increase in available water capacity is very small; 75% of the studies reported had values between 0.7 and 2 mm 100 mm^{-1} with an increase of 10 g C kg^{-1} soil. Compared with reported annual rates of carbon sequestration after the adoption of conservation agricultural systems, the effect on soil available water is negligible. Thus, arguments for sequestering carbon to increase water storage are questionable. Conversely, global warming may cause losses in soil carbon, but the effects on soil water storage and its consequent impact on hydrological cycling might be less than thought previously.

Highlights

- We investigated how available water capacity can be increased with a 1% increase in soil organic carbon.
- We analysed data from 60 published studies and global databases with more than 50 000 measurements.
- The increase in organic carbon in soil has a small effect on soil water retention.
- A 1% mass increase in soil OC on average increased available water capacity by 1.16%, volumetrically.

Introduction

Soil water-holding capacity is one of the most important soil factors for plant growth, influencing carbon allocation, nutrient cycling and the rate of photosynthesis. Studies have shown that in many parts of the world, soil water-holding capacity controls yield and its volatility (Yang *et al*., 2014; Williams *et al*., 2016), and increasing soil water-holding capacity by the addition of organic matter (OM) was suggested as a means to buffer yields against future variable weather conditions. In addition, sequestering carbon in the soil by the addition of OM has been reported to contribute to the mitigation of climate change (Lal, 2004, 2006; Williams *et al*., 2016; Minasny *et al*., 2017). Furthermore, enhancing soil organic carbon (OC) can improve soil quality, for example by increasing nutrient retention, promoting aggregation and improvement in soil structure, and enhancing soil biotic activity and improvements in soil moisture and temperature regimes (Lal, 2004). Increasing soil OC is also suggested as a means of drought management (Lal, 2004).

The positive effect of OC on soil water retention has been much studied (Hudson, 1994; Rawls *et al*., 2003) and widely promoted, but there is still no clear consensus on its quantitative effect. Some studies have reported positive effects (Bauer & Black, 1992), whereas others showed a limited effect (Bell & Van Keulen, 1995). Some reports even present huge effects, for example a report by Maynard (2000) cited that the addition of leaf compost to soil in an inner city garden increased the soil's water-holding capacity by 7.5 mm 100 mm^{-1} soil. The validity of such an estimate is yet to be verified.

Correspondence: B. Minasny. E-mail: budiman.minasny@sydney.edu.au
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Given the paucity of such quantitative evidence-based information, we wished to answer the question: how many millimetres increase in available water capacity can be expected with an increase in soil organic carbon (OC) of $10\,\mathrm{g\,kg^{-1}}$ mineral soil (or 1%)? We carried out a meta-analysis on the reported quantity of water retention at saturation (SAT), field capacity (FC) and wilting point (WP) in relation to an increase in OC content. Consequently, we calculated the amount of water that is available to plants (AWC) as the difference between FC and WP. We also analysed various local, national and global soil databases and derived empirical relations that enable direct estimation of the effect of OC. We calculated the change in water content (expressed in either per cent mass or per cent volume, $\Delta\theta$) with an increase in OC (expressed in per cent mass, Δ(OC)), or $\Delta\theta/\Delta$(OC). Finally, we compiled this information to determine the best evidence-based estimates of OC effects.

Methods

Literature review

We conducted a literature review for studies that relate water retention and organic matter content; in particular, water content at saturation (SAT), field capacity (FC) and wilting point (WP). In some studies, SAT was assumed to be the same as total porosity. Field capacity is taken as water content at −5 kPa for studies from the UK, −10 kPa for studies from Australia, and −33 kPa for studies from the USA. There are also field-measured values equivalent to FC known as drained upper limit (DUL), the water content at which drainage from a pre-wetted soil had become negligible (Ratliff *et al.*, 1983). Wilting point is measured more consistently at −1500 kPa. Wilting point in the field is also known as crop lower limit (CLL), the soil water content at which plants were almost dead or dormant as a result of the water deficit. Available water capacity (AWC) is the difference between FC and WP. We recognize that there are differences in the definition of field capacity from different studies that may affect the calculation of AWC.

The criteria for the inclusion of material for this study were:

- Studies that examined the effect of application of organic amendments (e.g. sludge, compost, mulch, manure or management [e.g. no till]) on soil hydraulic properties (e.g. Kladivko & Nelson, 1979; Jordán *et al.*, 2010). The studies needed to report OM or OC content with one of the following water retention properties: SAT, FC, WP or AWC.
- Studies that compared areas with different soil OC contents (e.g. Bauer, 1974; Ankenbauer & Loheide, 2017).
- Pedotransfer function (PTF) studies, which derived empirical relations between soil water content at different potentials as a function of soil texture and OC (e.g. Gupta & Larson, 1979; Rawls *et al.*, 2003).

We differentiated studies that measured gravimetric water content (w in per cent mass $\mathrm{g\ 100\,g^{-1}}$) and those that measured volumetric water content (θ in per cent volume $\mathrm{mm\ 100\,mm^{-1}}$). Reported organic matter content was converted to organic carbon (OC) using the van Bemmelen factor of 0.58. We then calculated the change in water content (expressed in either per cent mass or per cent volume) with an increase in OC (expressed in per cent mass), or $\Delta\theta/\Delta$(OC).

For studies on the application of organic amendments to the soil, we selected only studies that showed a difference in treatment of at least $10\,\mathrm{g\,kg^{-1}}$ OC. We then fitted a linear regression between OC and θ and estimated the slope of the line as $\Delta\theta/\Delta$(OC).

For databases with different soil texture and mineralogy, the following linear relation was established to include the effect of soil texture:

$$\theta = b_0 + b_1\mathrm{Clay} + b_2\mathrm{Sand} + b_3\mathrm{OC}. \tag{1}$$

The response of OC to θ was estimated from the coefficient b_3.

For published pedotransfer functions where the relationships are linear, similar to Equation (1) above (e.g. Gupta & Larson, 1979), we took the regression coefficient of OC as estimates of $\Delta\theta/\Delta$(OC). For published PTFs with complex nonlinear equations (e.g. Rawls *et al.*, 2003) or parametric PTFs (e.g. Wösten *et al.*, 1999), which predicted parameters of a water retention function, we calculated the increase in θ at SAT, FC and WP with an increase in OC from 0.5 to 1.5% for each percentage of sand and clay content of a texture triangle. This increase in OC was used because it represents the most reasonable change in OC in agricultural soil from the addition of organic matter.

We also grouped the response of OC based on soil texture into three groups, following the USDA soil texture classes:

- Coarse texture (clay 0–35%, sand 44–100%), which includes: sand, loamy sand, sandy clay loam and sandy loam.
- Medium texture (clay 0–40%, sand 0–52%), which includes: loam, clay loam, silt, silt loam and silty clay loam.
- Fine texture (clay 36–100%, sand 0–64%), which includes: clays, sandy clay and silty clay.

Here we define sand according to the USDA classification as particles between 50 and 2000 μm.

Analysis of soil databases

We took advantage of databases that have been compiled for various purposes, such as national collation for mapping, or for deriving PTFs. We analysed local, national and international data that contain measured water retention, particle-size distribution and OC content. These include:

- The International Geosphere-Biosphere Programme Data and Information System (IGBP-DIS) soil database (Tempel *et al.*, 1996), which contains a uniform set of global soil data for the development of pedotransfer functions. The dataset contains data from ISRIC and USDA NRCS. To avoid overlap with the NCSS data described below, which are also used in this study, we used only data from ISRIC. Field capacity was measured at −33 kPa gravimetrically.

- The UNSODA (UNsaturated SOil hydraulic Database) (Nemes *et al*., 2001), which contains measured soil water retention, texture and OC content of soil samples from around the world. We used samples from undisturbed cores only, with FC set at a volumetric water content of −33 kPa.
- GRIZZLY (Haverkamp *et al*., 1997), which is a database that contains 660 soil samples collected from laboratories and field experiments in different countries. Field capacity (FC) was set at a volumetric water content of −33 kPa.
- Ritchie *et al*. (1987) compiled a database of field-measured soil water limits and laboratory-measured properties from the USA. Drained upper limit (DUL), equivalent to FC, has the largest measured water content of a soil after it had been wetted and allowed to drain until drainage rate is negligible. Crop lower limit (CLL) represents the smallest water content of a soil after plants have stopped extracting water (Ratliff *et al*., 1983).
- The APSRU (Agricultural Production Systems Research Unit) project, which contains measurements of DUL and CLL throughout Australia, including the southwest of Australia, Victoria, New South Wales, Queensland and some areas in Tasmania (Dalgliesh *et al*., 2006).
- Forrest *et al*. (1985) contains measurement of soils from eastern Australia (mainly in southern Queensland to southern Australia), where FC was measured from undisturbed cores at the potential of −10 kPa.
- Prebble (1970) contains soil profile measurements from Queensland, where water content at a potential of −33 kPa was used to represent FC.
- Geeves *et al*. (1995) includes soil data from wheat-growing areas in southern NSW and northern Victoria, Australia; water content at a potential of −33 kPa was used to represent FC.
- The National Soil Site Collation or NSSC (Searle, 2014) is a compilation of Australian soil data collected by research and government agencies. The NSSC database contains soil measurements from survey and research projects throughout the country. We selected two sets of data from this database, which contains measured water retention, soil texture and OC.

For each database, we fitted a linear model as in Equation (1), and we calculated the response of OC to θ from the slope of the regression. For databases with a large variation in soil texture, we fitted a separate regression for each of the soil texture groups.

The neural network model

To model and understand the effect of OC on water retention more consistently, we derived point PTFs to predict water content at saturation (SAT), −33 kPa (FC) and −1500 kPa (WP) from the National Cooperative Soil Characterization (NCSS) database. The NCSS is a national soil characterization database available from the USDA at the Natural Resources Conservation Service (Soil Survey Staff, 1995) that contains more than 100 000 samples with measurements of soil texture, organic carbon content, and water retention at saturation (SAT), −33 kPa (FC) and −1500 kPa (WP) from the USA. We filtered the data for outliers, and excluded histosols and soil with andic properties because they behaved differently from mineral soil. Water content was measured gravimetrically and was converted to a volumetric basis by the corresponding bulk density. We used only data with OC content less than 10%, which is usually more common in agricultural soil. In addition, we split the data into topsoil (observed depth of 0–30 cm) and subsoil (30–100 cm); this resulted in 27 638 data.

We fitted a feed-forward neural network model (Hornik *et al*., 1989) to the data. The network has five hidden units with inputs: sand, clay, OC and output of water content at SAT, FC and WP. To account for variation in the data we ran a bootstrap, a sampling with replacement method (Efron, 1979) with 100 realizations. Therefore, we had 100 neural network models and we used the average of the models as a prediction.

Results

Gravimetric water content

We needed to differentiate between studies that measured gravimetric and volumetric water content. We found 25 studies in which gravimetric water content (w) had been measured with estimates of $\Delta w/\Delta(\mathrm{OC})$ (Table S1, Supporting Information). The data in Figure 1 show that the average increases in gravimetric water content (g 100 g^{-1}) with an addition of 10 g kg^{-1} (or 1%) OC are: 4.6, 3.7, 1.4 and 2.1 for saturation, FC, WP and AWC, respectively. Table 1 lists the summary of the analysis. This result is in contrast with the early conclusions of Riley (1981) and Jong (1983), who indicated that increased OC contents resulted in a shift of the whole water retention curve, or increased water contents at all potentials.

With the van Bemmelen factor set to 0.58, an increase of 1% OM would increase the saturation level by 2.7% only, of which 1.2% is considered to be available to plants.

Volumetric water content

For volumetric water content (θ), we found 19 studies that derived empirical relations between water retention and OC (PTF studies) and 16 studies on the effect of OM addition on water retention, and analysed 12 datasets to estimate $\Delta\theta/\Delta(\mathrm{OC})$ (Table S2, Supporting Information). The results for volumetric water content (Figure 2) are similar to those for gravimetric water content, and we can see that the average increases in volumetric water content (θ) with an addition of 1% (10 g kg^{-1}) OC are: 2.9, 1.6, 0.17 and 1.2 mm 100 mm^{-1} for SAT, FC, WP and AWC, respectively (Table 2).

The increases in θ when we considered all textures (general relations) are modest. However, if we make a distinction based on texture, the increase is much larger in coarse-textured soil, followed by medium-textured soil and least in fine-textured soil. In general, the largest increase in volumetric water content is at saturation or total porosity, followed by FC and a small increase in WP (Table 2).

The increases in θ in coarse-textured soil for SAT, FC and WP are: 4.6, 2.3 and 0.9 mm 100 mm^{-1}, respectively. For medium-textured soil θ increased by 3.6, 2.1 and 0.7, respectively,

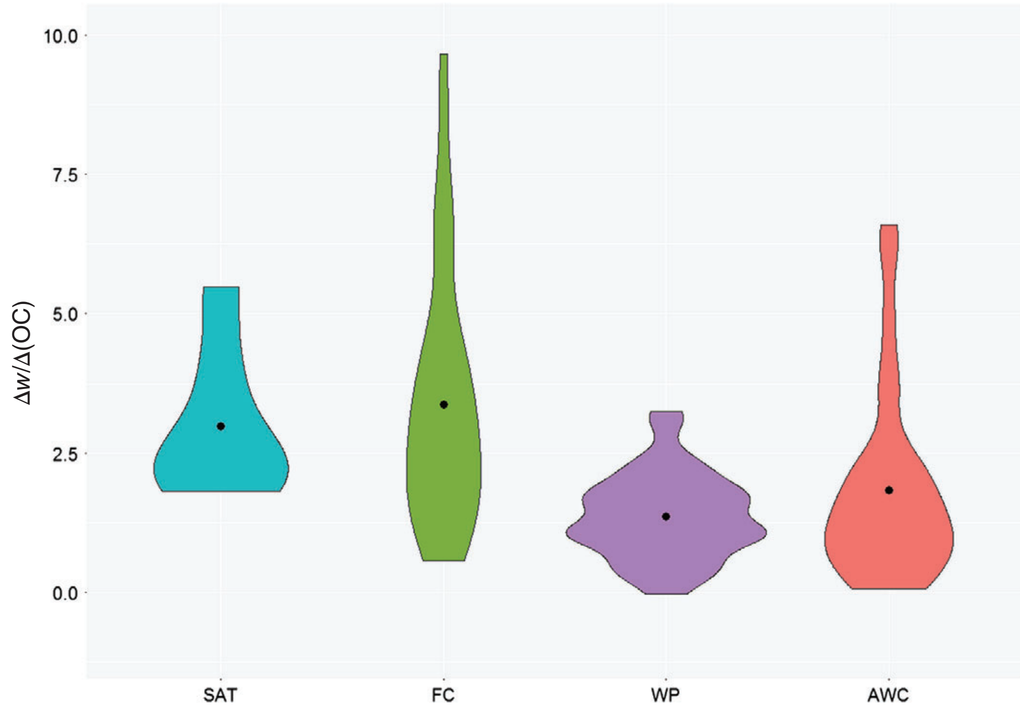

Figure 1 A violin plot of reported $\Delta w/\Delta$(OC), rate of increase in gravimetric water content (g 100 g^{-1}) with a 10 g kg^{-1} increase in OC. A violin plot is similar to a boxplot, where each side represents the density plot of the variable. The point in the middle of the violin represents the mean of the data. OC, organic carbon; SAT, saturation; FC, field capacity; WP, wilting point; AWC, available water capacity.

Table 1 The rate of gravimetric water content increase (g H_2O 100 g^{-1} soil) with an increase of 10 g C kg^{-1} mineral soil.

	SAT	FC	WP	AWC
Mean	4.61	3.71	1.36	2.13
Standard deviation	3.43	2.93	0.77	2.35
n	9	32	33	30

SAT, saturation; FC, field capacity; WP, wilting point; AWC, available water capacity; *n*, number of samples.

Table 2 A summary of the rate of increase in volumetric water content (mm H_2O 100 mm^{-1} soil) with an increase of 10 g C kg^{-1} mineral soil.

Texture		SAT	FC	WP	AWC
General	*n*	14	23	20	19
	Mean	2.95	1.61	0.17	1.16
	SD	1.53	1.54	1.55	1.01
Coarse	*n*	12	19	18	19
	Mean	4.59	2.33	0.86	1.94
	SD	2.17	2.96	1.74	1.28
Medium	*n*	12	22	21	21
	Mean	3.59	2.11	0.68	1.79
	SD	1.65	1.74	1.19	1.5
Fine	*n*	9	12	11	11
	Mean	3.23	1.28	0.54	1.41
	SD	2.09	2.05	1.74	1.95

SAT, saturation; FC, field capacity; WP, wilting point; AWC, available water capacity; SD, standard deviation; *n*, number of samples.

and for fine-textured soil by 3.2, 1.3 and 0.5 mm 100 mm^{-1}. The increase in AWC is modest, with an average of 1.9 mm 100 mm^{-1} in coarse-textured soil to 1.4 mm 100 mm^{-1} in fine-textured soil. The average values are similar to those of Hudson (1994), who reported that Δ(AWC)/Δ(OC) was 1.28 for sands and 2.51 for silt loam. Seventy-five per cent of the studies reported increases in AWC of between 0.7 and 2.1 mm 100 mm^{-1} with a 10 g kg^{-1} increase in soil OC. Negative values of $\Delta\theta/\Delta$(OC) also occur in 25% of the data for FC and 2.5% for WP and AWC, especially in fine-textured soils.

Discussion

The results from various studies and databases showed consistently that the increase in water content with the addition of organic matter is greatest for saturation (potential of 0 kPa), followed by field capacity (−10 or −33 kPa) and wilting point (−1500 kPa). Organic matter can increase soil's water retention directly and indirectly. Many reports, either from laboratory or field studies, have shown consistently that bulk density decreases (and thus porosity increases) with increasing OM, irrespective of texture (Adams, 1973). A hypothesis of this increase is that it results from dilution of the soil matrix with the less dense organic material (Soane, 1990; Kay, 1998). The mixture model of Adams (1973)

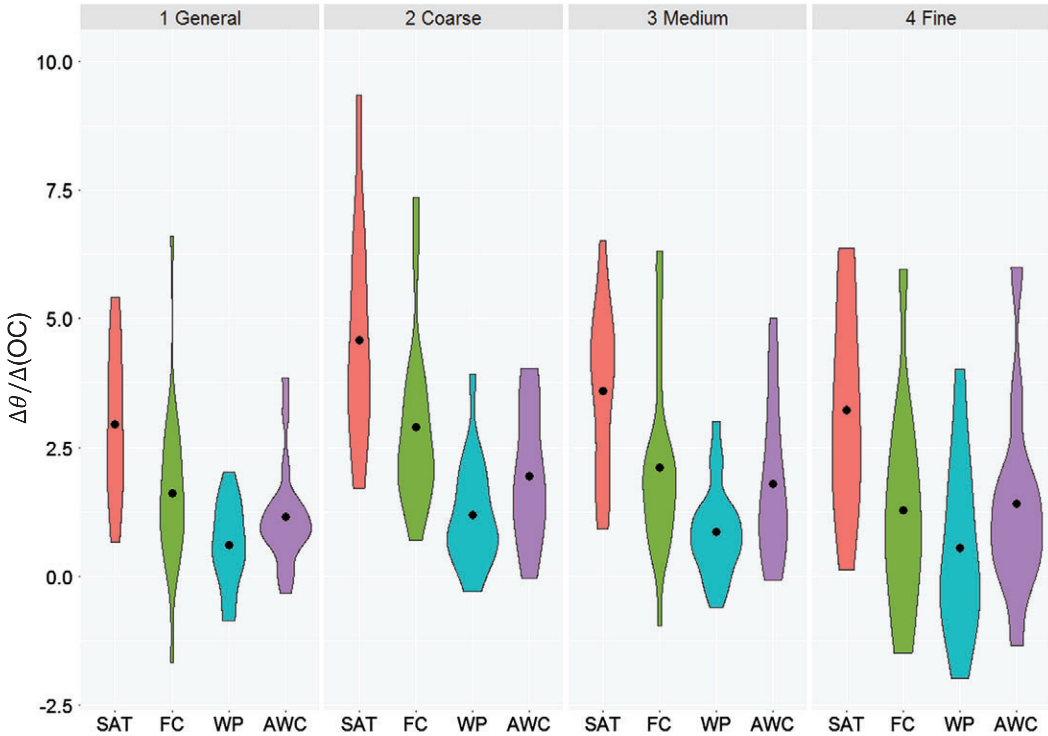

Figure 2 A violin plot of reported $\Delta\theta/\Delta(\mathrm{OC})$, rate of increase in volumetric water content (mm 100 mm^{-1}) with a 10 g kg^{-1} increase in OC grouped by texture class. A violin plot is similar to a boxplot, where each side represents the density plot of the variable. The point in the middle of the violin represents the mean of the data. OC, organic carbon; SAT, saturation; FC, field capacity; WP, wilting point; AWC, available water capacity.

estimated that the total porosity increases 2.1 mm 100 mm^{-1} with 1% (10 g kg^{-1}) increase in OC. This model implied that organic matter does not interact with the mineral framework (Honeysett & Ratkowsky, 1989).

Other proposed mechanisms include improvement of aggregation and structure, and the large surface area of organic matter (Sharma & De Datta, 1994; Franzluebbers, 2002). The formation of stable soil aggregates could create larger volumes of macropores, mesopores and micropores (Kay, 1998). Giusquiani *et al*. (1995) show by an examination of thin sections that plots treated with composts had more elongated pores (>50 μm) than the control. There is also a hypothesis that OM increases a soil's surface area; however, the small increase in water content at WP (equivalent to a pore diameter of 0.2 μm), which is controlled mainly by adsorption forces, does not seem to support this idea.

Experiments on the addition of organic matter to soil do not always show positive results for an increase in water retention at field capacity and wilting point. Earlier research suggested that OM affected the AWC for coarse-textured soils only with less than 20% clay content (Jamison & Kroth, 1958; MacRae & Mehuys, 1985). There is another possibility that increased aggregation does not necessarily translate into an increase in AWC because increased aggregation can decrease the micropore volume (MacRae & Mehuys, 1985). Such speculation is yet to be verified, however.

Despite all these inconsistent findings and controversy, our meta-analysis from many studies and empirical relations derived from a large number of samples show consistently that there is a positive effect of OC on water retention; however, this effect is mainly on water content at saturation and decreases with increasing water suction. The large effect of OC on porosity and bulk density leads to the assumption that its effect on soil water retention can be substituted by bulk density in pedotransfer functions (Zacharias & Wessolek, 2007).

To visualize the effect of OC, we developed a neural network model using a large database ($n = 27\,638$) from the USDA NRCS, which predicts θ at SAT, FC and WP from inputs of clay, sand and OC. The results were consistent with our meta-analysis showing that the increase is largest for saturation, followed by FC and WP (Table 2). Interestingly, our model revealed that the increase in water retention $\Delta\theta/\Delta(\mathrm{OC})$ for subsoil was larger than for topsoil. The average $\Delta\theta/\Delta(\mathrm{OC})$ values for SAT, FC and WP for topsoil were 2.68, 1.04 and 0.27 mm 100 mm^{-1}, respectively, and for subsoil 5.41, 1.36 and 0.55 mm 100 mm^{-1}, respectively. A possible explanation for the more pronounced effect on subsoil is that topsoil values are affected by management and cultivation practices. Nevertheless, the larger increase for both FC and WP made the increase in AWC smaller in subsoil.

Figure 3 shows the response of water retention with increasing OC. As expected, the largest increase is in SAT, followed by FC

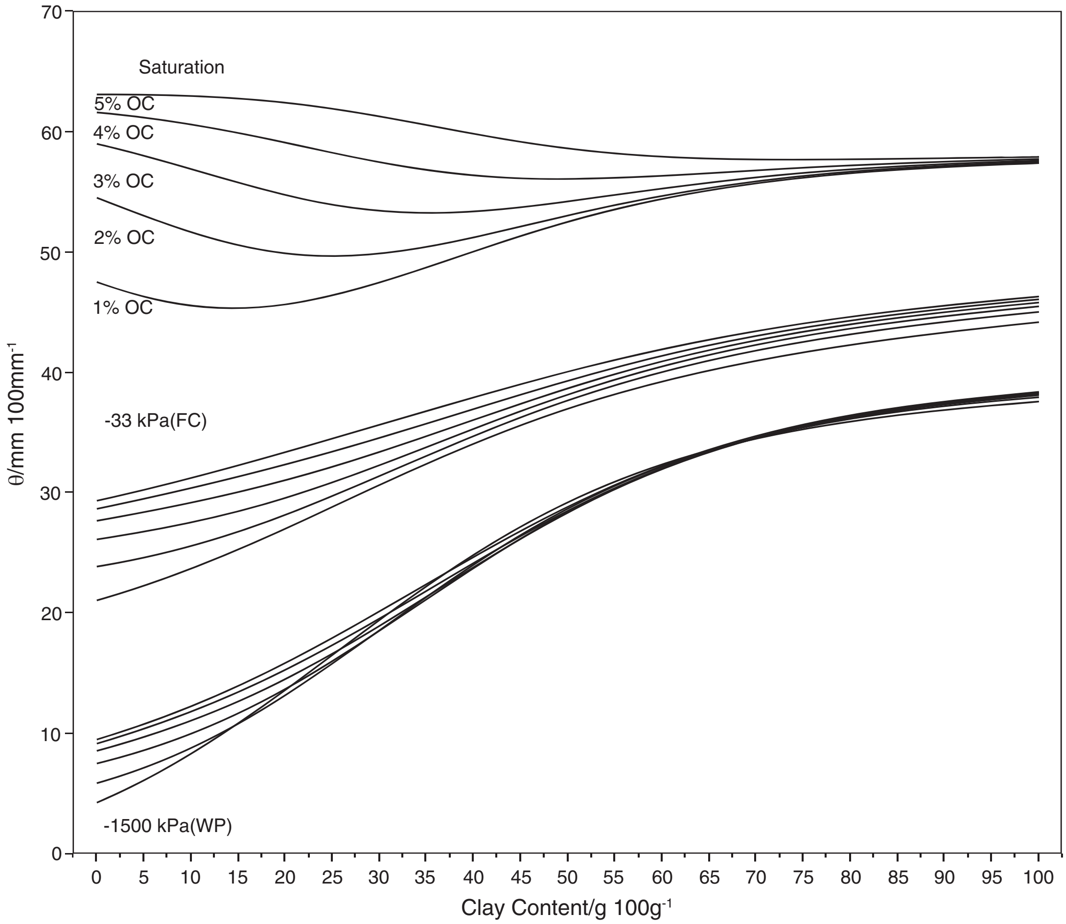

Figure 3 Modelled response of water content at SAT, FC and WP with increasing clay content (on the *x*-axis) and OC content (lines on the graph). The line for each water content represents OC at 1, 2, 3, 4 and 5%, successively. The model was trained on the NSSC dataset. SAT, saturation; FC, field capacity, WP, wilting point; OC, organic carbon.

and WP. The largest increase is from 0 to 1% OC, and the increase tends to become smaller with increasing OC content. There are diminishing returns associated with adding more and more organic carbon. The increase in water content is significant for sandy soils with 0 to 20% clay content, and becomes smaller from 20 to 40% clay and insignificant when clay is greater than 40%. As both FC and WP increase with increasing OC content, the largest gain in AWC occurs in sand–sandy clay loams (Figure 4). The result for FC is similar to those presented by Rawls *et al*. (2003), except that our result did not show a negative effect with an increase in OC for clay content larger than 60%.

We are aware of the limitations of this study, and we list some of those to be considered.

- The analysis used data with a definition of field capacity based on a potential of either −10 or −33 kPa. These differences might affect the results for AWC, and in addition field capacity could be more dynamic depending on a soil's internal drainage (Assouline & Or, 2014). Nevertheless, our analysis also included field-determined FC data, the DLL. However, such data (e.g. Ritchie *et al*. (1987)) did not show the significance of OC for predicting DUL.
- Our analysis was based on a compilation of studies with the addition of or amendment with organic matter, management effects and soils with varying organic matter contents. Treatment studies also vary in terms of short- and long-term additions of different organic amendments and management. Soils with different mineralogy might have different responses to organic carbon contents. The types of organic matter can also be an important factor in determining aggregation. Nevertheless, results from controlled studies of OM addition (such as Daynes *et al*., 2013) showed similar results to PTF studies (e.g. Hudson, 1994). We analysed the difference between estimates from PTFs and treatment-effect studies and showed that, except for FC, both groups of data showed similar median values (Table S3, Supporting Information). The Δ(FC)/Δ(OC) for treatment studies had a slightly smaller median value (1.32) than that for PTF studies (2.01).
- This study does not explicitly consider the effect of plants (such as a cover crop) on soil water storage (e.g. Basche *et al*., 2016).

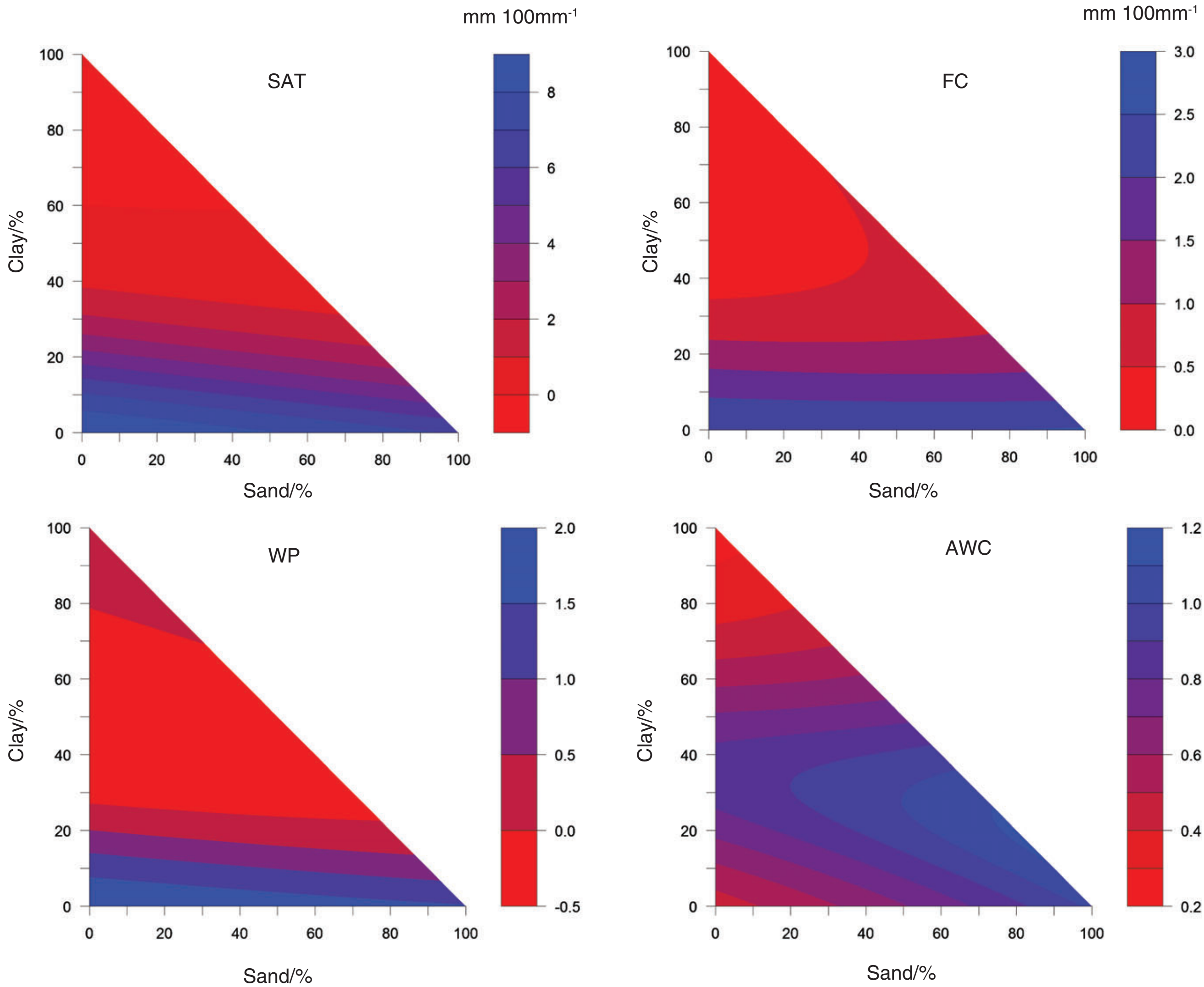

Figure 4 Modelled response of the rate of increase in water content (mm 100 mm^{-1}) at SAT, FC, WP and AWC with an increase in OC content from 5 to 15 g kg^{-1} as a function of sand and clay contents. The model was trained on the NSSC dataset. Sand is defined as particles between 50 and 2000 μm. SAT, saturation; FC, field capacity: WP, wilting point, AWC, available water capacity; OC, organic carbon.

Daynes *et al*. (2013) demonstrated that including plants further enhanced the effect of OM on soil water retention.

- Pedotransfer functions using clay, sand and OC contents (Equation (1)) might not resolve all of the variation in water retention. Structural effects such as compaction, biopores, other cementing agents (such as Fe oxides and $CaCO_3$) and shrinking and swelling clays are not resolved by this model. We chose a simple multiple linear model (Equation (1)) rather than more complex data mining models because it is more straightforward for deriving the effect of OC. The accuracy of the linear model for various databases is also quite good (Table S2), with average R^2 values increasing from SAT, FC and WP: 0.4, 0.6, 0.7, respectively.
- We used the van Bemmelen factor of 0.58 for converting between OM and OC; the actual value might vary with texture.

These limitations do not detract from our conclusions. Climate-smart farming practices such as conservation agriculture have been advocated to build up soil carbon, and thus improve water-holding capacity. However, the rate of soil carbon sequestration and resulting increase in available water capacity do not correspond. Application of OM to soil does not translate directly to its build up in soil. Studies on the effect of best management practices resulted in an annual sequestration rate of 0.1–1.0 Mg C ha^{-1} (Minasny *et al*., 2017) or 0.005–0.05% C for topsoil (0–15 cm), which translates to a negligible annual increase of 0.01–0.1 mm 100 mm^{-1} for a coarse-textured topsoil. The benefits of conservation agriculture might be through indirect effects of mulching that reduce evaporation and runoff, improved soil aggregation and enhanced biogeochemical functioning. Studies that showed a large increase in AWC applied organic matter at large rates, which are not applicable in real farming conditions. For example, Jordán *et al*. (2010) showed an increase in AWC of 3.7 mm 100 mm^{-1} after application of 10 Mg ha^{-1} of mulch for an increase in 40 g kg^{-1} of OC. Similarly, Ankenbauer & Loheide (2017) showed an increase in AWC from 17 g to 37 mm 100 mm^{-1} in a meadow for an increase of 150 g kg^{-1} OC.

Although there is little effect of OM on AWC for plant uptake, the increase in water content at SAT might be relevant for other hydrological functions. The increased storage at SAT is useful for the additional retention of water in soils during periods when the soil is close to FC. This additional storage resulting from an increase in OC content can improve the buffering capacity of soils against flooding events. In addition, increased SAT is usually accompanied by increased saturated hydraulic conductivity and infiltration capacity.

Conclusions

From the large number of studies and databases we analysed, we concluded that the effect of addition of OM on soil-available water capacity was modest, with average values of between 1.4 and 1.9 mm 100 mm^{-1} per 10 g kg^{-1} increase in OC. Sandy soil was more responsive to the increase in OC, whereas the effect on clayey soil was almost negligible. The largest effect of OC was in large pores, possibly from the formation of macroaggregates, and its effect decreases with a decrease in size of pores.

The results also suggest that the gradual loss of organic matter from soil would have a minimal effect on the hydrological cycle. Global warming might cause a loss in soil carbon, but the effects on soil water availability to plants and consequent effects on the hydrological cycle might be less than we thought previously. The negative feedback could be less serious. In addition, suggestions that sequestering carbon would increase soil water storage are questionable. We have shown that even with the best scenario of farm management practices, available water capacity cannot be increased meaningfully. Nevertheless, storing carbon in the soil should still be pursued for improving soil structure, atmospheric CO_2 attenuation and nutrient cycling. Macropores created by organic matter can still have important effects in increasing infiltration and gas transport.

Supporting Information

The following supporting information is available in the online version of this article:

Table S1. A compilation of studies with estimates of the increase in grams of water (g H_2O 100 g^{-1}) with an increase in 1 g OC per 100 g mineral soil.

Table S2. A compilation of studies with estimates of the increase in volume of water (mm H_2O 100 mm^{-1}) with an increase in 1 g OC per 100 g mineral soil.

Table S3. The statistical distribution of $\Delta(\theta)/\Delta(\mathrm{OC})$ for studies listed in Table S2 that compare amendment or treatment studies and PTF studies for coarse, medium and fine-textured soils. The median test examines whether the equality of the medians from the two types of studies is different.

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