Spatial variability of soil depth and profile organic carbon stocks of Alaska

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ABSTRACT : GC43C-0948

Amount of Soil organic carbon (SOC) in permafrost affected soils is estimated to be comparable or double than that currently in the atmosphere. Because of polar amplification under expected climate change, degradation of permafrost carbon may lead to strong feedbacks with the atmosphere. The objective of this study was to predict the fine-resolution spatial variability of soil depth and whole profile SOC stocks across Alaska. We used spatially referenced environmental variables (topographic attributes, land cover, climate, and bedrock geology) and georeferenced SOC profile data (n=472) in a local regression kriging framework to predict the spatial variability of soil depth and SOC stocks at 60-m spatial resolution across Alaska. Data trends were modeled using environmental variables by using a geographically weighted regression approach and the residuals were kriged using a moving window approach. Estimates of soil depth and SOC stocks were validated using independent datasets (n= 60). SOC stock of Alaska ranged from 1 to 296 kg m^{-2}, and the total was estimated to be 77 Pg. The predicted SOC stocks had a mean estimation error (MEE) of -2.5 kg m^{-2} and a root mean square error (RMSE) of 26.3 kg m^{-2}. Similarly, the predicted soil depth of the study area ranged from 18 to 241 cm, and had a MEE of -17.5 cm and a RMSE of 62.4 cm. Fine-scale spatial heterogeneity in soil depth and SOC stocks was large, but followed a broadly increasing trend from South to North.

OBJECTIVE

❖ The objective of this study was to predict the spatial variability of soil depth and whole-profile SOC stocks at a fine resolution (60 m spatial resolution) for the State of Alaska.

STUDY AREA & DATA SOURCES

❖ State of Alaska.

❖ 422 georeferenced SOC profile observations from National Soil Characterization Database and 50 SOC profile data from Ping et al. (2008) study.

❖ Digital elevation model and land cover data of 60 m spatial resolution was extracted for the study area from the database of USGS (Multi-Resolution Land Characteristics Consortium, 2010).

❖ The bedrock geology data was obtained from USGS database (Beikman, 1980).

❖ Long term (1961-1990) mean annual air temperature (MAAT) and mean annual precipitation (MAP), were obtained from the PRISM database (Daly et al., 2001).

SATIAL PREDICTION & VALIDATION APPROACH

Fig : 1 Distribution of SOC profile observations across Alaska.

❖ A local regression kriging approach was used to predict the spatial variability of soil depth and SOC stock at 60 m spatial resolution.

The local regression kriging process adopted in this study can be summarized as:

$$\hat{SOC}_{LRK}(x) = \hat{SOC}_{GWR}(x) + \hat{\varepsilon}_{MOK}(x)$$

where, $\hat{SOC}_{LRK}(x)$ = predicted values of the SOC using local regression kriging,

$\hat{SOC}_{GWR}(x)$ = Geographically weighted regression predicted values of the variable.

$\hat{\varepsilon}_{MOK}(x)$ = kriged values of the residuals at point x using a moving window ordinary kriging.

❖ We used a K-fold validation approach (Mishra et al., 2010; Martin et al., 2011).

$$MEE = \frac{1}{n}\sum_{i=1}^{n}(\hat{C}_s(x_i) - C_s(x_i))$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{C}_s(x_i) - C_s(x_i))^2}$$

$$RPD = \frac{SD}{RMSE}$$

where, $C_s(x_i)$ is the measured C concentration, $\hat{C}_s(x_i)$ is the estimated C concentration, *SD* is the standard deviation and *n* the number of validated observations.

RESULTS

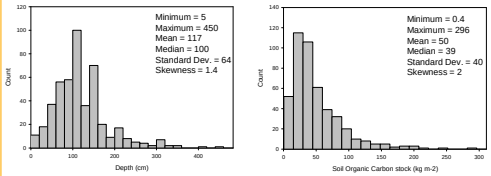

Fig : 2 Histograms showing descriptive statistics of soil profile depth (left) and SOC stocks (right).

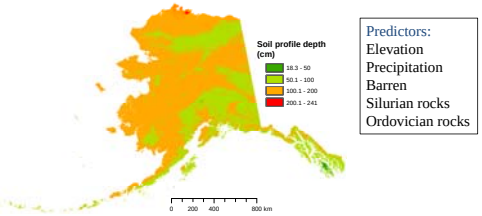

Fig : 3 Soil profile (O-C horizon) depth distribution across Alaska.

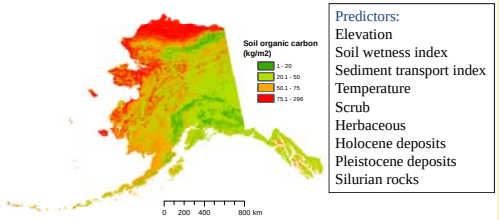

Fig : 4 Whole-profile SOC stock distribution across Alaska.

Table: Validation indices of soil depth and SOC stocks

Validation Parameters	Soil Depth (cm)	SOC stocks (kg m-2)
MEE	-17.5	-2.5
RMSE	62.4	26.3
RPD	1	1.5

MEE is mean estimation error; RMSE is root mean square error; RPD is ratio of performance to deviation

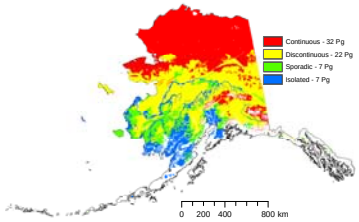

Fig : 5 Distribution of SOC stocks across permafrost zones of Alaska.

FINDINGS & LIMITATIONS

❖ Our SOC stock estimate is higher than previous studies due to considering whole soil profile and raster based spatial modeling approach.

❖ Higher prediction accuracy was obtained for SOC stock than soil profile depth.

❖ Soil wetness, long-term average annual air temperature, and land cover types were primary controllers of SOC stocks in Alaska.

❖ Prediction errors could be lowered by even distribution of SOC profile observations and incorporating other environmental variables such as time since pedogenesis, fire frequency, and intensity.

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