Comments on

Science to Inform Management of Subsided Lands in the Sacramento-San Joaquin Delta

Steve Deverel, HydroFocus, Inc. December 1, 2025

Overarching Comment

There seems to be a need for recommending prioritization of lands for implementation of land uses that will reverse and stop subsidence. The SUBCALC model (Deverel and Leighton, 2010) has been used to estimate business-as-usual greenhouse-gas emissions and subsidence rates for prioritization of areas for implementation of rice and wetlands (e.g. Vaughn et al. 2024; HydroFocus et al. contribution to ARB scoping plan, 2022). Modeling and data collection efforts are needed to identify and prioritize areas where the relative probability of failure increases where marsh deposits are thin as illustrated in Figure 11 of Deverel et al. (2016a).

Specific Comments

On page 3,

Suggested changes in red and underlined

"Mesocosm- and pilot-scale projects initiated in 1993 on Twitchell Island demonstrated that intentionally and perennially inundating land to establish managed freshwater wetlands can reverse subsidence"

This narrative should be accompanied by citations as follows.

Deverel, S. J., Bronwen Wang, and S. A. Rojstaczer. "Subsidence in the Sacramento-San Joaquin Delta, in (Borchers, JW, ed.) Proceedings of the Joseph Poland Subsidence Symposium." *Association of Engineering Geologists* (1998).

Miller, R.L., Fram, M., Fujii, R. and Wheeler, G., 2008. Subsidence reversal in a re-established wetland in the Sacramento-San Joaquin Delta, California, USA. *San Francisco Estuary and Watershed Science*, *6*(3).

Also on page 3,

"More recently it has been demonstrated that inundating agricultural land to grow rice also has the potential to slow or arrest subsidence."

Please cite

Deverel, S.J., Ingrum, T. and Leighton, D., 2016. Present-day oxidative subsidence of organic soils and mitigation in the Sacramento-San Joaquin Delta, California, USA. *Hydrogeology Journal*, *24*(3), pp.569-586.

On p, 5

Suggested change in red and underlined

A collateral benefit of the inundation in both situations is that they avoid carbon dioxide emissions released by the microbial oxidation of peats and, in the case of managed wetlands, promote sequestering of carbon by biomass accumulation. Over time, if implemented at a large scale these practices could convert the Delta from a significant **source** of carbon dioxide emissions, an important greenhouse gas (GHG), to a major **sink.** Methane is another potent GHG that is produced by freshwater wetlands and the production of methane, which contributes to the net GHG balance, will be discussed in depth later.

For this writing on p. 6, citations are needed.

Types of active and planned projects in the Delta to mitigate land subsidence include: (1) reversing subsidence by managed wetland restoration, (2) slowing or arresting subsidence by cultivating rice, (3) developing floating tule wetlands in deeply subsided islands (Deverel et al. 2024), and (4) designing a landscape, i.e., crop and wetland mosaics, that locates managed wetlands, rice, and other crops based on site-specific soil and hydrologic characteristics such as elevation and drainage (Deverel et al. 2017). Benefits of these projects include arresting and reversing subsidence, avoiding carbon emissions, carbon sequestration, and habitat restoration. For instance, rewetting projects on Sherman and Twitchell Islands in the Central Delta indicate that these land conversions have provided a net reduction of 10 tons/acre/year of CO_2e (carbon dioxide equivalent), as described during the workshop.

See Hemes et al. 2019 for more accurate estimates. 10 tons/acre/year of CO_2e is high. Also, Tyler Anthony at DWR is currently quantifying the emissions reductions on Sherman and Twitchell for the carbon market verification. He would have a better handle on this number.

References

Deverel, S., Jeffres, C., Dore, S., Corline, N., Xu, L., Olds, M., Haas, S.M., Schellenbarger, G.G. and Eckes, D., 2024. Investigation of Floating Peat Wetlands, Sacramento–San Joaquin Delta, California. *San Francisco Estuary and Watershed Science*, *22*(4).

Deverel, S., Jacobs, P., Lucero, C., Dore, S. and Kelsey, T.R., 2017. Implications for greenhouse gas emission reductions and economics of a changing agricultural mosaic in the Sacramento–San Joaquin Delta. *San Francisco Estuary and Watershed Science*, *15*(3).

For this writing on p. 9

"However, the understanding of the factors that control and affect subsidence processes and subsidence reversal rates in organic soils at decadal time scales are less well documented, e.g., primary and secondary consolidation, organic soil density, temperature, depth to groundwater table, and biomass accumulation".

Please note that Deverel et al. 2014, simulated decadal accretion on Twichell Island and provided insight about consolidation and biomass accumulation. Deverel et al. 2020 presented 20 years of accretion on Twitchell Island and demonstrated similar rates as presented in Deverel et al. 2014.

Also, the depth to groundwater table data need requires more explanation. We know that accretion only occurs where the soil is inundated. So any depth groundwater would inhibit this accretion.

Also on page 9

Institutional focus and commitment to long-term monitoring in areas where subsidence reversal projects are underway will greatly enhance understanding necessary to improve management and restoration since these efforts are attempting to duplicate in decades what nature required millennia to accomplish.

It is worth noting that instrumentation has been installed in the Twitchell and Sherman wetlands and is being used to measure accretion rates.

There is also a need to further evaluate the potential for rice cultivation and other paludiculture (agriculture on wet or rewetted peatlands) crops to reverse, and not just arrest, subsidence.

Land surface elevation changes have been measured in rice on Staten since 2021 and will continue to be measured for the foreseeable future. Data presented in Deverel et al. (2025) (see Figure below) show stable and increasing land surface elevation. Land surface elevation fluctuates with changing dept to groundwater. Instrumentation is planned for rice on Holland Tract and Roberts Island.

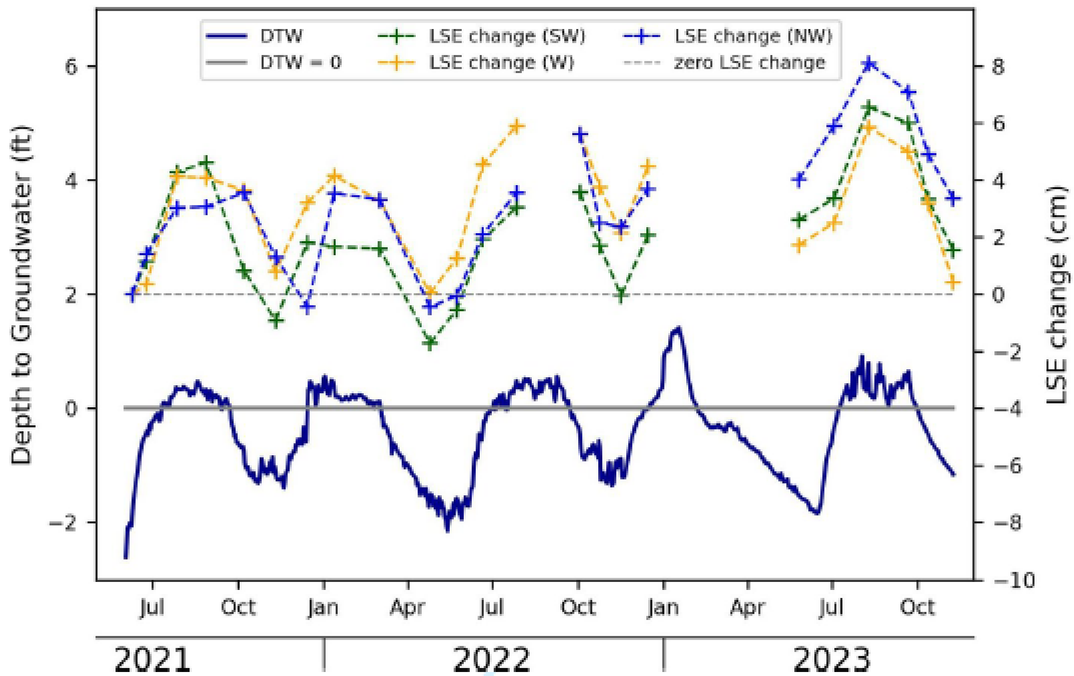

Figure 9. Sedimentation erosion table data for the Staten rice field land surface elevation change (LSE) for the varying SET locations (SW, W, NW indicate locations southwest, west and northwest of the EC tower) in the rice field and depth-to-groundwater (DTW). Elastic land-surface elevation changes are the result of changing groundwater levels due to draining for planting and flooding after planting in the spring and draining and flooding before and after harvest in the fall.

Source

Deverel et al. 2025, Interdisciplinary assessment of implementation of alternate land uses on subsided islands, Sacramento-San Joaquin Delta, In revision for publication in San Francisco Estuary and Watershed Science

Also on p. 9

There is also a need to further evaluate the potential for rice cultivation and other paludiculture (agriculture on wet or rewetted peatlands) crops to reverse, and not just arrest, subsidence.

It seems noteworthy that research in the Neatherland demonstrated accretion in experimental paludiculture plots.

Temmink, R.J., Robroek, B.J., van Dijk, G., Koks, A.H., Käärmelahti, S.A., Barthelmes, A., Wassen, M.J., Ziegler, R., Steele, M.N., Giesen, W. and Joosten, H., 2023. Wetscapes: Restoring and maintaining peatland landscapes for sustainable futures. *Ambio*, *52*(9), pp.1519-1528.

On page 10.

Over the past 150 years, half of the initial stock of organic carbon in the Delta wetlands has been lost to the atmosphere (Drexler et al., 2019).

Using more recent data, Vaughn et al. (2024) reported that two-thirds of the initial carbon stock had been lost.

The spatial variability of current peat thickness can help predict future subsidence risk and prioritize mitigation efforts.

Elaboration could help here. The peat thickness influences the under-seepage levee failure risk. The thinner the marsh deposits (peat thickness plus underlying tidal mud thickness), the greater the risk of under-seepage forces that increase the potential for erosion of levee foundation materials (Devere et al. 2016a).

While inundating peat soils generally reduces the microbial oxidation of organic matter that produces CO_2, it also creates conditions of low oxygen availability that promote generation of methane (CH_4) and nitrous oxide (N_2O), which are potent global warming gases.

The available data indicate N_2O emissions for drained organic soils are greater than for rice and wetlands (Anthony and Silver, 2024, Winham-Myers et al. 2018; Ye and Horwath, 2016)

Anthony, T.L. and Silver, W.L., 2024. Hot spots and hot moments of greenhouse gas emissions in agricultural peatlands. *Biogeochemistry*, *167*(4), pp.461-477.

Windham-Myers, L., Bergamaschi, B., Anderson, F., Knox, S., Miller, R. and Fujii, R., 2018. Potential for negative emissions of greenhouse gases (CO2, CH4 and N2O) through coastal peatland re-establishment: Novel insights from high frequency flux data at meter and kilometer scales. *Environmental Research Letters*, *13*(4), p.045005.

Ye, R., & Horwath, W. R. (2016). Nitrous oxide uptake in rewetted wetlands with contrasting soil organic carbon contents. Soil Biology & Biochemistry, 100, 110–117.

p. 18

Establishing a managed wetland can cost the farmer more than $10,000/acre because of regulation costs (permits, meetings, reporting requirements) and removing land from production.

I suggest documentation of this number as it seems elevated. My previous conversations with landowners and the Webb Tract wetland planning indicate lower per acre construction costs.

p. 21 Recommendations

I suggest exploring other options besides the carbon market such as documented in this publication.

Anderegg, W.R., Blanchard, L., Anderson, C., Badgley, G., Cullenward, D., Gao, P., Goulden, M.L., Haya, B., Holm, J.A., Hurteau, M.D. and Lague, M., 2025. Towards more effective nature-based climate solutions in global forests. *Nature*, *643*(8074), pp.1214-1222.

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This ongoing burial led to storage of over 308 million tons (280 million metric tons) of carbon in the undisturbed Delta (SFEI, 2022).

This promotes microbial oxidation of the organic matter in the drained organic soil and generation of carbon dioxide. SFEI (2022) concluded that 8.1 x 1010 cubic feet (2.3 x 109 cubic meters) of the pre-reclamation 1.9 x 1011 cubic feet (5.1 x 109 cubic meters) of organic soil in the Delta has been consumed, mostly by this microbial oxidation. Thus, 45% of the original volume of organic soil has been lost.

Better to cite numbers in Vaugh et al. (2024) which were based more comprehensive analysis; 7.8 billion cubic meters, two-thirds has disappeared.

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Currently, the price of carbon on the voluntary market is significantly lower than the value of farm crops on a per acre basis, requiring subsidies to maintain profitability.

Perhaps worth noting that the price per ton of carbon has increased substantially, probably close to $30 per ton based on discussion of proposed sale of Twitchell and Sherman carbon offsets. Perhaps worth a conversation with Tyler Anthony