Quantifying and Extrapolating Soil Inorganic Carbon across Soils of the Western Snake River Plain, Idaho, using Pressurized Calcimetry

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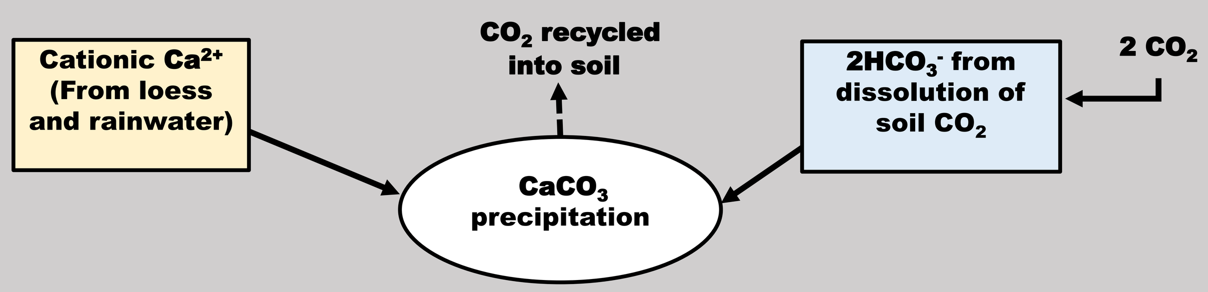
INTRODUCTION

What is soil inorganic carbon (SIC) and why is it so important?

- **Soil is the largest terrestrial reservoir of carbon, with storage as inorganic carbon being estimated as much more significant in the Western Snake River Plain (WSRP) than organic carbon (USDA 2000).**
- **Due to the long residence time of this reservoir, it is important to understand the quantity of carbon within the pool and any potential fluxes in and out of the soil to assess anthropogenic activities that may be releasing CO_2 into the atmosphere.**



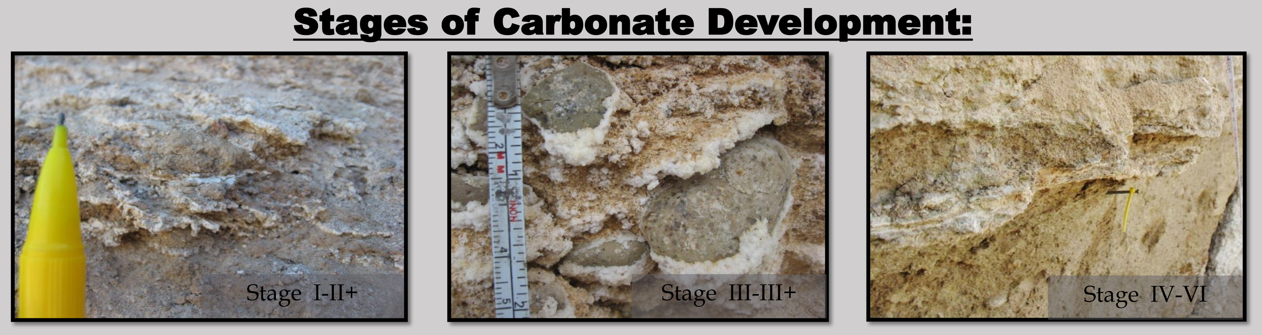
Resulting Net Reaction:

$$Ca^{2+}_{(aq)} + 2HCO^{-}_{3(aq)} \leftrightarrow CaCO_{3(s)} + CO_{2(g)} + H_2O_{(l)}$$

What are the overall controls on pedogenic carbonate development?

- **The basic soil-forming factors: anything that climate, soil organic activity, topography during pedgoensis, the parent material from which the soil is derived, all of which influence loess deposition (Jenny 1941).**

Stages of Carbonate Development:



General whitening of the soil matrix due to grain coating and string-like wisps that occur in root transpiration zone.*	Any visible clasts become coated and the overall horizon becomes plugged (III+).*	Indurated laminar plates of carbonate dominating the soil structure with minor brecciation (IV) to major brecciation due to multiple recementations (VI).*
General age required for development: 7,000 years.**	Increasing age and soil development →	General age required for development: 400,000 years.**

*Stages obtained from Gile et al. 1981

**Ages obtained from a study by Gile & Grossman in, Las Cruces, N.M., a study area with similar climate and parent material (1979).

Photo credit: Dawn Jarrels

HYPOTHESES

- **Carbon storage in the form SIC comprises the most significant carbon reservoir in the WSRP.**
- **There will be strong variability between each transect due to differences in soil forming factors such as age and relief.**
- **Peak SIC content in high stage K-horizons will be lower than 12% due to silica replacement as described by Blank, et al. (1998) and Othberg (1994).**

METHODS

Sample Collection

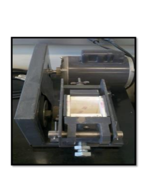
- Auger and/or trenched (depth normalized afterwards)

Sample Preparation

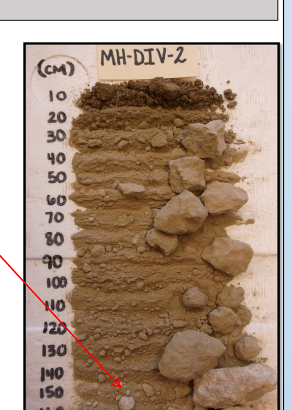
- Soil Taxonomy
- Sieve to 2mm
- Crush to 2cm
- Divide to 60g
- Powder to 250µm

Calcimetric Analysis

- Samples measured to precisely 2.0g
- 20% HCl measured to precisely10.0mL
- Calcimetric reaction:
  $CaCO_{3(s)}+2HCl_{(aq)} \rightarrow CaCl_{2(aq)}+CO_{2(g)}+H_2O_{(l)}$
- CO_2 is captured and measured (kPa x100)
- Calcimetric Calibration Line* [$y = 1.2982x + 0.0014$] $R^2 = 0.9995$
  *recalibrated per batch of HCl



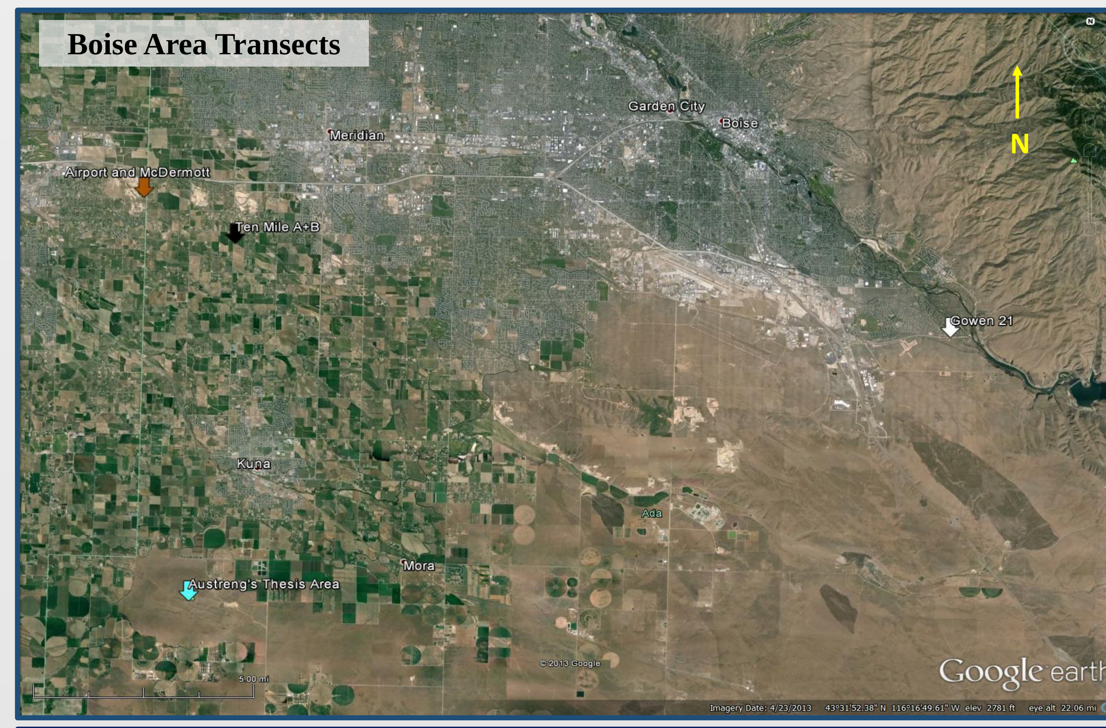
Soil color is indicative of $CaCO_3$ accumulation. Whitening increases at a depth to which irrigation & rainfall can translocate Ca^{2+}ions until moisture is diminished and calcium carbonate precipitates. The MH-DIV-2 sample (right) demonstrates these visual changes. At a depth of 165cm, the soil becomes increasingly more white where a K horizon is forming.

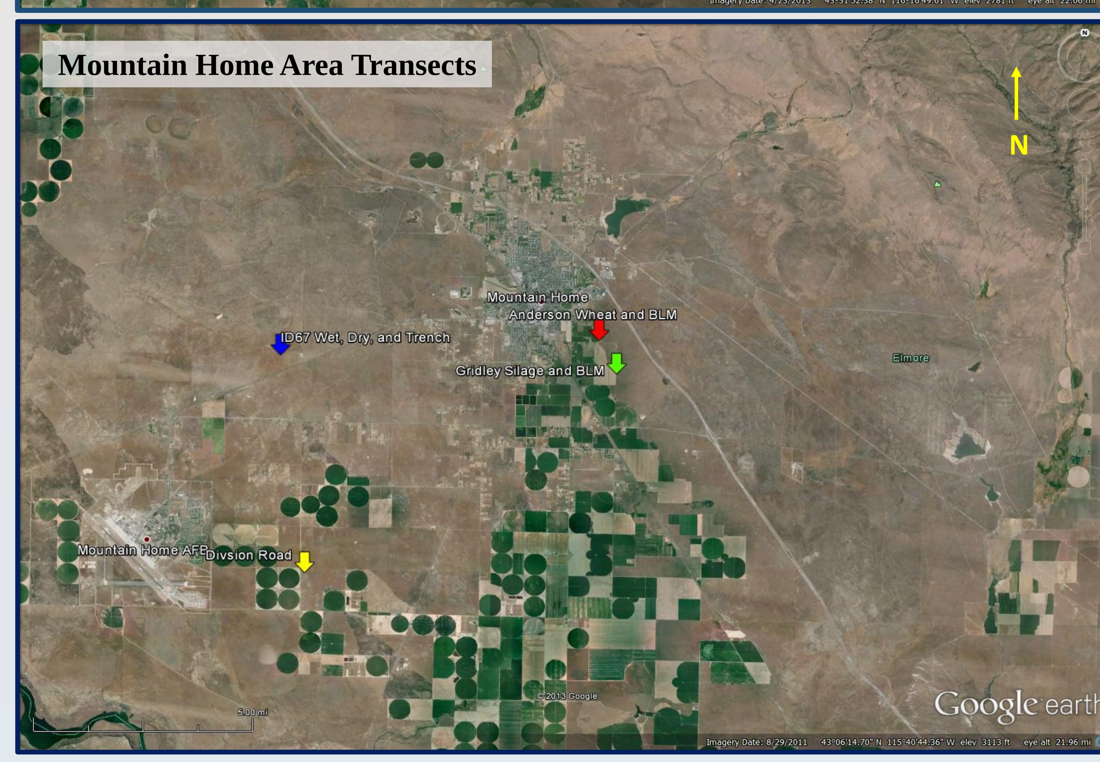


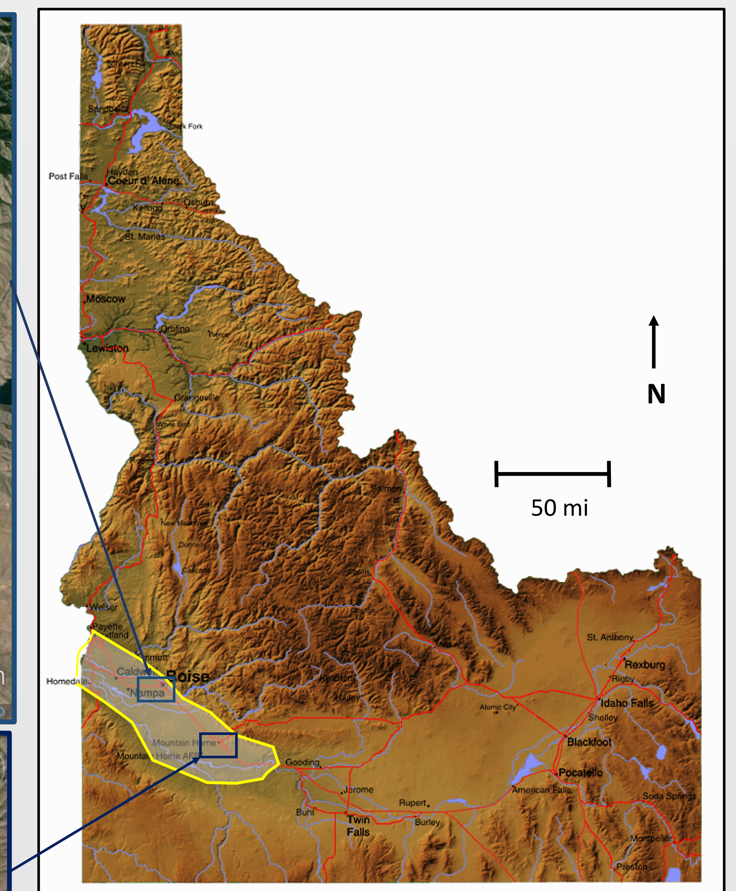
Analytical Analysis

- **Mass of $CaCO_3$** (within each sample)= [(Pressure derived from acidification within calcimeter) - 0.0014]/1.2982
- **Soil Inorganic Carbon (SIC) %** (of each sample) **=** (0.12 x Mass of $CaCO_3$) / (Mass of sample = 2.0 grams)
- **Soil Bulk Density**= (Volume of extracted soil including moisture and pore space) / (Dried Mass)
- **Soil Bulk Mass =** (Sample interval of 5 or 10 cm) x (Area of soil unit in cm^2) x Avg Soil Bulk Density (1.22 g/cm^2)
- **Total Inorganic Carbon (TIC)** (of Sample interval) = (SIC %) x (Soil Bulk Mass)
- **Total Inorganic Carbon** within the soil unit= $\sum_{X=1}^{n} SIC$

STUDY AREAS







Study Area Characteristics:

- **Located in the WSRP, a NW trending basin feature. Extrapolated area for this study is shown above is ~9550 km².**
- **Naturally dominated by big sagebrush (*Artemisia tridentata* varieties), bunchgrass, and a growing number of invasives such as cheatgrass.**

Mtn. Home Climate Data:

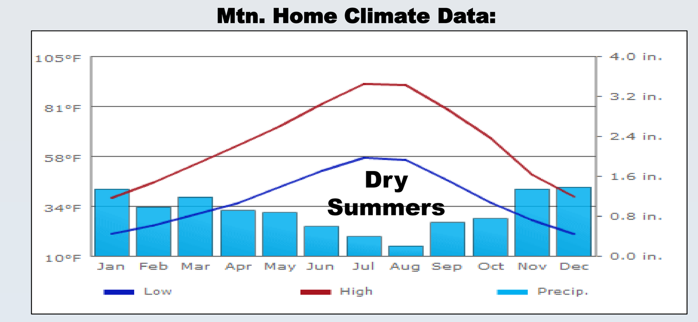


Table 1: Mtn. Home Area Transects

Transect	Geologic Setting[1]	Soil Series	Taxonomic Class[2]
Anderson Wheat and BLM	Overlying Undiff. Quaternary Basalt and Alluvium	Chilcott	Fine, smectitic, mesic Abruptic Xeric Argidurids
Gridley Silage and BLM			
Division Rd			
ID 67 Wet			
ID 67 Dry			
ID 67 Trench			

[1]Based off Shervais et al., 2004.
[2]From USDA-NRCS Soil Survey

Table 2: Boise Area Transects

Transect	Terrace	Max Age[1] (ka)	Soil Series	Taxonomic Class[2]
Gowen 21	Gowen	572 +/- 0.21	Elijah	Fine-silty, mixed, superactive, mesic Xeric Argidurids
Ten Mile - A	Amity	0.974 +/- 0.098	Chilcott	Fine, smectitic, mesic Abruptic Xeric Argidurids
Ten Mile - B				
McDermott Rd.			Chilcott (Disturbed)	
Airport Rd.				

[1]Obtained from K-Ar age (Othberg 1992).

SIC CONTENT

Figure 1: SIC Content with Depth at Non-Irrigated Sites in WSRP, ID

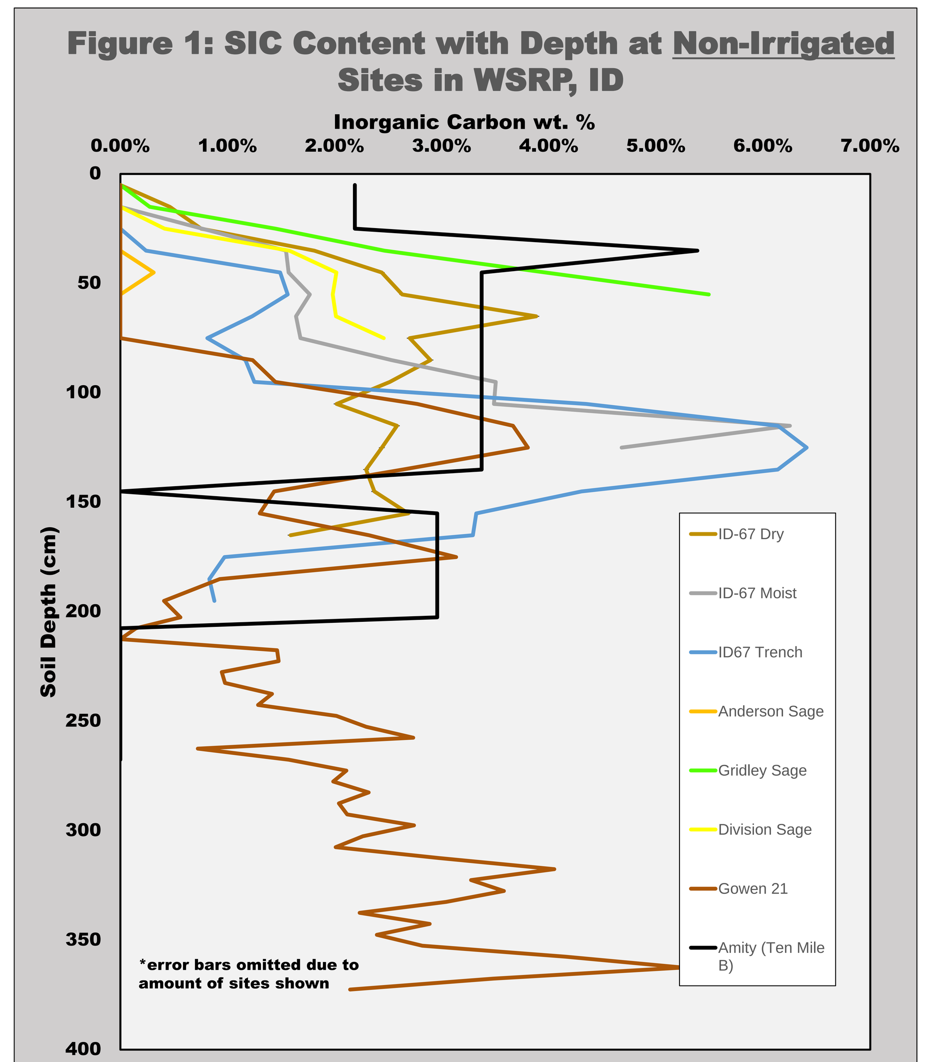
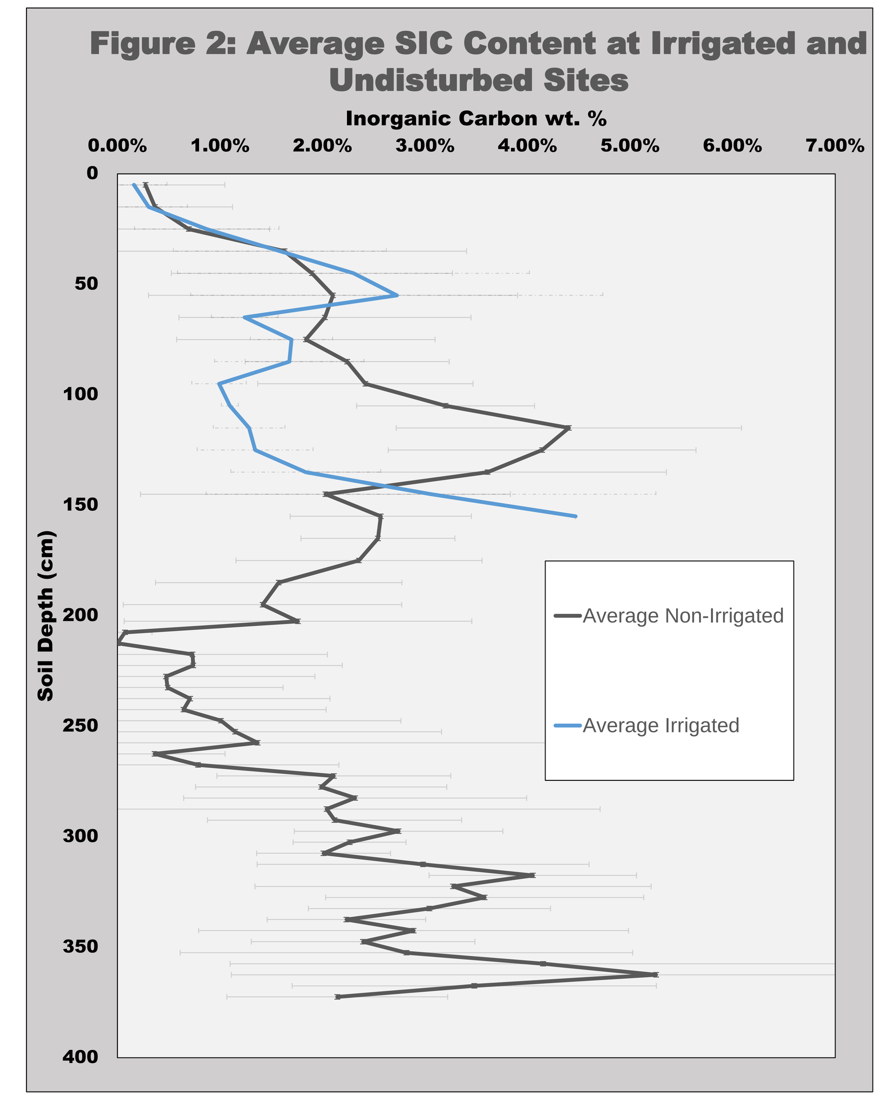


Figure 2: Average SIC Content at Irrigated and Undisturbed Sites



EXTRAPOLATION

Figure 6: Average SIC Storage as a Function of Depth

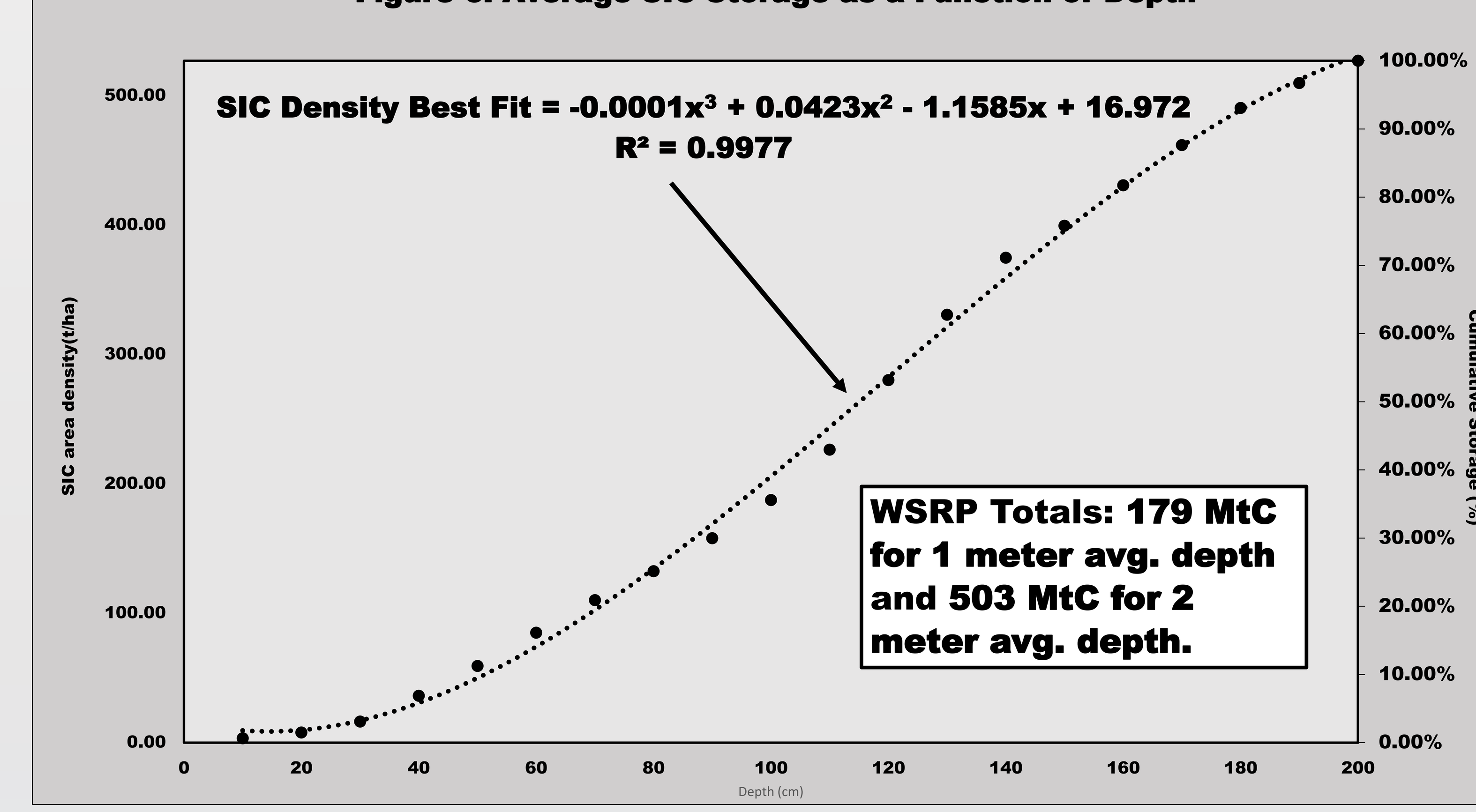


Table 6: Soil Carbon Area Densities (t/ha to 1 m)

WSRP Average	USDA (2000)		Austreng (2012)*		Elijah (Gowen)	Chilcott (Mtn. Home and Amity)
SIC: 188	SIC: 320-640	SOC: 26-75	SIC: 32-57	SOC: 23-44	SIC: 33	SIC: 187

*taken to only ~60 cm depth

DISCUSSION

Duripans and Silca Replacement:

- **Possible sources of silica replacement or co-precipitation could be the slower kinetic dissolution of silica from feldspars in the loess supply which could be translocated to the impassable horizon. Blank et. al suggest a complete removal of overlying B and argillic horizons during times of greater wind erosion and direct in-situ leaching of loess into the carbonate matrix, both of which suggest loess to be a source of silica (1998).**

Uncertainty and Error:

- **Extrapolation models make assumptions about soil depth which varies dramatically.**
- **Field contamination, difficulty in breaching through hardpan with an auger in many sites in Mountain Home.**
- **The age of soil development in Mountain Home sites has not been determined, absolute age of geologic surfaces is undifferentiated.**

CONCLUSIONS

- **SIC represents the largest reservoir of carbon in the soils of the WSRP, far exceeding SOC (Soil Organic Carbon).**
- **There is significant variability in the amount of SIC between sites and within sites due to differences in soil forming factors.**
- **There is evidence to suggest precipitation of opaline silica within the samples based on lower than expected SIC contents in K-horizons.**

FUTURE WORK

- **Select a more diverse set of soils with differing states of development, parent material, and geomorphic surfaces to create a more reliable representation of total carbon storage. Combine this with more data of physical parameters of soil to create a more robust model.**
- **Petrologically analyze carbonate samples, specifically looking at supposed silica development. Determine whether silica micromorphology has an impact on the overall resistance of layers to dissolution.**
- **Obtain OSL (Optically Stimulated Luminescence) to better understand soil ages, development rates of pedgoenic carbonates and correlate them to known climactic variations (i.e. Milankovitch cycles).**

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