Addendum to "*Soil Syst*. 2018, 2, 64" on SOC & NPP

Robert J. Blakemore [1,2]*

[1] VermEcology, 101 Suidomichi, Nogeyama, Yokohama-shi, Kanagawa-ken 231-0064, Japan.
[2] Kanagawa Prefectural Museum of Natural History, Odawara, Kanagawa-ken 247-0007, Japan.
* rob.blakemore@gmail.com

Abstract: This addendum briefly revisits conclusions whilst clarifying three likely errors in the original land recalibration paper. Soil is confirmed as both the greatest sink and source for excess atmospheric CO_2. Most terrestrial net primary production (NPP = ~218 Gt C/yr) is ultimately processed in topsoil and soil organic carbon (SOC) stocks now total >10,000–12,000 Gt. More excess carbon is released into the air and water from SOC loss (>20 Gt C/yr) due to land clearance for pasture/crops, fires, agrichemical poisoning and erosion, than from fossil fuels (~10 Gt C/yr). NOAA's Barrow bounce and isotopic analyses support high terrestrial flux up to ~800 Gt C/yr and CO_2 turnover time of ~1–4 years. Earth's re-humification via compost offers the best and only practical/time-critical fix for climate, strategy for species extinction plus remedy for human health.

Keywords: topography; soil carbon sequestration; humus; earthworms; climate, vermi-compost.

---

1. Introduction

A 10-yr case study by the author (Blakemore 2018b *Soil Sys.* 2, 64)[1] presented a reasoned argument that undulating and rugose terrain was being neglected in most accounts of natural resources. When considered, fractal land-surface area at least doubles, from prior flat 15 Gha to >30 Gha with three major, ecologically interlinked consequences: 1/. Soil organic carbon (SOC) raises from 1500–3000 to >8580 Gt; 2/. Global biomass and biodiversity at least double (Blakemore 2018b: figs. 11–15, tab. 10)[1]; and 3/. Net primary production (NPP) estimates grow from ~60 to ~218 Gt C/yr. Latest atmospheric isotope research implicitly supports these land recalibration results.

Three likely errors in the original paper require clarification and an objection by proponents of French 4p1000.org also needs a reply as their manifesto claims: "*If we take the land area of the world as 149 million km²* [14.9 Gha], *it would be estimated that on average there are 161 tonnes of SOC per hectare*" yet they falsely report global SOC of just 1500 Gt (e.g web.archive.org/web/20191205162521/https://www.4p1000.org/ accessed 27th May, 2020) despite many authors already having given much higher estimates. For example, SOC total by Reiners (1973)[2] was 9120; IPCC (2013)[3] had up to 4800; Lal et al. (2011: 1)[4] 4600 (plus 1700 inorganic carbon); Köchy et al. (2015)[5] 3000; and "HWSD" dataset 2469.5 Gt to 1 m (Heiderer & Köchy 2011: 50, tabs. 11,18)[6] that doubled for >1 m is >4938 Gt. Determining a true SOC value is imperative.

2. Subsequent Studies Supporting SOC Stock Raise

Overall, the original study (Blakemore 2018b: tab. 5)[1] found flat soil surfaces are about doubled for measurements down to sample size of cm², or quadrupled at mm² scale. Greater soil area accommodates more plants/biocrust/phytomenon and has more exposure to the elements thereby validating productivity (NPP) and soil organic matter (SOC) increases. Grounded studies subsequent to the 2018 terrain/topsoil recalibration paper tend to confirm new concepts and support elevated results, in particular SOC stocks reasonably raised above 8580 Gt to >10,000–12,000 Gt partly due to starting values now much higher than just 1500–3000 Gt SOC, e.g.:

1. IPCC's most recent report (IPCC 2019a: 2-97)[7] has: "*global soil organic carbon (SOC) stock down to 1 m depth, varying between 2500 Pg to 3400 Pg* [cf. 4p1000.org 1500 Pg!] *with differences among databases largely attributable to C stored in permafrost*". Median SOC value of ~3000 Gt doubled >1 m is ~6000 and, if reasonably doubled again for neglected terrain, is ~12,000 Gt.
2. IPCC (2019a, 2019b)[7–8] values consolidated with cryosols (permafrost) and peats are 4700–5600 Gt (median ~5000) to >3 m depth, readily doubled for terrain to ~10,000 Gt SOC.
3. Tifafi et al. (2018)[9] found datasets, e.g. SoilGrids's 3421 Gt, underestimate field data by >40% to likely give >5700 Gt SOC to just 1 m soil depth (doubled for depth = ~11,400 Gt?).
4. Gross & Harrison (2019)[10] cite bulk density (BD) errors in SOC field data up to -36%.
5. Cotching (2018)[11] confirmed national SOC databases (e.g. Australia or UK) to limited depths underestimate on-the-ground field survey results by 8–83%.
6. Nichols & Peteet (2019)[12] report an overlooked 510 Gt extra SOC in northern peatlands.
7. Blakemore (2019a, 2019b, 2020)[13–15] collates how bulk density, flat-Earth, shallow soil and peat miscalculations now raise SOC totals from low earlier figures to >10,000 Gt.
8. Crowther et al (2019: fig. 2C)[16] falsely claims just 1500 Gt SOC (from 4p1000.org?), but their SoilGrids dataset graph has 4595 Gt to 2 m (pers. obs.) that may be doubled for terrain and soil deeper than 2 m plus an extra 510 Gt peat to >10,000 Gt SOC (Figure 1).

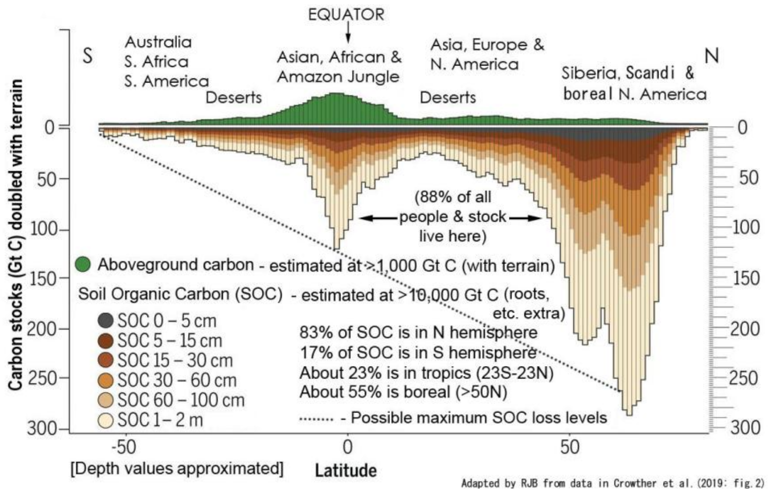

Figure 1. Adapted from Crowther et al. (2019: fig. 2C)[16] clearly demonstrating relative importance and geographical allocations of flammable trees and other aboveground vegetation vs. soil SOC carbon storage to just 2 m (yet base of boreal permafrost may reach 1.5 km). Forests are cleared and land degraded mainly to satisfy excessive red-meat diets. Options for re-greening of dishes and of deserts, especially in over-grazed Australia, India, N. Africa and Mid East, offer greatest global potential for restoration of lost humus. Cf. Blakemore (2018: figs. 11–12, tab. 10)[1].

Blakemore (2018b: 19, tab. 6)[1] stated: "*Tangible sub-samples are taken on the ground at fixed core sample volumes with a constant planimetric area (cm^{-2} or m^{-2} perpendicular to the centre of the Earth) and then multiplied by a biome's area, thus mass may be adjusted to comply only by adding biome area by adding terrain/topsoil relief.*" As elaborated via emails and blog (Blakemore 2019b)[14], key points are:

1. SOC was upped not only for terrain, but also due to global soil bulk density re-calculations that compel revision in a way that only terrain can explain.

2. Bulk density and soil carbon data **are** planimetric because all vertical samples are sliced horizontally so blindly ignore terrain yet **all** calculations must be for truly bumpy biomes.

Two likely outcomes are either these many results of more than 1500 Gt SOC are wrong (and earth *is* flat), or else the objectors' planimetric model is false. Some flaws in a shifting geometry argument (and how inadequate sampling fails to reflect real-life terrain so cannot possibly account for soils' true total carbon content) are shown in Figure 2 (cf. Blakemore 2018b: figs. 1, 6–9, A1–4)[1].

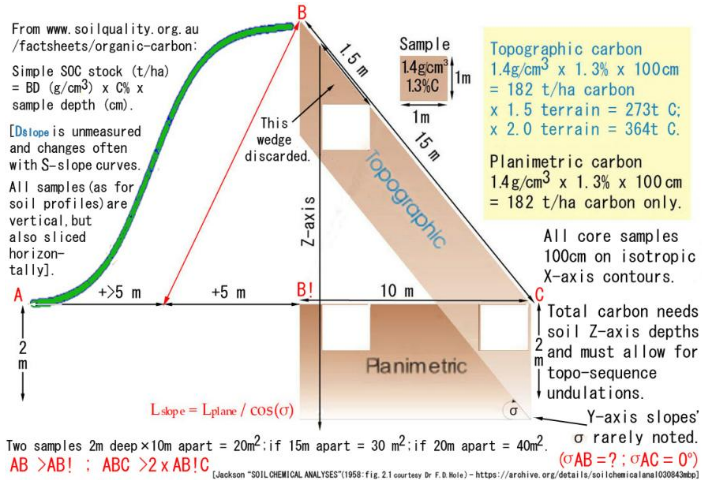

Figure 2. Idealized soil sampling for bulk density, % carbon and total SOC. Shifting shape invariably changes area. An Asian tamanoren bead-curtain of length L, if tilted 48° (red angle arrow) due to gravity reduces its planimetric footprint by a third from $L_{slope} = L_{plane} / \cos(\sigma)$ but not its composition: Albeit compressed, also offset. Properly leveled, the conceptual curtain's footprint ups +50%. Soil samples – like bead-strings – are always vertical to depth. Plus sigmoid curvature and tortuosity (green) along a natural slope's Y-axis transect may stretch its true surface area by another +50%, or +100% overall. Any up slope has an equal down slope somewhere to further double this effect. A tip-truck with its constant soil content is another analogy. As most land on Earth is demonstrably non-flat, all biome calculations henceforth require recalibration for real topographical surface areas.

3. Corrections and Clarification

Three possible errors (and contingency Table 6) in the original Blakemore (2018b)[1] paper regarding SOC underestimation, soil Bulk Density (BD) backcheck and Net Primary Production (NPP) were clarified and corrected by Blakemore (2019a, 2019b, 2020)[13–15]. In summary:

1. SOC total is now at least >10,000–12,000 Gt (as noted above) (not just >8580 Gt).
2. BD recalculations (Blakemore 2019a)[13] require just × 2–5 land area (not × 4–6).
3. NPP is confirmed within bounds of 120–220 Gt C/yr (~218?), GPP of >>240 Gt C/yr with soil respiration/decomposition (SR) ~200 Gt C/yr (Blakemore 2020)[15] (Table 1).

Table 1. Land productivity vs. human emission (assumed as fossil fuels FF but also due to SOC loss) showing soil humus is both Earth's greatest emission source and natural carbon capture store (CCS).

Reference [A] /Parameter [B]	NASA (2011)[17]	IPCC (2001: 188, 191; 2013: fig. 6.1, 547; 2019a, 2019b)[3,7–8,18]	Le Quéré et al. (2018: fig. 2)[19]	Blakemore (2018b: tab. 11, 2019a, 2019b, 2020)[1, 13–15]
Terrestrial GPP (Gt C/yr) [C]	123	~123	123.2	>>240 (240–440)
Terrestrial NPP (Gt C/yr) [C]	63	~60	?	120–220 (~218?)
Total Soil Respiration (SR) [C]	60 (**87%**)	40–70 (**82–88%**)	?	120–200

incl. Roots – Gt C/yr **(%)**				**(90–95%)** C
Terrestrial NEP = (NPP-SR)	3	5–10	?	10–20
FF emissions – Gt C/yr **(%)**	9 (**13%**)	~9 (**12–18%**)	10.9	~10 (**5–10%**)
Air (CO_2) excess – Gt C/yr	+4	+4	+4.7	~4.7 (2.2 ppm)
Soil SOC stock (Gt C) D	2300	~4700–5600 D	3200–4100	>10,000 D

A NASA, IPCC and Le Quéré et al. all also have a passive, mostly self-cancelling ocean/air exchange of ~80–90 Gt C/yr from surface ocean dissolved organic carbon DOC stock of 700–1000 Gt C (all the rest is DIC), here discounted as a relatively small net effect (ca. -0.4–2.4 Gt C/yr – see Le Quéré et al.[19] cf. Lee et al. 1998[20]). Plant respiration from leaves simultaneously cancels about a third of GPP, root respiration is ~30% of total soil respiration. NASA has ~50:50 allocation above- or below-ground yet fewer than 10% of studies measure belowground NPP[15]. Unrealistic artificial CCS of fossil fuel gas is, at best, 0.7 Gt or just 0.3% vs. ~218 Gt C/yr "natural" NPP, most ultimately stored, respired or combusted. Halting all fossil use would have zero effect on excess CO_2 drawdown that is only possible with topsoiling/rehumification via earthworm-worked compost. (Le Quéré et al. 2018[19] data now replaced by www.earth-syst-sci-data.net/11/1783/2019/ without much change).
B In general, despite minor isotopic bias (plants preferentially use standard ^{12}C over minor ^{13}C or trace ^{14}C), there is no CO_2 source discrimination for photosynthesis regardless if "natural" or human induced/FF.
C NPP = GPP-PR; IPCC (2019a: 2-94)[7] say plant autotrophic respiration (PR) is "*approximately one half of GPP*"; SR & RR after Riach et al. (2002)[21], Bond & Thompson (2010)[22], etc. (see Blakemore 2019a, 2020)[13,15].
D IPCC [7–8] SOC values vary yet miss crucial new data from Blakemore (2018)[1] and as proffered herein.

Original and latest isotope studies using $^{13}C/^{12}C$, $^{18}O/^{16}O$ or ^{18}OCO, and $^{17}O/^{16}O$ support raising GPP/NPP (e.g. Welp, Keeling et al. (2011)[23], van der Velde et al. (2013)[24], Liang et al. (2017)[25] and Laskar et al. (2019)[26]). With a passive, self-cancelling ocean exchange at ±80–90 Gt C/yr, isotope estimates give global carbon exchange scaled up to 772, 779.2 or as high as 897 Gt C/yr. Koren et al. (2019: figs. 1, 4b)[27] model NPP of 114 Gt C/yr and air↔leaf flux of -400–750 Gt C (i.e., ±350 Gt C/yr). Human fossil fuel (FF) emissions of +10 Gt C/yr mainly in northern hemisphere are trivial against such large leaf fluxes exemplified by Scripps' Keeling curves "natural" net CO_2 fluxes of ±20 Gt C/yr at Mauna Loa, Hawaii and ±40 Gt C/yr at NOAA's Barrow, Alaska (Figure 3).

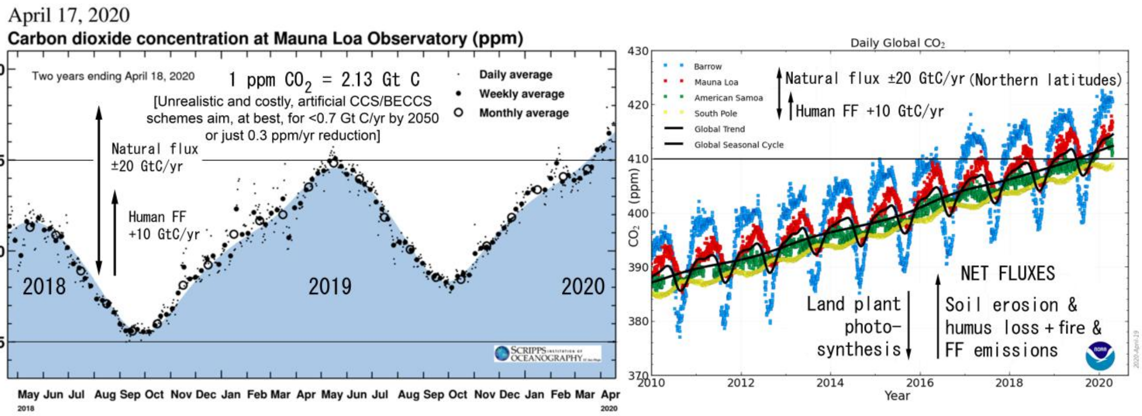

Figure 3. Human activities disrupt plant/soil fluxes more than fossil fuel (FF) burning does: Mauna Loa's flux of +10ppm or >20 Gt C just for winter months is greater than annual FF +10 Gt C/yr that, if it were sole influence, would raise rates by 4.7 ppm rather than current 2.2 ppm. Natural rhythm in Barrow's short summer drawdown flux (above rhs in blue of ~20 ppm = NPP >40 Gt C) is in boreal region with just ~15% of total vegetation (Fig. 1). At twice Mauna Loa's flux (~10 ppm), full-yearly global NPP is seemingly within 200–400 Gt C/yr. Despite corona virus industrial shutdowns, 2020's peak spiked to 420 ppm showing FF CO_2 reduction has disproportionately lesser effect on carbon totals that are more dependent upon relentless soil SOC loss. Fewer cars or less red meat help cut GHG emissions, but drawdown is possible only with organic humus restoration. (Temperatures may yet rise due to lower aerosol radiative forcing of smog plus its cloud seeding).

Welp, Keeling et al. (2011)[23] stated: "O*ur analysis suggests that current estimates of global gross primary production, of 120 petagrams of carbon per year, may be too low, and that* ***a best guess*** *of 150–175* *petagrams of carbon per year better reflects the observed rapid cycling of CO_2.*" As global carbon cycle is almost entirely due to land's GPP and the ocean's GPP is negligible, assuming NPP is about half of GPP gives their global land NPP of 75–88 Gt C/yr. However, Liang et al. (2017)[25] used oxygen isotopes to model GPP and found: "*The **terrestrial flux** is quantified to be 345 ± 70 PgC year*$^{-1}$*, falling in the range reported in the literature, 200–660 PgC year*$^{-1}$" and CO_2 turnover time "*τ is 1.9 ± 0.3 years.*" This potentially gives a land NPP of ~172.5 Gt C/yr (not just 60 Gt C/yr).

IPCC (2001: 191)[18] had "*leaf water*" carbon flux of 270 Gt C/yr giving a ~3 yr atmospheric CO_2 transit time. Liang et al. (2017)[25] derived an estimate of 130 ± 25 Gt C/yr for GPP with a "***best guess***" for "*soil invasion*" of 120 ± 20 Gt C/yr, but they speculated (fig. 5D) GPP up to 220 Gt C/yr. Of note is that prior or subsequent [26] isotope studies had much higher terrestrial flux, up to 722 or 817 Gt C/yr, values more than twice Liang et al.'s 345 Gt carbon flux figure, suggesting their GPP guestimates may be doubled too: From 130–220 up to 260–440 Gt C/yr. This agrees with upping of NPP to 120–220 (viz. ~218 Gt C/yr) and also with observed soil respiration/decomposition rate of ~100 ± 12 Gt C/yr[22] also doubled for terrain to ~200 Gt C/yr (as detailed in Blakemore 2020)[15]**.**

Assuming ~50% of GPP carbon is released by Plant Respiration (PR)[7,17] and reasoning a land NPP of ~218 Gt, if matched by PR of ~200 Gt, gives GPP (= NPP + PR) of ~418 Gt C/yr, well within the realm of 395–817 Gt C/yr terrestrial flux (Laskar et al. 2019)[26] and allowing ample allocation of up to ~400 Gt C/yr for combined non-photosynthetic "*leaf water*" and passive CO_2 "*soil invasion*".

The most feasible explanation for increased GPP and flux rates (assuming LAI leaf-area-indices are accurate) is land area raised as per Blakemore (2018b)[1]. Factoring in terrain best justifies newly modeled values. Furthermore, the ocean is a closed-system passively absorbing as little as 0.4 Gt C/yr from excess atmospheric CO_2 (Lee et al. 1998)[20], or just 4% of the 10 Gt C/yr emitted by fossil fuels, thus it is not a main consideration of this report, neither should it be for IPCC nor for other carbon-cycle models. Land/soil:sea:fossil flux partition ratios are reported as 817:80:10 Gt C/yr [26].

In graphical summary, data in IPCC (WG1-TAR1 2001: fig. 3.1d)[18] as presented by Houghton (2007: fig. 1)[28] and forming a basis for IPCC (2019a,b) [7–8] are tentatively revised (Figure 4).

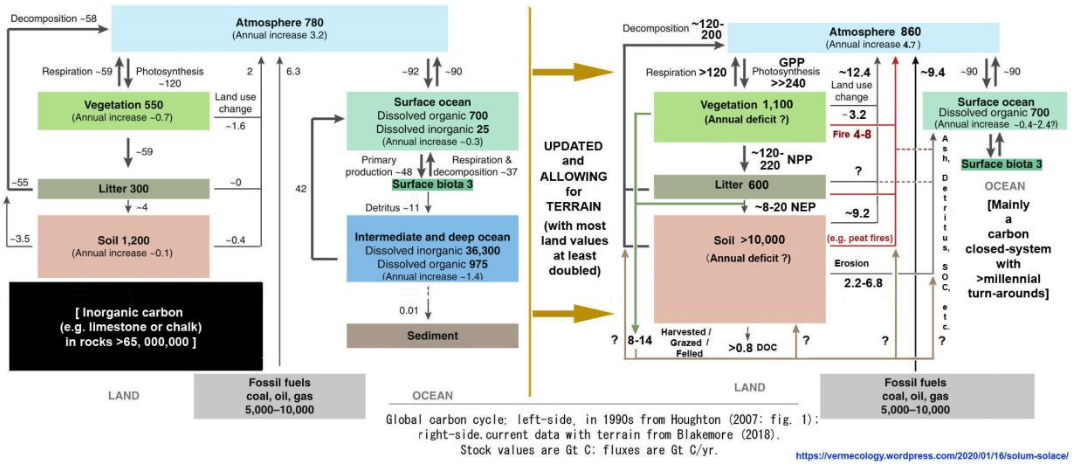

Figure 4. Carbon cycle relevant to atmospheric CO_2 accumulation and land sequestration fixes (after Houghton 2007: fig. 1)[28] updating IPCC, NASA/NOAA data with details provided in Blakemore (2020)[15]. Ocean loading from topsoil erosion, wash-off, drainage and ash far exceeds atmospheric input. Dissolved soil organic/inorganic C (DOC/DIC) also leaches into groundwater or flows to seas.

4. Corroboration and Consequences

As a general rule, carbon turnover time (τ) is a carbon stock reservoir divided by its flux (either GPP or just NPP). Rapid replacement of all 860 Gt C in atmospheric CO_2 is realistic if land's active GPP is ~200–800 Gt C/yr (τ = 860 / GPP = ~1–4 yrs) with a lesser, passive exchange of net ~0.4–2.4 Gt C/yr into CO_2 + HCO_3 saturated seas. As NPP is about half GPP, an NPP of ~220 has τ = ~2 yrs.

Independent agreement for terrestrial NPP of ~218 Gt C/yr, or above, with potential NEP of 10 Gt C/yr × 2 for terrain, and CO_2 turnover time of 1–4 yrs are from diverse studies, e.g.:

1. NOAA's Barrow site net summer drawdown if ~20 Gt C/yr (Fig. 3), from Taiga/Tundra being just ~9% of annual global NPP (Blakemore 2018a: fig. 3)[1], gives terrestrial NPP ~220 Gt C/yr [*Q.E.D.*]. This is mainly from steppes, nil for seas (Bartsev et al. 2012: fig. 3)[29]. Citing NOAA (www.esrl.noaa.gov/gmd/ccgg/isotopes/c13tellsus.html): "*Oceanic exchange–which would affect total carbon dioxide but not $\delta^{13}C$–appears to play little to no role in determining overall CO_2 at Barrow.*"
2. Revisiting Darwin's work a Century later, Lee (1985: tabs. 18, 21)[30] has mean earthworm surface casts dry mass of 105 t/ha/yr and about equal subsoil casting gives 210 t/ha/yr. With a 26 Gha topsoil mantle this is 5460 Gt/yr humus processing. At an average cast carbon content of ~4% gives 218.4 Gt C/yr or about the entire annual NPP, as to be expected for balanced Nature.
3. Duursma & Boisson (1994: 124, 134–5)[31] for oceans state: "*The turnover time of water masses, which transport CO_2 into the deep sea in polar regions, where the CO_2 is released at lower latitudes, is of the order of a thousand years (650 year in the Atlantic to 2000 in the Pacific)… Increased atmospheric CO_2 will only slightly affect the CO_2 level in the oceans, since the latter contain 55 times more CO_2 than the atmosphere. Thus there will be no feedback based on increased atmospheric CO_2, or at most very little (<2 % of effects on land)... The average annual primary production of the world oceans of 30 gigatons carbon*".
4. UNEP (2002: 10)[32] had 320 Gt C/yr GPP = NPP of 160 (-30 in sea = >130 Gt C/yr on flat land?).
5. Dusenge et al. (2018: fig. 1)[33] ignore ocean's minor contribution, stressing the value of land.
6. Terrestrial NEP (IPCC 2001, Liang et al. 2017)[18,25] of 10 Gt C/yr × 2 for terrain = 20 Gt.
7. Prof. Rattan Lal [34–36] endorses SOC and NPP rate re-evaluations [1] as reasonable.
8. For atmospheric $^{12}C^{16}O_2$, IPCC (2007: 948)[37] says: "*turnover time is only about four years*", Berry (2019)[38] has "*4 to 5 years*" (cf. with different reckoning Blakemore (2019c)[39] has "*<3.6 yrs*" for NPP or ~1.8 yrs for GPP). Using other C and O isotopes Welp, Keeling et al. (2011)[23], Liang et al. (2017)[25] and Laskar et al. (2019)[26] gave global CO_2 turnover times of 0.9–2.8 yrs (median ~1.8 yrs) , mainly due to terrestrial terrain.

In addition to carbon SOC pool, other factors affecting organic storage rates in soil are, for example: Leaf litter/log necromass, roots, earthworm biogenic calcite in 'inorganic' carbon (SIC) and earthworm bodies washing off into rivers (Blakemore 2019d)[40], plus dissolved organic/inorganic carbon (DOC/DIC) leaching. Total SOC from values herein of up to 12,000 Gt, may be increased 27% for glomalin [41] to 15,000 Gt (ten times 4p1000.org value!) with an additional >1000 Gt in plant root/mycorrhiza and 600 Gt in surface litter/logs (Figs. 1,4) to likely sum >16,600 Gt C. Plus a partly biogenic inorganic SIC pool of >1558 to 2 m (Lal 2019a: tab. 1)[33] with a dissolved inorganic DIC pool of 1404 (= 2962 Gt C), doubled for depth/terrain to ~6000 Gt, yields >22,600 Gt soil carbon *in toto*. Unintentionally, the objectors are thus correct: "*Current estimates of soil organic carbon stocks* ***are not*** *four to six times underestimated*"; indeed – more likely these are over ten times underestimated.

5. Conclusions

Whittaker & Likens (1973)[42] said: "*Despite the immensity of the biosphere, man has reduced its biomass and is beginning, with pollution, to affect its productivity*." As natural and GPP carbon cycling (400–800 Gt C/yr) is up to 80 times fossil fuel emissions (~10 Gt C/yr), the cause of CO_2 accumulation in air is inability of biomes to fix and reabsorb excess due to biomass clearing, grazing, poisoning, burning and an unwitting destruction of topsoil with critical decline of earthworms [38,42]. Referring to taiga and the steppes (from whence the author has recently described new earthworm species [44]), Bartsev et al. (2012: fig. 3)[29] also noted: "*measures taken by the world community to reduce greenhouse gas emissions are of less importance than preservation of wild natural resources*." The latest, 1542 page, IPCC (2019a)[7] land report (not marine) mentions "*compost*" just 14 times, "*earthworm*" once (both inappropriately linked to "*biochar*" that offers no advantage over time-proven compost and may actually harm soils' essential functions and beneficial fauna), and hits for "*humus*" are zero but "*fish*" get >100! Yet immediate application of natural, organic vermi-compost helps restore humic SOC and S/ECCS [39,43] offering a scalable, mostly cost-free and completely safe remedy to time-critical global species extinctions caused by interlinked and cumulative factors of agrichemical poisons plus topsoil erosion that are exacerbated by climate [38].

The *Drawdown Review* (2020: 13)[45] supports soil as the only feasible way to remove excess CO_2 from air (98.5%), compared to costly, overhyped and un-natural CCS (1.1%) or ocean (0.4%).

Regarding new NPP/GPP estimates herein, how reliable is the current 'official' data? Before remarking on the uncertainties and complexities of previous $^{18}OC^{16}O$ isotope standard estimates, Beer et al. (2010)[46] said: "*In the absence of direct observations, a combined GPP of all terrestrial ecosystems of 120 Pg C year*$^{-1}$ *was obtained by doubling global biomass production estimates without an empirical basis of spatially resolved biomass production and its relationship to GPP*." In other words, it was a best guess. Their source was IPCC TAR-3 report (2001: tab. 3.2)[18] with NPP of ~60 Gt C/yr, but from a 'flat-Earth' of just ~15 Gha. When doubled for terrain to ~30 Gha this NPP becomes ~120 Gt C/yr, but may be increased further to account for often neglected sub-soil NPP, root exudates, etc.

Whilst isotopic analyses by Welp, Keeling et al. (2011: supplement)[23] led to a "***best guess** for terrestrial GPP*" as high as 175 Gt C/yr, their soil invasion estimate within an uncertainty of 15–450 Gt C/yr had a likely range of "*50–220 Pg C yr*$^{-1}$ *.. a relatively high case, for which there is little evidence at the moment, and lower values would increase GPP*". Moreover, they provided a global turnover time (τ) as short as just 0.9 yrs requiring ~900 Gt C/yr flux to recycle all atmospheric CO_2 carbon each year

Terrain allowance thus raises all land values and best explains annual global carbon flux from isotopic analyses, as noted above, of up to 722–817 or as high as 900 Gt C/yr. An NPP value of ~218 Gt C/yr (Blakemore 2018b)[1] may therefore be entirely reasonable and is substantiated by Barrow drawdown data. Furthermore, a justifiable GPP of ~436 Gt C/yr gives a ~2 year CO_2 turnover time.

Certainties are that CO_2 is rising, land is not flat and ignorance of soil outweighs knowledge. Figures in this report are not definitive although more realistic than those by proponents of just 60 Gt C/yr NPP, 15 Gha terrain, or 1500 Gt SOC who must now raise their manifestly low values.

Conflicts of Interest: The author freely declares no external funding nor conflict of interest.

References

1. Blakemore, R.J. Non-flat Earth Recalibrated for Terrain and Topsoil. *Soil Syst*. **2018b**, 3, 64.
2. Reiners, W.A. Terrestrial detritus and the carbon cycle. *Brookhaven Symp. Biol*. **1973**, 24: 303–27.
3. IPCC. Climate Change: The Physical Science Basis. www.ipcc.ch/report/ar5/wg1/. **2013**.
4. Lal R. et al. Recarbonization of the Biosphere. IASS, Potsdam, Springer, Heidleberg. **2011**, pp. 558.
5. Köchy, M. et al, Global distribution of soil organic carbon—Part 1: Masses & frequency distributions of SOC stocks for the tropics, permafrost regions, wetlands, and the world. *Soil* **2015**, 1, 351–365.
6. Hiederer, R.; M. Köchy. Global Soil Organic Carbon Estimates and the HWSD. EU. **2011**. pp. 79.
7. IPCC. Special Report on Climate Change, Desertification, Land Degradation. **2019a.** https://www.ipcc.ch/site/assets/uploads/2019/08/Fullreport-1.pdf.
8. IPCC. Special Report on the Ocean & Cryosphere in a Changing Climate. **2019b**. https://report.ipcc.ch/srocc/pdf/SROCC_FinalDraft_FullReport.pdf.
9. Tifafi, M. et al. Large differences in global and regional total soil carbon stock. *Global Biogeochem. Cycles* **2018**, 32. https://doi.org/10.1002/2017GB005678. (Online - www.theses.fr/2018SACLV021.pdf).
10. Gross, C.D.; Harrison, R.B. Quantifying and comparing soil carbon stocks: Underestimation with the core sampling method. *Soil Sci. Soc. Am. J.* **2018**, 82, 949.
11. Cotching, W.E. Organic matter in the agricultural soils of Tasmania, Australia – A review. *Geoderma* **2018**, 312, 170-182. http://dx.doi.org/10.1016/j.geoderma.2017.10.006.
12. Nichols, J.E; Peteet, D.M. Rapid expansion of northern peatlands and doubled estimate of carbon storage. *Nature Geosci*. **2019,** 12, no. 11, 917-921, doi:10.1038/s41561-019-0454-z.
13. Blakemore, R.J. https://vermecology.wordpress.com/2019/07/02/the-ocean-lies-still/. **2019a**.
14. Blakemore, R.J. https://2019/09/20/soc-upped-after-uninvited-comment-on-soil-syst-2018-2-64/. **2019b**.
15. Blakemore, R.J. https://vermecology.wordpress.com/2020/01/16/solum-solace/. **2020**.
16. Crowther, T.W. et al. The global soil community. *Sci*. **2019,** 365, 6455. doi.org/10.1126/science.aav0550.
17. NASA. https://earthobservatory.nasa.gov/features/CarbonCycle. **2011**.
18. IPCC. CLIMATE CHANGE. webpages.icav.up.pt/PTDC/CVT/098487/2008/IPPC,%202001.pdf. **2001**.
19. Le Quéré, C. et al. Global Carbon Budget 2018. *Earth Syst. Sci. Data* **2018**, 10, 2141–2194. https://doi.org/10.5194/essd-10-2141-2018. (Online - www.earth-syst-sci-data.net/10/2141/2018/).
20. Lee, K. et al. Low interannual variability in recent oceanic uptake of atmospheric carbon dioxide. *Nature* **1998,** *396, 155-159*. https://www.nature.com/articles/24139.
21. Riach, J.W. et al. Interannual variability in global soil respiration, 1980-94. *Glob. Ch. Bio*. **2002,** 8, 800-812. https://cdiac.ess-dive.lbl.gov/ftp/ndp081/GCB2002.pdf.
22. Bond-Lamberty, B.; Thompson, A. Temperature-associated increases in the global soil respiration record. *Nat. Letts*. **2010,** 464. doi:10.1038/nature08930.
23. Welp, L.R.; Keeling, R.F. et al. Interannual variability in the oxygen isotopes of atmospheric CO_2 driven by El Nino. *Nature* **2011**, 477(7366),579–582**.** doi:10.1038/nature10421**.**
24. van der Velde, I.R. et al. Biosphere model simulations of interannual variability in terrestrial $^{13}C/^{12}C$ exchange. *Global Biogeochem.Cycles* **2013,** 27, 637–649. doi:10.1002/gbc.20048.
25. Liang, M.-C. et al. Oxygen isotope anomaly in tropospheric CO_2 *Sci. Reps.* **2017**, 7(1):13180. 10.1038/s41598-017-12774-w.
26. Laskar, A.H. et al. Triple oxygen and clumped isotope compositions of CO_2 in the middle troposphere. *Earth & Space Science* **2019**, 6, 1205–1219. doi.org/10.1029/ 2019EA000573.
27. Koren, G.; et la. Global 3-D Simulations of the Triple Oxygen Isotope Signature $\Delta^{17}O$ in Atmospheric CO_2. *JGR Atmos.* **2019**, 124(15), 8808–8836. https://doi.org/10.1029/2019JD030387.
28. Houghton, R.A. Balancing the Global Carbon Budget. *Annu. Rev. Earth Planet. Sci*. **2007**, 35:313–47. *
29. Bartsev, S. et al. *Procedia Environ. Sci*. **2012,** 13, 194-201. https://core.ac.uk/download/pdf/82433487.pdf.
30. Lee, K.E. Earthworms: Their Ecology & Relationships with Soils. Academic Press, Sydney, **1985**, pp. 411.
31. Duursma, E.K.; Boisson, M.P.R.M. Global oceanic and atmospheric oxygen stability considered in relation to the carbon-cycle and to different time scales. *Oceanol. Acta* **1994**, 17, 117–141.
32. UNEP. Atlas. archive.org/stream/worldatlasofbiod02groo#page/10/mode/2up. **2002.**
33. Dusenge, M.E. et al. Plant carbon metabolism & climate change: elevated CO_2 & temperature impacts on photosynthesis, photorespiration and respiration. *New Phytol*. **2019**, 221: 32-49.
34. Lal, R. Carbon Cycling in Global Drylands. *Curr. Clim. Change Rep.* **2019a,** 5, 221.
35. Lal, R. Conceptual basis of managing soil carbon: Inspired by nature and driven by science. *J. Soil Water Conserv.* **2019b**, 74(2), 29A-34A. doi:10.2489/jswc.74.2.29A.

36. Lal, R. Managing Soils for Resolving the Conflict Between Agriculture and Nature: The Hard Talk. *Eur. J. Soil Sci.* **2020**, 71(1), 1–9. https://doi.org/10.1111/ejss.12857.
37. IPCC. WG1, AR4 Report. www.ipcc.ch/site/assets/uploads/2018/05/ar4_wg1_full_report-1.pdf. **2007**.
38. Berry, E.X. Human CO_2 Emissions Have Little Effect on Atmospheric CO_2, *Int. J. Atm. & Oc. Sci*. **2019**, 3(1), 13–26. doi: 10.11648/j.ijaos.20190301.13.
39. Blakemore, R.J. Humic Carbon to Fix Extinction, Climate and Health. *Veop* **2019c,** 3, 1–8. Online: https://veop.files.wordpress.com/2019/05/veop-3-2019.pdf.
40. Blakemore, R.J. vermecology.wordpress.com/2019/11/11/earthworm-cast-carbon-storage-eccs/. **2019d**.
41. Comis D., 2002. Glomalin: Hiding place of a third of the World's stored soil carbon. *Ag. Res. Mag*. **2002**, 50(9), 4–7. http://www.ars.usda.gov/is/ar/archive/sep02/soil0902.htm.
42. Whittaker, R.H.; Likens, G.E. Primary production: The biosphere and man. *Hum. Ecol*. **1973**, 1**,** 357–369. https://doi.org/10.1007/BF01536732.
43. Blakemore, R.J. Critical Decline of Earthworms from Organic Origins under Intensive, Humic SOM-Depleting Agriculture. *Soil Syst*. **2018**, 2(2), 33. www.mdpi.com/2571-8789/2/2/33.
44. Blakemore, R.J. Earthworms newly from Mongolia. *Zookeys* **2013**, 285**.** DOI:10.3897/zookeys.285.4502.
45. Project Drawdown: The Drawdown Review. **2020**. https://drawdown.org/sites/default/files/pdfs/Drawdown_Review_2020_march10.pdf.
46. Beer, C.; et al. Terrestrial Gross Carbon Dioxide Uptake. *Science* **2010**, 329, 834–838.

*This paper acknowledges scientific works of Sir John Houghton who died aged 88 from suspected Covid-19.