ORGANIC FARMING RESEARCH FOUNDATION
Fostering the improvement and widespread adoption of organic farming.

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From: Mark Schonbeck, Ph.D., Research Associate, Organic Farming Research Foundation

To: US Global Change Research Program and Intergovernmental Panel on Climate Change

CC: Brise Tencer and Vicki Lowell, Organic Farming Research Foundation;
Climate Change Subcommittee, National Campaign for Sustainable Agriculture

Re: Second Order Draft of Assessment Report 6 (AR6) from Working Group I of the Intergovernmental Panel on Climate Change (IPCC).

General comments

I submit these comments on behalf of the Organic Farming Research Foundation (OFRF) with whom I have worked as a Research Associate for the past five years. During this time, OFRF conducted an in-depth review of research into organic production systems conducted with funding from the United States Department of Agriculture (USDA). Based on this review we developed and published a series of practical guidebooks on soil health in organic farming, one of which focused on Climate Change Mitigation, Adaptation and Carbon Sequestration (available at https://ofrf.org). Worldwide, agriculture and land use impacts account for about 25% of total greenhouse gas (GHG) emissions, but the research we reviewed suggest that best management practices for soil health, sustainable agricultural production, forestry, and other land uses including restoration of natural areas, could make the global agricultural "footprint" climate-neutral through carbon sequestration and reduced methane and nitrous oxide emissions.

It is from this perspective that OFRF would like to submit the following comments for the IPCC's consideration in developing the final draft.

First, we want to express our gratitude to Working Group I of the IPCC for the tremendous amount of research, impartial analysis, thoroughness, and candor evidenced in the Summary for Policy Makers and throughout the report. We recommend some modifications in language and emphasis to better communicate to policy makers the dimensions of the climate crisis as well as some of the most promising response strategies. Specifically, we urge greater emphasis on"

- The potential of organic and sustainable production systems to contribute to carbon dioxide mitigation and community resilience to climate change;
- The potential for land-based photosynthesis and soil carbon sequestration as a biological carbon dioxide removal strategy; and
- Benefits of improving air quality (reduced aerosols) to public health and community resiliency.

In addition, we recommend that IPCC amend the report with new information gained from the impacts of the coronavirus pandemic and associated suspension of non-essential travel and some other economic activities on climate change drivers. Nationwide and global responses to the covid-19 crisis has reduced greenhouse gas (GHG) emissions in China by an estimated 25% (Wright, 2020), caused a 50% reduction in nitrogen oxides in California (Gohd, 2020), and visibly reduced NO2 levels over Italy and China (Ghosh, 2020). World-wide, the largest reduction in CO2 release in the last 50 years is predicted for 2020 by the Global Carbon Project (Nasralla et al., 2020). We urge the IPCC to amend the WGI report and its Summary for Policy Makers with a synopsis and analysis of these phenomena, and their potential to inform strategy and policy to retain and continue GHG reductions during economic recovery after the pandemic subsides. In essence, the covid-19 crisis offers humanity an opportunity to develop a "new normal" that permanently reduces GHG emissions while regenerating more sustainable and equitable regional, national, and global economies.

References:

Ghosh, I., 2020. *Emissions on lockdown: China and Italy*. World Economic Forum. Accessed April 5, 2020 at https://www.weforum.org/agenda/2020/03/emissions-impact-coronavirus-lockdowns-satellites/.

Gohd, C., 2020. Shutdowns from coronavirus create blue skies in California, could inform future pollution control. SPACE.COM. Accessed April 5, 2020 at https://www.space.com/coronavirus-california-emissions-reduced-blue-skies-ozone-increase.html.

Nasralla, S., V. Volcovici and M. Green, 2020. *Coronavirus could trigger biggest fall in carbon emissions since World War Two*. Reuters, April 3, 2020. Accessed April 5, 2020 at https://www.reuters.com/article/us-health-coronavirus-emissions/coronavirus-could-trigger-biggest-fall-in-carbon-emissions-since-world-war-two-idUSKBN21L0H.

Wright, 2020. *There's an unlikely beneficiary of coronavirus: The planet*. Accessed April 4, 2020 at https://www.cnn.com/2020/03/16/asia/china-pollution-coronavirus-hnk-intl/index.html.

Comments on the Summary for Policy Makers

General Comment on the SPM:

The Summary for Policy Makers (SPM) is a critically important part of this report, and must clearly communicate both the gravity and dimensions of the climate crisis (Sections A, B, C) and the most promising strategies and tactics for mitigation and adaptation (Section D). The current SPM clearly outlines the increased level of confidence that human activity is driving climate shifts based on additional research since AR5, the regional specificity of certain climate impacts, and the state of research underpinning alternative mitigation strategies. Yet, we believe that the SPM could communicate more effectively to policy makers the gravity of the crisis humanity faces, and what can and must be done to avert catastrophe. Specific comments by page number follow.

Page 4, lines 19 – 25:

The pink box summary for section A.1 could more fully communicate that, based on research advances since publication of AR5, human-caused climate change is now an established fact, and has pushed some climate components, such as mean surface temperature, to historic levels. Since busy policy makers are most likely to read the pink-highlighted summaries and skim over the rest, summaries should communicate the essential conclusions of each section as fully as practical. Suggested revisions for the A.1 summary (additional language IN CAPITALS, suggested deletions in [brackets]:

> "Several centuries of climate science research have increased knowledge about how Earth's climate varies naturally and how it responds to human perturbations. [These]-Advances SINCE AR5 are the result of more and higher quality observations, expanded information about past climates, improvements in theoretical understanding, and the development of more comprehensive climate models. Due to these multiple independent lines of evidence, human influence on the climate system since the mid-20th century is now an established fact, WITH SOME CLIMATE COMPONENTS NOW IN STATES UNPRECEDENTED IN THE HISTORY OF HUMAN CIVILIZATION."

Page 6, lines 5-12
The pink box summary statement for Section A.2 (from global to regional scales) again understates the AR6 findings regarding anthropogenic warming. This could lead policy makers to underestimate the magnitude of the problem, and to attribute more climate phenomena to natural regional, decadal, and multi-decadal phenomena than is warranted by the data. Based on the information provided in paragraphs A.2.1 – A.2.6, the summary statement could be strengthened as follows. Suggested additional language IN CAPITALS, suggested deletions in [brackets]:

> "Human-induced climate trends are superimposed on natural decadal or multi-decadal climate variability, whose effects are more pronounced at regional scales than at the global scale, and relatively larger for most water-cycle variables, including precipitation, than for temperature. SINCE AR5, ENHANCED CAPACITY TO DISTINGUISH INTERNAL VARIABILITY FROM FORCED CHANGE HAS CONFIRMED SUBSTANTIAL HUMAN-INDUCED INCREASES IN GLOBAL [The increase in] surface AIR temperature, GLOBAL OCEAN HEAT CONTENT, AND SEA LEVEL, [over land, especially in the tropics,] and [the] A RAPID decline in Arctic sea ice. [are already clearly discernible from natural variations]. In terms of future emergence, the relative strength of internal variability and human-induced trends will depend on the region, the variable, and the level of global warming (*high confidence*)."

Page 7
Section A.3 addresses the challenges of developing and delivering effective climate messaging, and the impact of the values and beliefs of those giving and those receiving the message on how it is received and utilized. Paragraph A.3.4 discusses storyline approaches to address unpredictable, "low likelihood, high impact" climate events. Note that, as the number of such "low likelihood, high impact" possible outcomes increases, the likelihood that *at least one* of these events will take place increases, and could easily exceed 50-50, especially under higher-emissions, greater warming scenarios. The challenge is that there is no way at this time to predict which of the "low likelihood" scenarios will come to pass, and when it will occur.

This section of the WGI report should clearly communicate this fact, which serves to underline the importance of prompt and effective policy action to limit global warming.

Page 8 lines 13-19
Section B.1 summary clearly and concisely states the unprecedented magnitude of GHG emissions and resultant radiative forcing.

Pages 9 line 34 – page 10 line 27
Section B.2, paragraph B2.2 cites the impact of stratospheric ozone thinning on stratosphere temperatures (cooling) and B.2.3 attributes a shift in weather patterns (contributing to poleward shift of jet streams) to a combined effect of human-caused stratospheric ozone thinning and increases in tropospheric greenhouse gases. However, there is no mention of ozone in the summary for Section B.2. Given the high likelihood and confidence level of inferences regarding the impact of human-induced stratosphere ozone losses on climate systems, it should be specifically mentioned by modifying the second sentence as follows (added language in CAPITALS):

> "Several aspects of the atmospheric circulation have likely changed since the mid-20th century, including widening of the tropical belt and poleward jet migration, and there *is medium confidence* that human influence*s*, INCLUDING STRATOSPHERIC OZONE DEPLETION AS WELL AS GREENHOUSE GAS EMISSIONS, contributed to these changes."

Page 12 lines 3 - 13
Section B.3 addresses ocean changes related to GHG emissions and climate change. Given the grave implications of ocean acidification (threatening to dissolve coral reefs, mollusk shells and other calcium carbonate based marine biota) and deoxygenation (a threat to all aerobic marine biota, which depend on oxygen) as well as sea level rise (destruction of low lying coastal cities worldwide), the critical importance of these ocean parameters might be emphasized by adding language to the first sentence of the pink box summary as follows:

> "The observed changes in the ocean are unprecedented over recent millennia, AND POSE MAJOR RISKS TO MARINE ECOLOGY AND HUMAN CIVILIZATION."

Page 24 lines 25-42
Paragraphs C.1.6 and C.1.7 are difficult to comprehend, largely because the terms "equilibrium climate sensitivity" (ECS) and "transient climate response" (TCR) are inadequately explained here and are also not defined in the Glossary. In order to make this information more useful to policy makers, ECS and TCR should be clearly defined, and their relationship to "low likelihood, high impact events" clarified.

Page 25 lines 23-43
Section C.2, paragraph C.2.1 states with "medium confidence" that sea surface temperature increases during the 21st century will exceed "many hazard thresholds relevant to marine ecosystems." It seems that ocean acidification and de-oxygenation pose even greater hazards to marine ecosystems. Thus WGI might consider adding the following statement at the end of paragraph C.2.1:

> "OCEAN ACIDIFICATION, AND DEXOYGENATION WILL LIKELY EXCEED MANY HAZARD THRESHOLDS RELEVANT TO MARINE ECOSYSTEMS."

In addition, these risks should be briefly and clearly mentioned in the Section C.2 pink box summary, after the second sentence and before the third, as follows:

> " … projected to increase (*high confidence)*. OCEAN WARMING, ACIDIFICATION, AND DEOXYGENATION THREATEN TO DISRUPT MARINE ECOSYSTEMS (MEDIUM CONFIDENCE). For the Antarctic Ice Sheet …"

Page 28 lines 6-7
Section C.4 Future Changes of the Water Cycle: One of the most serious consequences of higher temperatures will be increased evaporative demand, resulting in increased *soil* drying, especially in semiarid regions where dryland farming practices may leave the soil bare for extended fallow periods. Since this has major implications for agricultural production and food security, it should be drawn to policy makers' attention in the section summary. Thus, the third sentence in the section summary might be modified to read:

> "There is *high confidence* that increasing atmospheric evaporative demand will lead to further SOIL drying tendencies in some LOW_RAINFALL regions under higher global warming."

Page 29, lines 10-35
Section C.5, paragraph C.5.2 states that "There is high confidence that many regions will experience heat stress conditions above critical thresholds for health, agriculture and other sectors." This is a major finding that should be brought to policy makers' attention – by including it in the pink box summary at the beginning of the section. This can be done by expanding the third sentence in the summary into two sentences that bring home the critical nature of expected increases in heat extremes:

> "Warm extremes are projected to become more frequent (*virtually certain*), EXCEEDING CRITICAL STRESS THRESHOLDS FOR HUMAN HEALTH AND AGRICULTURE IN MANY REGIONS (HIGH CONFIDENCE). Cold extremes WILL BECOME less frequent (*extremely likely*) and precipitation extremes more frequent in most locations (*very likely*)."

Pages 33, line 32 – page 34, line 28
Section C.6 deals with "low likelihood, high impact climate trajectories" and accurately depicts their difficult-to-predict nature and the increased likelihood of such events as global warming increases beyond 1.5 C. However, it seems important to impress upon policy makers the catastrophic potential of such events. Qualifying the opening statement of the summary as "low confidence" and devoting the rest of the summary to a "high confidence" statement about volcanic eruptions (a natural climate driver that causes temporary cooling) could lead policy makers to minimize or even ignore the risk of unpredicted, catastrophic "low likelihood" climate shifts. Thus it seems important to re-frame the pink box summary, roughly as follows (Suggested additional language IN CAPITALS, suggested deletions in [brackets]):

> "The likelihood for unforeseen low-likelihood, high-impact events related to extremes and tipping points is larger for global warming above 1.5ºC, AND THE EFFECTS OF SUCH EVENTS ON HUMAN CIVILIZATION AND GLOBAL ECOSYSTEMS CAN BE CATASTROPHIC. WHILE THERE IS LOW CONFIDENCE REGARDING SPECIFIC EVENTS, SUCH AS ICE SHEET DESTABILIZATION OR [and there can

be] abrupt changes in the water and carbon cycles at the regional scale [low confidence], THE FREQUENCY OF CURRENTLY-RARE EXTREMES IS VIRTUALLY CERTAIN TO RISE SHARPLY WITH DEGREE OF WARMING. Major volcanic eruptions represent a source of irreducible uncertainty [for near-term projections], YET THEIR [. The] short-lived climate effects [following eruptions] are [however]well understood (high confidence)."

Page 39, lines 3 - 9
Section D.1 Limiting climate change. The short term warming effect of reducing aerosol precursor emissions should be more clearly counterbalanced with the immediate benefits of reducing air pollution. Consider modifying the last sentence in the Summary as follows:

> "Reductions in aerosol precursor emissions to improve air quality (AND THEREBY PROTECT PUBLIC HEALTH AND IMPROVE COMMUNITY RESILIENCE TO CLIMATE STRESSES) would lead to additional net near-term warming, which could be lowered by reducing methane and other ozone precursors simultaneously (*high confidence*)."

Page 41, line 29 – page 42, line 7
Section D.2 Geophysical Consequences of Carbon Dioxide Removal is based on a lot of information, summarized in Chapter 5, pages 88-99 and 165-66, that is highly relevant to policy makers. However, the language throughout section D2 of the SPM is quite general and does not deliver much of this vital information.

It is essential that policy makers can see at a glance the main CDR strategies and understand the strengths, drawbacks, and risks of each. In particular, policy makers should be informed of the potential for significant CDR accomplished through enhanced plant cover and photosynthesis in agricultural lands and restored natural areas. Organic agriculture, agroforestry, advanced grazing management, and other soil health-based production systems can contribute significant CDR (potentially rendering the world's agriculture carbon-neutral) while enhancing food system resilience to climate change impacts. *See additional comments and literature references on this topic in comments on Chapter 5 of the WGI AR6*.

We encourage IPCC WGI to consider amending the pink box summary and adding two paragraphs to Section D.2, as follows (new language in CAPITALS):

Suggested modifications to pink box summary:

> "Carbon dioxide removal (CDR) methods can sequester CO2 from the atmosphere (*high confidence*), but the sequestration can be weakened by evolving Earth system feedbacks (*medium confidence*). Wide-ranging potential side-effects of CDR methods have been identified and can either amplify or reduce local climate change and affect the achievement of other societal goals (*high confidence*). These effects are highly project-, region-, and context-specific affecting the level of confidence with which they can be assessed. OVERALL, CDR STRATEGIES BASED ON LAND PLANT PHOTOSYNTHESIS AND SOIL HEALTH MANAGEMENT APPER SAFEST AND MOST TECHNICALLY PRACTICAL."

New paragraphs:

"D.2.3. CDR STRATEGIES BASED ON LAND PLANT PHOTOSYNTHESIS AND SOIL BIOLOGICAL PROCESSES APPEAR SAFEST AND MOST PRACTICAL. THESE STRATEGIES INCLUDE AGROFORESTRY, ADVANCED GRAZING MANAGEMENT, ORGANIC AGRICULTURE, CONSERVATION AGRICULTURE, PERMACULTURE, SILVOPASTURE, AND RESTORATION OF NATIVE FOREST, PRAIRIE, AND WETLAND. PLANT AND SOIL-BASED CDR STRATEGIES THAT PROTECT BIODIVERSITY, COMMUNITY WATER SUPPLIES, AND FOOD SECURITY GENERALLY ENHANCE AGRICULTURAL AND COMMUNITY RESILIENCE TO CLIMATE CHANGE."

"D 2.4. BIOENERGY CROPS WITH CARBON CAPTURE AND STORAGE (BECCS) AND DIRECT AIR CAPTURE WITH CARBON STORAGE (DACCS) POSE RISKS OF LEAKAGE FROM UNDERGROUND OR UNDERWATER STORAGE OF CAPTURED CO2. CDR BASED ON OCEAN PHOTOSYNTHESIS THROUGH OCEAN FERTILIZATION AND ARTIFICALLY-CREATED UPWELLING, AND CO2 ABSORPTION THROUGH ALKALINE MINERAL APPLICATION TO LAND OR OCEANS COULD DISRUPT TREATED ECOSYSTEMS."

Page 42, line 12 - 33
Section D.3 addresses geophysical consequences of solar radiation modification (SRM). Adding a brief summary of SRM techniques and a little more detail on serious potential side effects would better inform policy makers. Based on information in Chapter 4 section 4.6.3, and Chapter 5, section 5.6.3, consider modifying language in Section D.3 as follows:

Add information to the pink box summary:

"Masking global greenhouse gas warming through solar radiation modification (SRM) would likely be incomplete, and large residual regional and seasonal climate changes would remain (*high confidence*). Detailed understanding of the climate response to SRM remains subject to large uncertainties. SERIOUS SIDE EFFECTS INCLUDE INCREASED OCEAN ACIDIFICATION (HIGH CONFIDENCE) AND, FOR STRATOSPHERE AEROSOL INJECTION, DELAYED RECOVERY OF THE OZONE LAYER."

Add a new paragraph immediately after the pink box:

"<u>D.3.1 SOLAR RADIATION MODIFICATION (SRM) METHODS TO REDUCE NET RADIATIVE FORCING OF CLIMATE CHANGE INCLUDE STRATOSPHERE AEROSOL INJECTION (SAI), BRIGHTENING LOW CLOUDS OVER OCEAN AREAS WITH SEA SALT AEROSOL, THINNING CIRRUS CLOUDS WITH ICE NUCLEATION TO ALLOW MORE LONG-WAVE RADIATION TO ESCAPE, IND INCREASING OCEAN ALBEDO WITH REFLECTIVE PARTICLES."</u>

Renumber the current paragraphs D.3.1 and D.3.2 as D.3.2 and D.3.3, and modify the last statement of D.3.2 as follows:

"SRM would not counteract, AND MAY INCREASE, ocean acidification (*high confidence*), AND SAI COULD ALSO SLOW THE RECOVERY OF THE STRATOSPHERIC OZONE LAYER."

Pages 42, line 38 – page 43, line 20
Section D.4 Detecting the effects of emissions reductions accurately states that it will take 25 years or more to see the effects of GHG emissions reductions on global temperature and other aspects of climate change. However, as currently framed, the pink box summary could lead some policy makers to rationalize that it is not worth the shorter-term economic costs and adjustments to undertake aggressive emissions reduction efforts, or to implement policy toward that goal. Even though reducing anthropogenic aerosols – fine particulates and other near-surface air pollutants – does initially result in a little more warming, mitigating these pollutants is vitally important to human health and to the overall well-being of agricultural and natural ecosystems – and thus to agricultural and society-wide resilience to climate change impacts.

This consideration should be succinctly added to the summary (page 42 lines 38-43) in order to encourage policy makers to undertake effective action to reduce GHG and pollutant emissions. Suggested revision (new language in CAPITALS):

> "Reductions in greenhouse gas emissions would limit globally averaged surface warming, but the resulting slowdown in warming would be temporarily masked by natural year-to-year variability (*high confidence*), as well as by additional warming due to reductions of cooling aerosols (FINE PARTICULATES AND OTHER AIR POLLUTANTS) – even when accompanied by reductions in other short-lived climate forcers. The detection time of mitigation benefits for surface air temperature would therefore be about 25–30 years for the global mean and near the end of the century at regional scales (*medium confidence*). HOWEVER, THE PUBLIC HEALTH BENEFITS OF REDUCING NEAR-SURFACE AEROSOL EMISSIONS WILL ACCRUE PROMPTLY, THEREBY ENHANCING AGRICULTURAL AND SOCIETAL RESILIENCE TO THE IMPACTS OF CLIMATE CHANGE."

Pages 43 line 25 – page 44 line 22
Section D.5 Climate information and societal linkages, paragraph D.5.4 succinctly states the biggest social challenge we all face in seeing effective action on climate change: "It is virtually certain that complex climate change information is understood differently by different groups of people." Unfortunately, there are many decision makers who will interpret the data summarized in the SPM to suggest that efforts to reduce emissions or enhance carbon dioxide removal (CDR) through natural processes are not cost-effective because they will not significantly change the global temperature curve or other climate indicators in the next couple of decades. Thus, it is vital that the Summary for Policy Makers clearly outline three key messages:

- The urgency of the climate situation.
- The long term efficacy of mitigation efforts in preventing catastrophic change by the end of the century, and
- The more immediate benefits to public health, agriculture, and community resilience of aggressive efforts to reduce all air pollutant emissions and optimize agricultural and land management practices for CDR and soil and ecosystem health.

WGI can enhance the delivery of these three messages in section D.5 by adding a few key phrases (in CAPITALS) to the pink box summary and to paragraph D.5.4, as follows:

Summary:

"Useful climate information for vulnerability, impacts, adaptation AND MITIGATION, and climate service applications depends on the regional context and sectoral assets in focus. Irrespective of the emission pathway that is followed, multiple climatic impact drivers will continue to change over all regions over the next decades as well as the longer course of the century (*high confidence*), YET AGGRESSIVE EMISSIONS REDUCTION PATHWAYS WILL GREATLY REDUCE THE SEVERITY OF WARMING AND OTHER CLIMATE IMPACT DRIVERS BY 2100 (HIGH CONFIDENCE). IN THE NEAR FUTURE, strong climate change mitigation and air quality measures would lead to notable air quality improvements (*high confidence*) WITH CRITICAL BENEFITS TO PUBLIC HEALTH AND SOCIETAL CAPACITY TO ADAPT TO CLIMATE CHANGE. Improved understanding of user needs and co-designing of climate information can enhance the provision of scientific evidence for decision making AND EFFECTIVE ACTION (*high confidence*)."

Paragraph D.5.4:

"It is *virtually certain* that complex climate change information is understood differently by different groups of people, RESULTING IN RESPONSES RANGING FROM EFFECTIVE MITIGATION AND ADAPTATION, TO IMPLEMENTATION OF CERTAIN STRATEGIES WITHOUT DUE CONSIDERATIONOF ECOLOGICAL OR SOCIAL SIDE EFFECTS, OR JUSTIFICATION FOR INACTION. Since AR5, there has been considerable progress in understanding climate information user needs, better facilitation of user engagement, further translation of climate data into impacts- and risk-relevant indices, GREATER UNDERSTANDING OF THE POTENTIAL OUTCOMES OF VARIOUS GHG MITIGATION AND CDR METHODOLOTIES, and an appreciation of climate scientists to involve communication specialists and social scientists to support the co-design and co-development process that is fundamental to a successful climate service. Climate services are being developed across regions, sectors (e.g., agriculture, water, energy, health), timescales (from sub-seasonal to multi-decadal) and target users (*high confidence*). User needs and decision-making contexts are very diverse and there is no 'one size fits all' solution to climate services (*very high confidence*). Processes that support collaborative learning and knowledge production involving a diversity of expertise, including both climate scientists and decision makers, can facilitate the integration of science evidence into decision making, AND SELECTION AND IMPLEMENTATION OF REGIONALLY APPROPRIATE CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES (*high confidence*)."

Draft Comments on Chapter 5

Page 89 lines 18-21 (Table 5.9):

Regarding carbon dioxide removal (CDR) methods summarized in Table 5.9 and discussed in more depth on pages 90 – 166:

Enhanced biological production and storage on land offers the safest, most practical, technologically accessible, and ecologically responsible CDR strategy, for the simple reason that the living plant is the most direct and powerful means to remove excess CO2 from the atmosphere and sequester the carbon in a stable combined form – stable soil organic matter. This is how the natural carbon cycle has operated ever since land plants evolved 450 million years ago. Lal et al. (2018) has estimated that, over the next 60 years, optimized biological production and land management can potentially store an additional 333 Pg carbon in soil and biomass, which would lower end-of-century atmospheric CO2 concentration by 156 ppm.

Afforestation, reforestation, and wetland restoration can sequester more than 2 Mg C (7.33 Mg CO2) per hectare annually as soil organic carbon (SOC) and perennial plant biomass. Best agricultural soil management systems for annual crop rotations, especially organic farming systems that integrate cover crops, diversified rotations, compost and other organic amendments, and judicious tillage; or conservation agriculture that integrates cover crops, diverse rotations, organic amendments, no-till, and judicious use of agrochemical inputs can sequester 0.45 – 0.67 Mg C/ha-year (= 1,6 – 2.5 Mg CO2/ha-yr) (based on multiple studies reviewed in NSAC, 2019, and Schonbeck et al., 2018). While avoiding tillage protects the soil biota from physical disturbance, the herbicides needed to effect no-till in annual crop production can also damage mycorrhizal fungi and other key components of the soil microbiome (Klein, 2019)

Advanced grazing management systems such as management intensive rotational grazing (MIG), and agroforestry practices like alley cropping, permaculture, multistory cropping, forest gardening, silvopasture, and woody perennial conservation buffers can sequester >2.25 Mg C/ha-yr (8.2 Mg/ha-yr CO2) (Feliciano et al., 2018; Machmuller et al., 2015; Teague et al., 2016; Wang et al., 2015).

In addition, organic farming systems protect the community of soil life from synthetic fertilizers, pesticides, and herbicides. Recent studies have confirmed that the soil biota plays an essential role in long-term soil organic carbon (SOC) storage, and that exposure to agrochemicals can be as harmful to certain components of the soil biota as excessive tillage (multiple references cited in Klein, 2019, and Schonbeck et al., 2019).

Based on the research findings summarized in these references, we urge IPCC to consider expanding the description in Table 5.9 of the “Agricultural Soil Management” CDR strategy (third row, fourth column of table) as follows:

> “Store carbon in soil through agroecological production systems including organic, conservation agriculture, agroforestry, and rotational grazing.”

References:

Feliciano, D., A. Ledo, J. Hillier, and D. R. Nayak. 2018. *Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions?* Agriculture, Ecosystems, and Environment 254:117-129.

Klein,K. 2019. *Pesticides and Soil Health.* Friends of the Earth, brief with literature references, 9 pp.

Lal, R., P. Smith, H. F. Jungkunst, W. J. Mitsch, J. Lehmann, P. K. R. Nair, A. B. McBratney, J. C. de Moraes Sa., J. Schneider, Y. L. Zinn, A. L. A. Skorupa, H. Zhang, B. Minasny, C. Srinivasrao, and N. H. Ravindranath. 2018. *The carbon sequestration potential of terrestrial ecosystems*. Journal of Soil and Water Conservation, 73(6): 145A-152A.

Machmuller, M. B., M. G. Kramer, T. K. Cyle, N. Hill, D. Hancock, and A. Thompson. 2015. *Emerging land use practices rapidly increase soil organic matter.* Nat. Commun. 6:6995. doi:10.1038/ncomms7995.

National Sustainable Agriculture Coalition (NSAC), 2019. *Agriculture and Climate Change: Policy Imperatives and Opportunities to Help Producers Meet the Challenge.* 78 pp. https://sustainableagriculture.net/publications/.

Schonbeck, M., D. Jerkins, and L.Snyder. 2018. *Soil Health and Organic Farming: Organic Practices for Climate Mitigation, Adaptation, and Carbon Sequestration.* Organic Farming Research Foundation, 78 pp. https://ofrf.org/research/reports/.

Teague, W. R., S. Apfelbaum, R. Lal, U. P. Kreuter,J. Rowntree, C.A. Davies, R. Conser, M. Rasmussen, J. Hatfield, T. Wang, R Wang, and P. Byck. 2016. *The role of ruminants in reducing agriculture's carbon footprint in North America.* J. Soil & Water Conserv. 71(2): 156-164.

Wang, T., W. R. Teague, S. C. Park, and S. Bevers. 2015. *GHG mitigation and profitability potential of different grazing systems in Southern great plain*. Sustainability 7:13500–13521.

Bioenergy with carbon capture and storage (BECCS) might be considered a technological method (4th category in Table 5.9) rather than land-based biological CDR. BECCS takes the carbon dioxide from biofuel combustion and uses technological processes to capture the CO2, similar to direct air capture with carbon storage (DACCS). The main difference between BECCS and DACCS is that the former intercepts the CO2 immediately after it is created through combustion, which can be done with either biofuel or other fuels. BECCS is one example of a larger technological category that might be called "carbon emissions capture and storage" and be used for *all* industrial combustion (for energy production or for manufacturing) including biofuel use.

Regarding *enhanced weathering*, it is unclear how the formation of *silicate* minerals (SiO4 in combination with aluminum, magnesium, potassium, iron, and other cations removes carbon from the atmosphere. If such a mechanism exists, it should be briefly explained in a footnote to the table.

Page 91, lines 5 - 23

Regarding *carbon cycle response over time in scenarios with CDR*, it is not at all clear why land-stored carbon (the land CO2 sink) would behave similarly to the ocean CO2 sink. Excess CO2 is stored in the oceans as dissolved CO2 in equilibrium with bicarbonate (HCO3-) and carbonate (CO3--), so when the vapor pressure of atmospheric CO2 declines, outgassing of CO2 from the ocean (with concomitant shift in the CO2-HCO3-CO3 equilibrium) is expected. However, CO2 is stored on land as plant biomass C and soil organic C, whose decomposition back into CO2 is driven primarily by temperature, moisture, soil disturbance, and forest clearing – and not (or at most to a very slight degree) by atmospheric CO2.

Thus, land-sequestered C would not necessarily convert back to CO_2 in response to biological, geochemical or technological CDR – or at least would not do so with the rapidity and predictability of ocean-dissolved inorganic carbon.

Page 94, lines 12-55
We appreciate IPCC WGI for taking into consideration issues of biodiversity and site-appropriateness of afforestation and reforestation efforts. Replacing cleared native forest with monoculture or low-diversity tree plantings, and efforts to convert prairie or savanna to forest can clearly be counterproductive for ecosystem health and CDR goals per se. Land-based biological CDR based on reforestation is most effective when high diversity native tree plantings are done in regions that were originally in forest prior to clearing or plant community degradation.

Page 95, lines 1 - 50
The paragraph on agricultural soil management for CDR covers the many practices that can sequester C, and accurately cautions that striving for enhanced plant biomass through increased N fertilization can boost N_2O emissions. Enhancing plant biomass production through N fertilization has also been shown to yield little or no additional soil C sequestration, and can even result in net soil C losses (Khan et al., 2007).

Agroforestry practices that integrate reforestation with food or fodder production merit greater emphasis in this paragraph. These include alley cropping, permaculture, forest gardening, multistory cropping, silvopasture, and buffer plantings such as hedgerow that include tree fruits or nuts). In addition, management intensive rotational grazing methods adapted to locale should be mentioned explicitly. As noted and referenced earlier (comments on page 89 of Chapter 5) agroforestry and advanced grazing management have been shown capable of sequestering >2.25 Mg C/ha-yr (8.2 Mg/ha-yr CO_2), compared to 0.45 – 0.67 Mg C/ha-year (1,6 – 2.5 Mg CO_2/ha-yr) for best integrated management of annual crop rotations (cover crops, tight diverse rotation, reduced till, best nutrient management). In addition, managed plant communities that include a diversity of food-bearing trees can play key roles in food security, especially in developing nations – thus accomplishing CDR without difficult tradeoffs in terms of food production, biodiversity, or other vital services.

Regarding *biochar*, Lal et al (2018) estimates that production and land application of biochar can sequester 0.5 – 0.9 Pg C annually (global total), accounting for 22 ppm of the 156 ppm reduction in end-of-century atmospheric CO_2 concentration from land-based biological CDR. However, feedstocks for biochar production must be selected and harvested with care. Removal of plant biomass from native plant communities or agricultural fields for biofuel, biochar, or compost production can have severe adverse impacts on biodiversity, water supplies, food security, cultural values, and resilience of rural communities to climate change. Conversely, conversion of organic “wastes” (manure from confined animals, food scraps, yard trimmings, municipal leaves) into either biochar or compost can make important contributions to soil health, soil carbon sequestration, and community resilience to climate change and other stresses.

The paragraph on bioenergy production with carbon capture and storage (BECCS) opens with the statement that BECCS is one of the most important CDR strategies for keeping global warming within 2 C. Yet, the remainder of the paragraph points out all the caveats and drawbacks to this approach, not the least of which are that large scale BECCS plantings would compromise both biodiversity and food security, and that effective CCS technologies remain to be developed. Thus, it seems clear that BECCS has less practical CDR potential than any of the other land-based biological CDR strategies discussed on this page.

References:

Khan, S. A., R. L. Mulvaney, T. R. Ellsworth, and C. W. Boast. 2007. *The myth of nitrogen fertilization for soil carbon sequestration*. J. Environ. Qual. 36:1821–1832.

Lal et al, 2018, cited above (see comments on page 89 of this chapter).

Pages 97, line 5 – page 98 line 28

The language clearly outlines the drawbacks and potential negative side effects of *ocean-based biological CDR methods*, especially ocean fertilization and artificial upwelling. Coastal plant community restoration is far more benign and well-aligned with natural ecosystem function, yet it has limited C sequestration potential on a global scale. This should further impel Working Group I to place more emphasis on nature-simulating land based (photosynthesis + soil microbial process) biological CDR as a safer and more practical strategy.

Page 98 line 31 – page 99 line 19

Regarding *enhanced weathering* achieved by spreading finely-ground alkaline rocks or minerals on land, the quantity of mined material required for an effective amount of CO2 removal will either be economically unfeasible or require huge mining operations with severe environmental impacts on biodiverisity, water quality, and rural communities near the mining activities. In addition alkalizing the soil on a broad scale will alter soil microbiomes, and may disrupt microbial ecology or have other adverse "side effects" on natural plant communities, and on lands used for agriculture or forestry. In addition, while the delivery of more alkaline river waters to the ocean could help ameliorate ocean acidification, the impacts of alkalization on stream and river biota and ecosystems is unknown and likely disruptive.

Alkalizing the ocean would, at least in theory, reverse a negative effect (acidification) of increasing atmospheric CO2. However, the mineral additions needed to effect alkalization may upset ocean ecological balance and, in any case, may be economically infeasible. The language on page 99 acknowledges that impacts of alkaline mineral applications in the amounts needed to effect substantive CO2 removal (114 Pmol to remove 27 Pg C by the end of the century) are unknown and possibly detrimental.

Technological chemical CDR including *Direct air capture and carbon storage* (DAC) seems risky if the CO2 is stored deep underground or under water, as the risks of leakage or failure of containment would exist in perpetuity. However, if captured carbon can be combined into a stable, solid mineral substance that can be either used to fabricate durable products or stored, this can be an important part of the climate solution provided that the process is both financially and ecologically cost-effective (i.e., process is energy-efficient and/or can be powered through solar or wind energy).

DAC seems far less efficient than CO2 capture at points of emission, such as the smokestacks of power plants, whether they are burning fossil fuels or biofuels as in BECCS.

Once again, land plant based photosynthesis coupled with soil microbial carbon stabilization appears far safer and more practical than any of the geochemical or technological-chemical methods. The former strategy utilizes natural processes by which carbon has been sequestered ever since land plants and their microbial symbionts co-evolved 450 million years ago.

Pages 99, line 38 – page 101, line 36
Regarding *Solar Radiation Modification (SRM) through stratosphere aerosol injection*, the low confidence in its net benefits for climate stabilization and agricultural production, and unpredictable "side effects" suggest that it merits at best a low priority among climate mitigation strategies. The one "high confidence" conclusion is that SRM would increase ocean acidification, a very serious side effect that must be avoided, and thus might merit removal of SRM from the list of CDR methods under consideration by decision makers.

Page 103, lines 46-50
The first paragraph under the heading "Carbon Dioxide Removal and Solar Radiation Modification" notes "low confidence" in global CO2 sequestration potential of land-based and ocean-based CDR methods, and the need to verify that they "are regionally feasible … present an actual and verifiable negative regional carbon balance, and have no negative unintended consequences." Land-based biological CDR, including soil health practices in organic farming and other agroecological production systems, agroforestry, advanced rotational grazing management, and restoration of native forest, prairie, and wetland plant communities, come closest to meeting these criteria.

Although more research is needed to quantify CDR potential and enhance regional feasibility, recent literature reviews indicate that these practices offer substantial CDR potential (NSAC, 2019; Schonbeck et al, 2018, cited above). For example, Lal et al (2018) cites a range of estimates for cumulative potential global CO2 removal over the next 60 years through land-based biological CDR of 208 – 458 Pg C, resulting in a reduction in atmospheric CO2 concentration of 97 to 214 ppm. Even at the low end of this range, this could make the difference between climate change to which ecosystems and human civilization can adapt, versus utter catastrophe that would leave our planet unrecognizable. Dr. Lal and his colleagues are among of the world's most highly regarded climate scientists and agroecologists. Thus we strongly urge the IPCC to take seriously their science-based advocacy of the ecological and common-sense strategy of land-based biological CDR that enlists plants and soil microbes in helping humanity repair the damage to Earth's climate.

In addition, unlike ocean-based, geochemical, and technological CDR methods, the "side effects" of photosynthesis-based CDR on currently managed lands are mostly beneficial, and include reduced soil erosion; increased agricultural, community, and ecosystem resilience based on improved soil health and biodiversity; and improved water quality through enhanced nutrient cycling. Holistic and locale-appropriate application of land-based biological CDR methods can protect and enhance both food security and biodiversity.

At the same time, we do acknowledge that the uncritical application of certain land-based biological CDR methods *can* undermine biodiversity, food security, and community resilience, as noted in the AR6 WGI report. Pitfalls to avoid include afforestation of areas not historically in forest, reforestation with monoculture tree plantings, and "land-grabs" of productive cropland that displace food production for local human communities with CDR or biofuel crop plantings. For example, large-scale monoculture plantings of the high-biomass perennial grass *Miscanthus X giganteus*, can achieve substantial CDR and provide biofuel, yet can also supplant native plant communities and food crops.

Pages 165-166 (table)
The summary table of impacts and side effects of CDR strategies is quite thorough, accounting for both desirable and negative "side effects" of each CDR strategy.

Under afforestation the table correctly notes that, if not applied wisely and in a site-appropriate manner, this strategy can pose risks to food security and biodiversity, and can threaten water supply in dry regions. As noted earlier (comments on pages 95) tree-based CDR strategies can be integrated with agricultural production and food security through agroforestry, use of locally-adapted food-producing tree species, silvopasture, and permaculture systems.

Under ocean fertilization and artificial upwelling, the table notes side effects of increased acidification, hypoxic zones, N_2O emissions, perturbation of oceanic ecosystems and communities, and possible toxic algal blooms. These are serious enough to consider taking these CDR strategies off the table, or at least making them much lower priority than land-based CDR strategies that utilize diverse crop, tree, and native plant species, and use no or minimal fertilizer and other agrochemical inputs.

Draft Comments on Chapter 6

Page 67, lines 23 - 33
Regarding the potential to reduce methane emissions by as much as 54% by 2050, the report states that, while literature estimates of potential methane mitigation "include additional reductions due to fast decarbonization, they also include very rapid reduction of emissions in agriculture which can be realized by assuming fast shift to intensive livestock rearing in developing countries which has been debated (e.g., Udo et al., 2011)." It is vital to emphasize that the most climate-mitigating approach to "intensive livestock rearing" is management-intensive rotational grazing (MIG). While cattle grazing on *low-quality grass on poorly managed pasture* do emit more enteric methane (up to 2X per unit production) than intensive confinement-raised cattle, this does not account for the methane and nitrous oxide emissions from liquid manure storage in confined animal feeding operations (CAFOs), nor the GHG emissions associated with grain production CAFO livestock. Furthermore, when unmanaged, overgrazed pasture is converted to MIG systems adapted to locale, per-animal enteric methane drops 30-50%, animal health and productivity improve, and grazing land managed under MIG typically sequesters >2 Mg C/ha-yr (7.3 Mg CO_2/ha-yr).

References:

Ominski, K. H., D.A. Boadi, K. M. Wittenberg, D.L. Fulawka & J.A. Basarab. 2001. *Estimates of Enteric Methane Emissions from Cattle in Canada Using the IPCC Tier-2 Methodology*. Canadian Journal of Animal Science 87, 459–467.

Machmuller et al., 2015 (cited above in comments on Chapter 5 page 89)

Stanley, P. L., J. E. Rowntree, D. K. Beede, M. S. DeLonge, and M. W. Hamm. 2018. *Impacts of Soil Carbon Sequestration on Life Cycle Greenhouse Gas Emissions in Midwestern USA Beef Finishing Systems*. Agricultural Systems, 162, 249–58. https://doi.org/10.1016/j.agsy.2018.02.003.

Teague et al., 2016 (cited above in comments on Chapter 5 page 89).

Wang et al., 2015 (cited above in comments on Chapter 5 page 89).