CORRESPONDENCE:

No-till agriculture and climate change mitigation

To the Editor — Recently Powlson *et al.*[1] published a Perspective in *Nature Climate Change* that strongly refers to Chapter 4 of the 2013 UNEP Emissions Gap Report[2]. They argue that we used mitigation potentials of no-tillage agriculture that are overly optimistic, which would lead to unrealistic expectations regarding no-tillage as a greenhouse-gas mitigation option. Below we respond to a few critical points of their review, although it merits a more in-depth discourse:

First, Powlson *et al.*[1] take important information out of context and misinterpret it. In the introduction to the chapter[2] we refer to a global mitigation potential of 1.1–4.3 $GtCO_2e\ yr^{-1}$. This does not relate to no-tillage only, as their Perspective suggests, but to the global annual mitigation potential of the entire agriculture sector. The range was taken directly from the 2011 and 2012 UNEP Emissions Gap reports, which derived their estimate from Smith *et al.*[3] and Golub *et al.*[4].

Second, Powlson *et al.*[1] would reach similar values when applying the mitigation potentials derived from their review to our activity data. We estimated past mitigation (or rather, avoided emissions) since conversion to no-tillage in a few countries for which the relevant activity data was available, by multiplying climatically disaggregated mitigation potentials with changes in area in a way similar to calculating an inventory. Next to the best estimate of cumulative avoided emissions, we also present here the wide ranges based on the uncertainties reported by Smith *et al.*[3] (Table 1). When applying this approach to the annual mitigation potential of no-till that Powlson *et al.*[1] propose, that is, 0.3 $tC\ ha^{-1}\ yr^{-1}$ or 1.1 $tCO_2\ ha^{-1}\ yr^{-1}$, the avoided emissions are higher than those presented by us. Even considering a decline in mitigation due to saturation consistent with that proposed in their Perspective would not lead to changes in magnitude. This suggests that all our estimates lie well within the range that can be derived from their study.

Third, Powlson *et al.*[1] do not improve existing greenhouse-gas mitigation potentials. While better mitigation potentials of no-till are sorely needed to more accurately represent the recalcitrance of soil organic carbon, its distribution with soil depth, the relationship between soil carbon concentration and mass, and a declining mitigation potential with time, it is unclear whether the single value they propose really presents a better option than the regionally disaggregated dataset we used. Considering the growing demand to estimate mitigation benefits following the introduction of improved agricultural practices at national scales, an inventory approach is often the only feasible option. In that regard we believe that our results give a fair overview of what has been achieved through the introduction of no-till.

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Nowhere do Powlson *et al.*[1] acknowledge the question that lay at the heart of our study: what are the mitigation co-benefits of technology change supported by agricultural development polices? Our work provided some answers and showed the urgent need

Table 1 | Achieved adoption and GHG mitigation through no-till management in selected countries.

Country	Climate zone*	Years since introduction	Area 2007–2008† (ha)	Mitigation‡			Mitigation§ from Powlson *et al.*[1] ($MtCO_2$)
				Low ($MtCO_2e$)	Mean ($MtCO_2e$)	High ($MtCO_2e$)	
Australia	warm-dry	32	17,000,000	-209.4	95.2	402.6	299.2
New Zealand	cool-moist	15	162,000	-0.1	0.7	1.4	1.4
China	cool-dry	9	2,000,000	-4.9	1.6	8.1	10.3
Kazakhstan	cool-dry	2	1,200,000	-0.6	0.2	1.0	1.3
USA	cool-moist	34	26,493,000	-18.2	241.3	509.8	500.7
Canada	cool-moist	23	13,481,000	-6.2	82.3	173.9	170.8
Brazil	warm-moist	16	25,502,000	-89.0	145.7	382.4	222.6
Argentina	warm-moist	15	19,719,000	-66.9	109.4	287.2	167.2
Bolivia	warm-moist	12	706,000	-1.9	3.1	8.1	4.7
Uruguay	warm-moist	9	655,100	-1.2	2.0	5.3	3.1

Although the mean shows significant mitigation due to the introduction of the practice, the large ranges are indicative of the uncertainties surrounding the assessment of carbon stock changes and GHG fluxes from soils, and point to the urgent need for more, spatially explicit and better defined activity data and mitigation potentials, particularly in developing countries. See ref. 2 for additional information. *Lacking better understanding where no-till has been introduced, we assume one climate zone throughout the country, considering, where possible, the regional distribution of no-till agriculture. †From Derpsch *et al.*[5], except for Australia and China[2]. ‡Mitigation estimates are based on mitigation potentials from Smith *et al.*[3] and were calculated by linearly extending annual adoption rates. The high range surrounding the mean is an indication of how uncertain the estimate is. §Achieved mitigation when applying the global mitigation potential of 0.3 $tC\ ha^{-1}\ yr^{-1}$, which translates into 1.1 $tCO_2\ ha^{-1}\ yr^{-1}$, as suggested by Powlson *et al.*[1], to the same activity data used for ref. 2.

for relevant information in formats useful to informed decision-making. There is much to do in that regard. ❐

References
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Reply to 'No-till agriculture and climate change mitigation'

Powlson *et al.* reply — In our recent Perspective[1], we concluded that no-till agriculture offered only limited potential for mitigating climate change through soil carbon (C) sequestration, in contrast to the claims made in the agriculture chapter of the 2013 UNEP Emissions Gap Report[2]. The authors of the UNEP report disagree with our conclusion and we are happy to respond to their comments[3]. They are correct that we concentrated totally on no-till rather than other agricultural practices as a means of mitigating climate change. This was deliberate because current uptake of no-till — and its probable rate of adoption in the medium term — is far greater than for the other practices mentioned, such as agroforestry and biochar applications to soil. And we have no disagreement with their comments on climate change mitigation through improved water and nutrient management and reduced use of fossil fuels — in fact, alterations to water and nutrient management are probably the most effective approaches in all agricultural systems, not only rice production.

We agree with Neufeldt *et al.*[3] that estimating soil C accumulation following adoption of no-till using a 'bottom-up' approach is, in principle, preferable to the 'top-down' method we used. In their Correspondence, Neufeldt *et al.*[3] accomplish bottom-up estimations of avoided emissions for specific countries by multiplying the area under no-till by a climate-relevant value for the annual rate of increase in soil organic C under the practice. They acknowledge the considerable uncertainty in rates of accumulation under no-till: for example, their estimate for Australia ranges from over 400 $MtCO_2e$ saved from past no-till adoption to additional emissions of over 200 $MtCO_2e$ compared with conventional cultivation[3]. In the face of such uncertainty the strong promotion of no-till as an effective means of climate change mitigation in the UNEP Emissions Gap Report[2] looks distinctly unjustified.

In our Perspective[1] we explained the numerous reasons why measurements of soil C change under no-till are almost always overestimates. These errors will have influenced the published values such as those of Smith *et al.*[4] and used by Neufeldt *et al.*[3], yet they continue to ignore them. They further ignore the findings from a large body of experimental data that we cited[1], showing either small rates of soil C accumulation under no-till or no effect in a substantial number of cases.

> No-till agriculture can deliver significant benefits for farmers and sustainability in many situations: reduced GHG emissions are a small but important additional benefit

Neufeldt *et al.* arrive at their estimations of future avoided emissions by assuming that historic rates of adoption of no-till over the past 2–34 years will continue indefinitely[3]. This assumption is highly questionable because in countries covering large areas where no-till is already widely adopted (for example, Australia, USA, Canada, Brazil, Argentina) the change in tillage practice will already have occurred in the most suitable situations.

A recent theoretical study[5] came to the conclusion that C sequestration in agricultural soils through changed management practices, including no-till, could provide "only a humble contribution to solving the climate problem of the coming decades". Of course, even small contributions are welcome — put colloquially, every little helps. But it is important that scientists are realistic when making statements about the relative magnitudes of mitigation achievable through different options. This is essential for assisting policymakers to arrive at evidence-based decisions on the prioritization of possible options. A recent meta-analysis[6] drew attention to the risk of crop yield losses in many environments if no-till is not accompanied by crop residue retention and/or crop diversification — together with no-till these practices are elements of 'conservation agriculture' so, from the viewpoint of food security and farmer livelihoods, caution is needed in proposing no-till alone as done by Neufeldt and colleagues[2,3].

We see no reason to alter the conclusion from our original Perspective[1]: "No-till agriculture can deliver significant benefits for farmers and sustainability in many (though not all) situations: reduced GHG emissions are a small but important additional benefit, not the key policy driver for its adoption." ❐

References
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