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Terrestrial carbon storage and  
sedimentation in the Coon Creek  
Watershed, Wisconsin

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**Terrestrial carbon storage and sedimentation in the  
Coon Creek Watershed, Wisconsin**

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Senior Integrative Exercise  
March 10, 2004

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# Terrestrial carbon storage and sedimentation in the Coon Creek Watershed, Wisconsin

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March 10, 2004

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## Abstract

This study examines the connections between recent terrestrial sedimentation and carbon burial and discusses the implications for the global carbon cycle. Land-use change has mobilized large quantities of sediment, causing sediment to accumulate on valley floors, altering the terrestrial sediment cycle. This accumulated sediment may be sequestering much of the “missing carbon.” Using a combination of fieldwork and laboratory work, I explored carbon storage within the well-studied Coon Creek watershed of southwestern Wisconsin. To examine the basin’s sedimentation history, soil profiles were compared to existing sedimentation data and examined for carbon and nitrogen content. Two profiles reached buried pre-settlement soil, displaying the entire post-settlement sedimentation history of the valley. Recurring intervals of relatively low carbon percentages in site profiles indicate that most sediment eroded from heavily cultivated areas. Periods of high carbon values most likely represent eroded A-horizons from agricultural fields. The total amount of carbon found to be sequestered in the basin for the period 1850-1975 is  $8.056 \times 10^{11}$  grams. To bury this amount of carbon, these processes would have to occur over only  $1.4392 \times 10^{12} \text{ m}^2$  or 3.0% of global land capable of sequestering carbon. These results suggest that terrestrial sedimentation may account for the “missing carbon sink.”

Keywords: carbon storage, missing sink, soil erosion, land-use change, Wisconsin

## **Introduction**

This paper examines the linkages between agriculture-induced erosion and terrestrial carbon sequestration and investigates the ability of these geomorphic processes to account for a portion of the global “missing carbon sink.” As geomorphic agents, humans have a major impact on the landscape, mobilizing vast quantities of sediment, altering the terrestrial sediment cycle (Hooke, 1994). The fact that the terrestrial sediment cycle is not currently in equilibrium and is in fact storing significant amounts of sediment on land has serious implications for the global carbon cycle (Stallard, 1998). In 2002, Katja Meyer investigated carbon sequestration in the Canon River Wilderness Park in Northfield, Minnesota to further explore the possibility that terrestrial processes could account for the “missing carbon.” However, without a complete historical sediment model for the area, Meyer relied on computer modeling to create different scenarios that yielded final carbon and sediment volumes similar to her field and laboratory data (Meyer, 2002). In this paper, I combine carbon analyses throughout the Coon Creek Basin (SW Wisconsin) with the well-documented historical sedimentation data (Trimble, 1983). Trimble’s sediment budgets for the basin from 1850-1975 allowed me to analyze changes in the carbon distribution within the watershed since the introduction of agriculture to the region. In the following pages, I will present the results of these studies and their implications for the landscape of a small catchment along with their effect on the global carbon cycle.

## Background

### *The missing carbon sink*

Industrial activity and land use change since the 1850s have resulted in an increase in atmospheric carbon dioxide. It is estimated that a total of more than 280 Gt ( $1 \times 10^{15}$  g) of carbon has been emitted into the atmosphere since the 1850s (Marland and Boden, 2003). Half of these anthropogenic emissions remain in the atmosphere. Oceanic uptake and forest regrowth account for a substantial portion of the anthropogenic carbon, however, scientists have been unable to identify the reservoirs that store the remaining 110 Gt of carbon (McCarty and Ritchie, 2002). These missing carbon reservoirs have been termed the “missing carbon sink” (Table 1).

Stallard (1998) proposed that this “missing carbon sink” is linked to terrestrial sedimentation. Terrestrial processes such as agricultural practices tend to accelerate erosion 10 to 100 times the rate of natural erosion, and all but 10 percent of that eroded sediment is trapped in terrestrial basins (McCarty and Ritchie, 2002). Consequently, significant volumes of sediment have accumulated on valley floors and other terrestrial depositional environments since the introduction of agriculture. These accumulated sediments, according to Stallard, are sequestering much of this “missing carbon.” In addition, the continual photosynthetic production of organic carbon associated with soil development contributes to the carbon sink (Figure 1). Agricultural erosion successfully removes the top layer of soil, setting soil development back in time, effectively adding new fixed carbon to the uncovered, less developed, and carbon-poor soil. On average, agricultural practices result in an 89% loss of soil carbon at the time of field abandonment (Knops and Tilman, 2000). Recovery to 95% of pre-agriculture soil carbon

Table 1: Carbon cycle budget for anthropogenic effects. Gt = Gigatons of carbon. Modified from Bice, 1999. Data from IPCC, 1996.

<b>Sources</b>	
Fossil Fuel Burning and Cement Production	$5.5 \pm 0.5$ GtC/yr
Forest Burning and Soil Disruption	$1.6 \pm 1.0$ GtC/yr
<b>Total Anthropogenic</b>	<b><math>7.1 \pm 1.1</math> GtC/yr</b>
<b>Sinks</b>	
Storage in Atmosphere	$3.3 \pm 0.2$ GtC/yr
Oceanic Uptake	$2.0 \pm 0.8$ GtC/yr
Forest Regrowth	$0.5 \pm 0.5$ GtC/yr
<b>Missing Sink</b>	<b><math>1.3 \pm 1.5</math> GtC/yr</b>

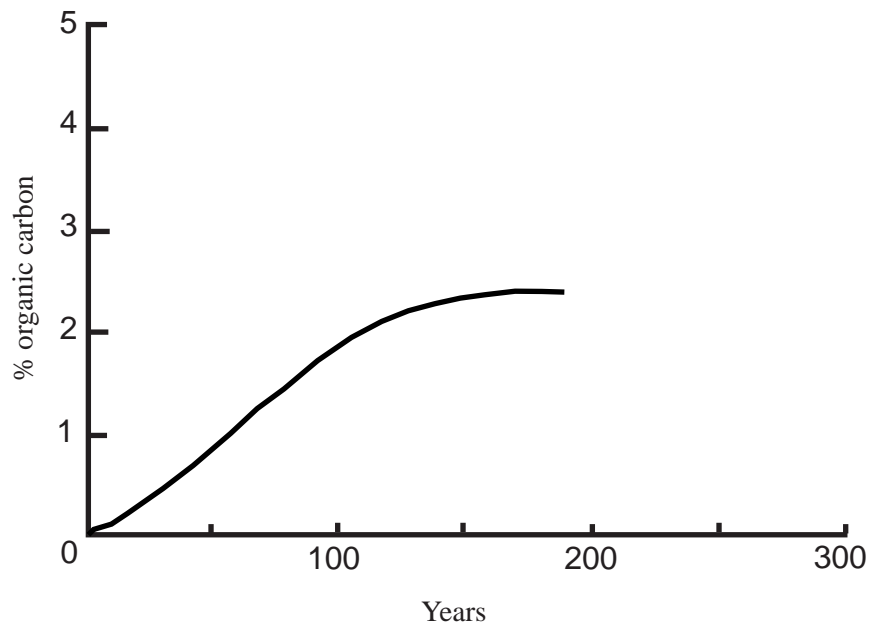


Figure 1: Generalized graph showing percent of organic carbon ( $\text{kg/m}^2$ ) in soil over time. Modified from Birkeland 1974.

levels is estimated to require at least 230 years (Knops and Tilman, 2000). This new carbon fixation creates a sink, removing atmospheric carbon dioxide.

Low carbon content in subsoil means that less carbon is given off in soil respiration. Since the rate of photosynthetic uptake of carbon remains the same, more carbon is coming into the soil than is being released, creating an imbalance between photosynthetic uptake and soil respiration (Bice, 1999). The soil is taking in more carbon than it is releasing, creating a sink. The sequestering of carbon in valley floor sediments creates another imbalance in the carbon cycle given that sequestered carbon is not returned to the atmosphere. This decrease in atmospheric carbon dioxide goes unnoticed because it is countered by the increases in anthropogenic emissions, forest burning and soil disruption. However, as conservation measures reduce the size of carbon storage reservoirs, this sequestered carbon will be returned to the cycle once again, escalating levels of atmospheric carbon dioxide.

Models of global carbon burial illustrated that carbon sequestration is at its peak between 30 and 50°N (Fan et al., 1998; Stallard, 1998). Stallard's calculations show that the burial of 1.5 GtC/yr is entirely plausible. Therefore, terrestrial sedimentation processes may well account for much of the "missing carbon" (Stallard, 1998).

### *Previous studies*

A previous study done by Katja Meyer '02 explored carbon sequestration within the Cannon River Wilderness Park in Northfield, MN (Figure 2). Because regional historical sedimentation data was not available, Meyer used computer modeling to determine whether reasonable rates of sedimentation and erosion could account for the





Figure 2: Location of Coon Creek watershed with respect to Cannon River Wilderness Park in Minnesota. Grey area designates the "Dritless Area." Modified from Meyer 2002.

accumulation of carbon in the Wilderness Park valley floor (Meyer, 2002). Her modeling revealed that rates similar to those measured in Coon Creek could account for observed carbon distributions and that terrestrial sedimentation may account for a portion of the “missing sink.” While her model served as a reasonable approximation of real world dynamics, she emphasized that having a more specific sedimentation and erosion record would have been helpful in creating a carbon budget for the Cannon River Wilderness Park.

### *The Coon Creek Watershed*

Unlike the Cannon River Wilderness Park, the Coon Creek Watershed in Southwestern Wisconsin has a very complete sedimentation record for the area since the introduction of agriculture in the 1850s. Along with parts of SE Minnesota, NE Iowa and NW Illinois, the southwestern part of Wisconsin is often called the “Driftless Area” (Figure 2). Unlike its surrounding neighbors, this small part of the continent escaped the last glaciation, allowing the land to continue developing the way it had been. Consequently, the Driftless Area is characterized by rolling hills and well-drained loess soils with silt-loam texture (Slota, 1969; Trimble, 2000). The Coon Creek Basin has narrow valleys and steep valley sides. The underlying bedrock is consolidated sedimentary rocks consisting of older sandstone and shale, and younger dolomite. The uplands are covered by a Pleistocene loess with a silty loam texture, while the valleys are covered by Pleistocene sandy terraces (Slota, 1969; Trimble, 1983). The nature of this terrain makes it very susceptible to erosion. It follows that unregulated agricultural practices in the late nineteenth century and early twentieth century accelerated erosion

throughout the valley to the point where more than 15 cm of sediment were accumulating on valley floors each year (Trimble, 1983).

By the 1930s, it was evident that the Coon Creek basin had a severe erosion problem. In response to the country's need to address its agricultural erosion problems, the Soil Conservation Service decided to conduct an intensive study of soil erosion involving surveys throughout a basin, land-use studies and aerial photography. With its severe erosion problems, Coon Creek basin was the perfect candidate. Thus, conservation efforts began in 1933 (Roldan, 2002; Slota, 1969; Trimble, 1983). In 1938, a series of stream projects were conducted in the area under Happ and Witzgall. In addition to these stream transects, McKelvey created a pre-agriculture sediment profile for each transect completed by Happ and Witzgall (Trimble, 1983). In 1974 and then later in 1993, Trimble re-surveyed Happ and Witzgall's transects. With these data, Trimble was able to create a sediment budget for the Coon Creek Watershed since 1938. He had determined the influx and efflux of sediment into the watershed and how it changed over time.

Trimble found a large amount of sediment moving downstream. Unregulated agricultural practices from 1850 until 1933 (the beginning of conservation measures) had caused excessive erosion of soil from fields. Over time, these eroded soils accumulated as sediment on valley floors. However, the sediment yields (the amount of sediment Coon Creek carries to the Mississippi) remained constant over time. Thus, Trimble concluded that measurements of sediment yields do not necessarily reflect erosion rates, confirming that the terrestrial sediment cycle of the watershed was not in a steady-state (Trimble and Lund, 1982).

Trimble's work demonstrates that conservation measures in the Coon Creek watershed have been surprisingly effective. Accumulated sediment in the upper reaches of the watershed is currently being eroded away by the stream, causing erosion rates to exceed sedimentation rates. In fact, sediment levels in the upper reaches are returning to below that of 1938. However, downstream banks continue to accumulate sediment because the stream has reached its full carrying capacity by that point. Therefore, while upstream sedimentation rates remain less than upstream erosion rates, downstream sedimentation rates exceed downstream erosion rates (Trimble, 1983).

#### *Land-use factors influencing soil dynamics*

Since 1850, agriculture has played a major role in landscape and soil dynamics. Most of the upland and valley regions in Coon Creek basin have been cultivated and or grazed for decades. It is therefore important to examine the impact that these practices have on the soil. Cultivation of the land results in a loss of the soil's A-horizon, and thus a loss in carbon and nitrogen (Harden et al., 1999). Soil that is eroded from agricultural fields is no longer available for decomposition at the eroding site. Therefore, within the first few decades of cultivation, soils may lose over 80% of their original organic matter due to erosion (Harden et al., 1999).

Similar to the rest of the Midwest, the agriculture in Coon Creek basin is predominantly corn and soybeans. Corn cobs and soybeans contain the majority of the nitrogen in the plant. Thus, when these parts are removed, this nitrogen is no longer able to return to the soil, decreasing the nitrogen concentration. Grazing, on the other hand,

results in an increase in carbon and nitrogen levels in the upper 30 cm of the soil due to the deposition of animal urine and feces (Reeder and Schuman, 2002).

In 1933, conservation measures focused their attention on controlling erosion. Practices such as contour plowing, contour strip cropping and improving rotations were introduced to farmers in the Coon Creek watershed. This shift in agricultural practices, not a change in land-use, was effective in reducing upland erosion (Roldan, 2002).

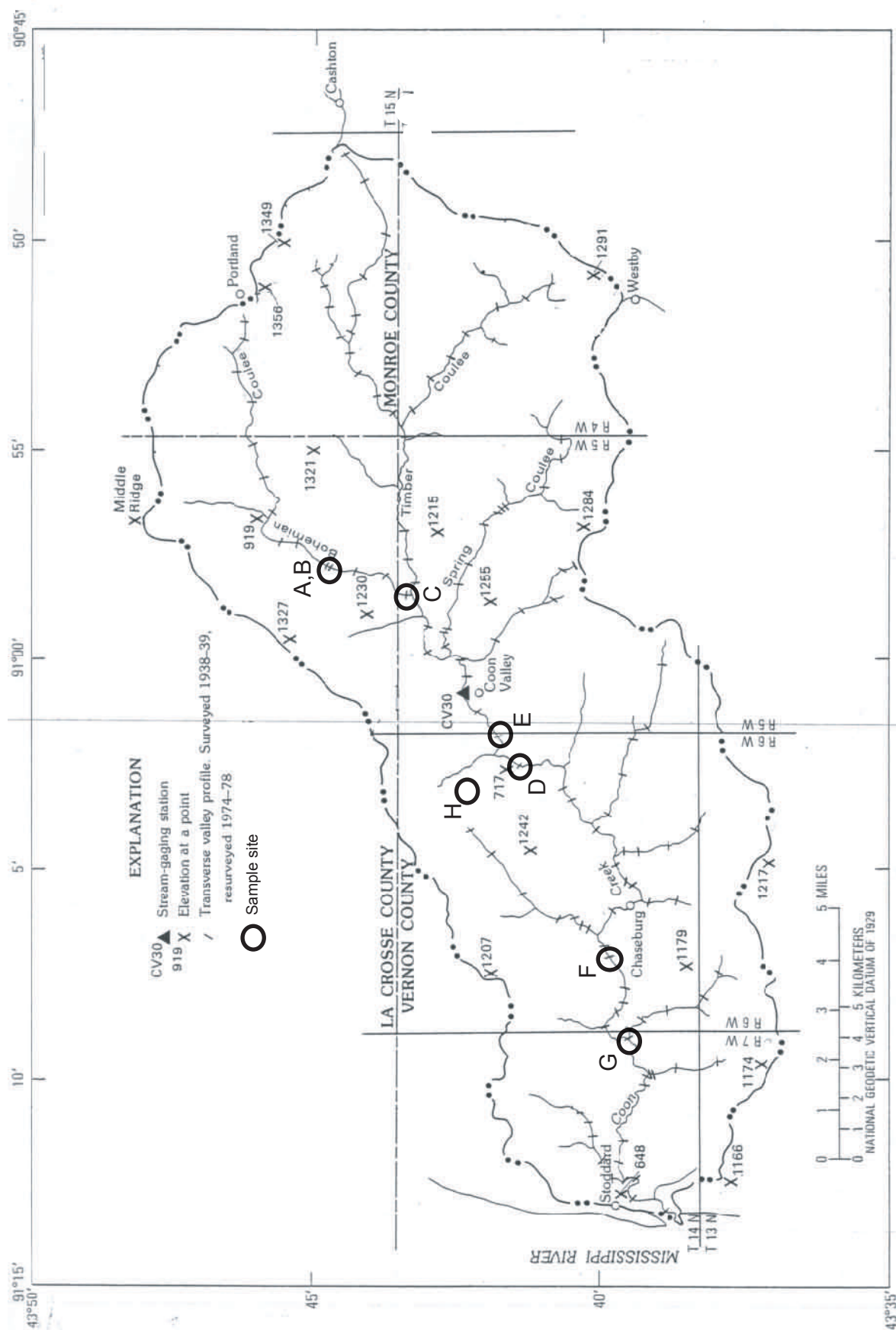
## **Methods**

### *Fieldwork*

In order to understand the history of carbon sequestration in the Coon Creek basin, fieldwork was carried out during the summer of 2003. Eight soil profiles were collected either through auguring or were collected from incised riverbanks (Figure 3). Sites were chosen to coincide with Trimble cross-sections. When Trimble's site markers could not be found or could not be reached due to natural or human-made boundaries, profiles were taken within close proximity to a site. Based on Trimble's division of the watershed, three sites were taken from upstream reaches, four from downstream regions and one from a ridgetop. Seven of the sites were taken on an established Trimble transect line or within very close proximity to one. The ridgetop profile was the only site not on or near an established transect line.

Soil samples were collected at varying depths on each soil profile.

Approximately 100 soil samples were collected throughout the Coon Creek Basin. Wet sample color was determined at the site according to Munsell Color classification, and



photos of profiles were taken if possible. Samples were then laid out to dry for one month.

#### *Laboratory work*

Back in the laboratory, 10-15 grams of each soil sample was weighed out and any macroscopic roots found in the soil were removed so as not to skew carbon percentages. The sub-samples were then placed in a drying oven at 100°C overnight. Once the samples were dry, the dry sample color of the soil was recorded. These samples were then ground for 10 minutes each using a Spex Certiprep 8000 dual mixer mill and then stored in airtight glass vials until further use. The total carbon and nitrogen of 30-50 mg of each prepared soil sample was later determined using a Costech Instruments ECS 4010 Elemental Combustion System.

#### **Results**

Carbon percentages ranged from 0.192 to 4.948%. Carbon tended to be concentrated at the surface of the soil, with a decline in carbon percentage with depth. Nitrogen percentages ranged from 0.013 to 0.218%. Unlike carbon, nitrogen did not tend to concentrate in particular segments of the profiles. These percentages, as well as C/N ratio data, are further summarized in graphs (Figure 4). Note that several profiles have carbon rich horizons at depths much greater than the A-horizon (sites B, E, G and especially F). Also note the high C/N ratios in sites A and C. Ridgetop soil carbon percentages (site H) were extremely low compared to valley soil percentages. Wet and dry color tests indicate distinct color differences between upper and lower soil samples in

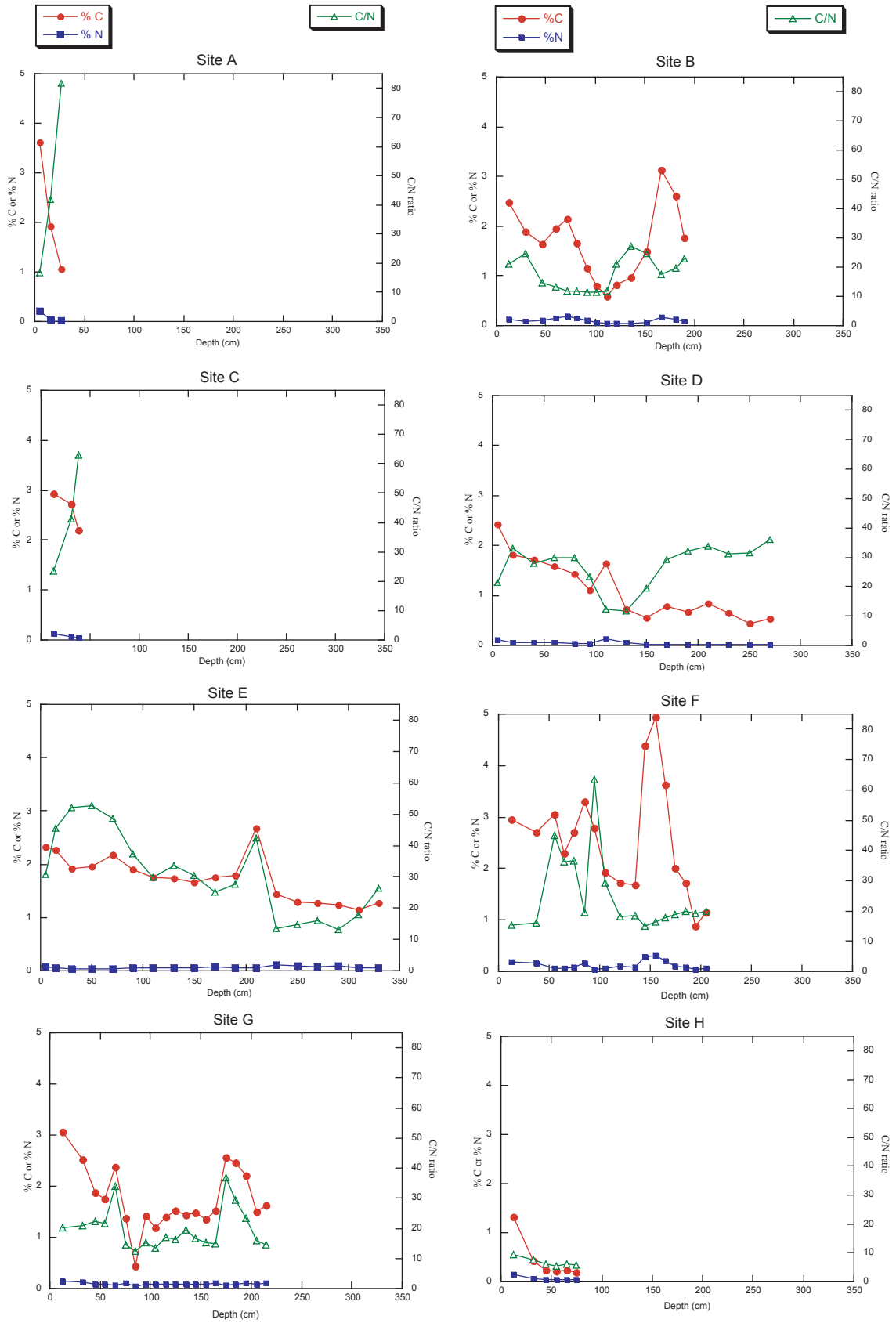


Figure 4: Graphs of carbon and nitrogen percentages and C/N ratios for each site profile.



most profiles. Surface soil tended to be darker than the underlying soil. However, in some profiles like F and B, dark soil would also appear further down in the profile (Figure 5). This soil was often darker than the surface soil. Site profiles were not assigned soil horizons due to complex sedimentation histories.

To calculate a carbon budget for the Coon Creek Watershed, each site profile was compared to its established corresponding Trimble cross-sectional profile (Figures 6, 7, 8). Each of these cross-sectional profiles illustrates the depth of the soil relative to time. Using his data, ages were assigned to sample profiles. The time periods used were: 1850-1938 and 1938-1975. Sediment accumulation since 1975 has been very minimal; therefore, the sedimentation period 1975-2003 has been excluded from the study. In two profiles, pre-agricultural soil was uncovered. This verdict was based on the soil's dark color, high carbon percentages and available cross-sectional information. Carbon percentages for assigned time periods in each profile were averaged. Carbon percents of each time period for *all* profiles were then averaged, resulting in two average carbon percentages: 1.807% C for 1850-1938, and 2.141% C for 1938-1975.

These percentages were then used to calculate the carbon influx and efflux into the Coon Creek basin. Using Trimble's sediment budget calculations for each time period, the grams of carbon coming into the system (sources), being stored in the basin (sinks) and flowing out of the system (yields) per year were determined (Figure 9). These "sinks" were then multiplied by the number of years represented in their respective time periods, and then added together to give  $8.056 \times 10^{11}$ , the total grams of carbon stored in the basin from 1850-1975 (Table 2). Since the depositional area of the basin is

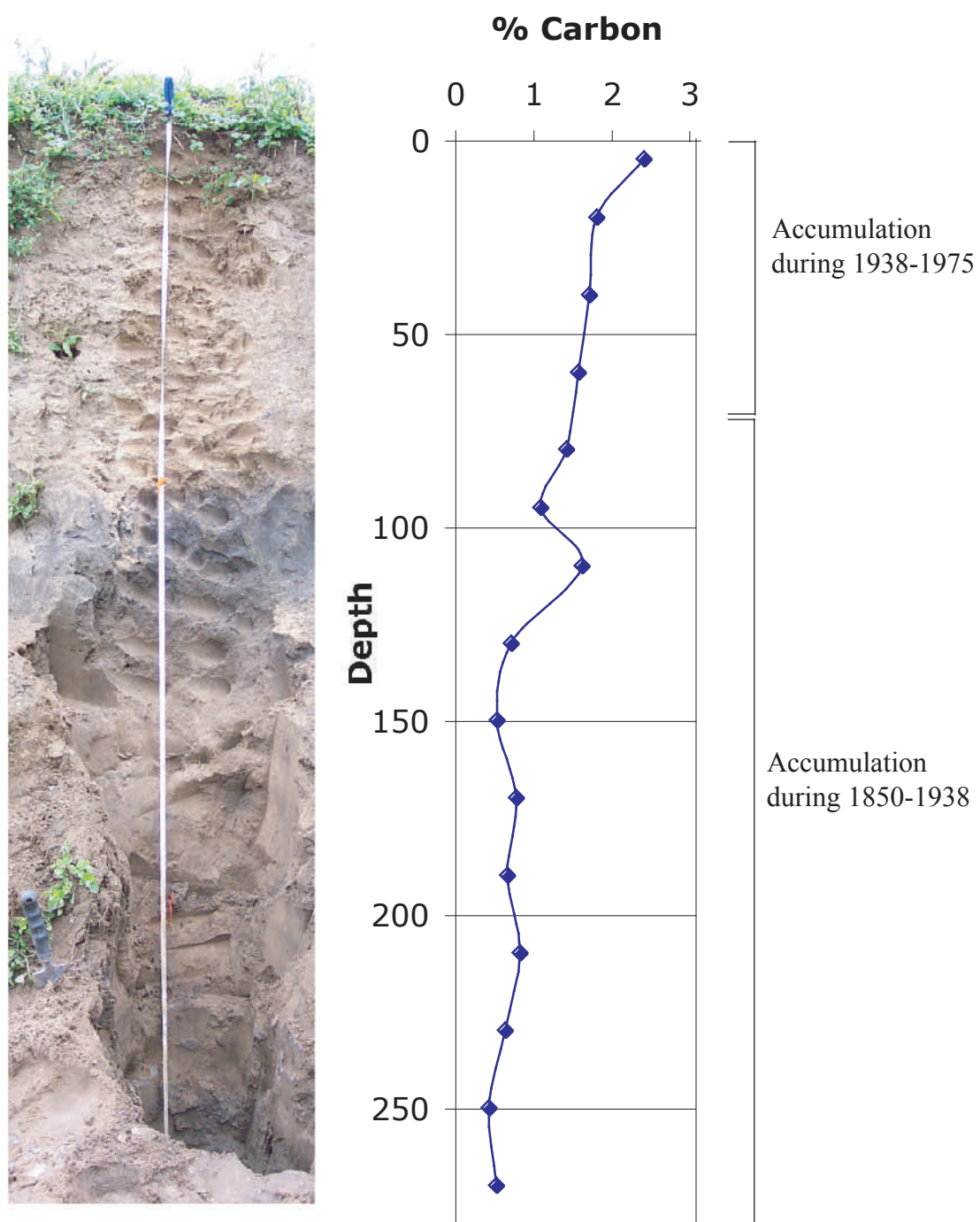


Figure 5: Photograph of site profile D with profile graph illustrating carbon percentage with depth. Note the correlation between the dark soil and the carbon percentage increase.

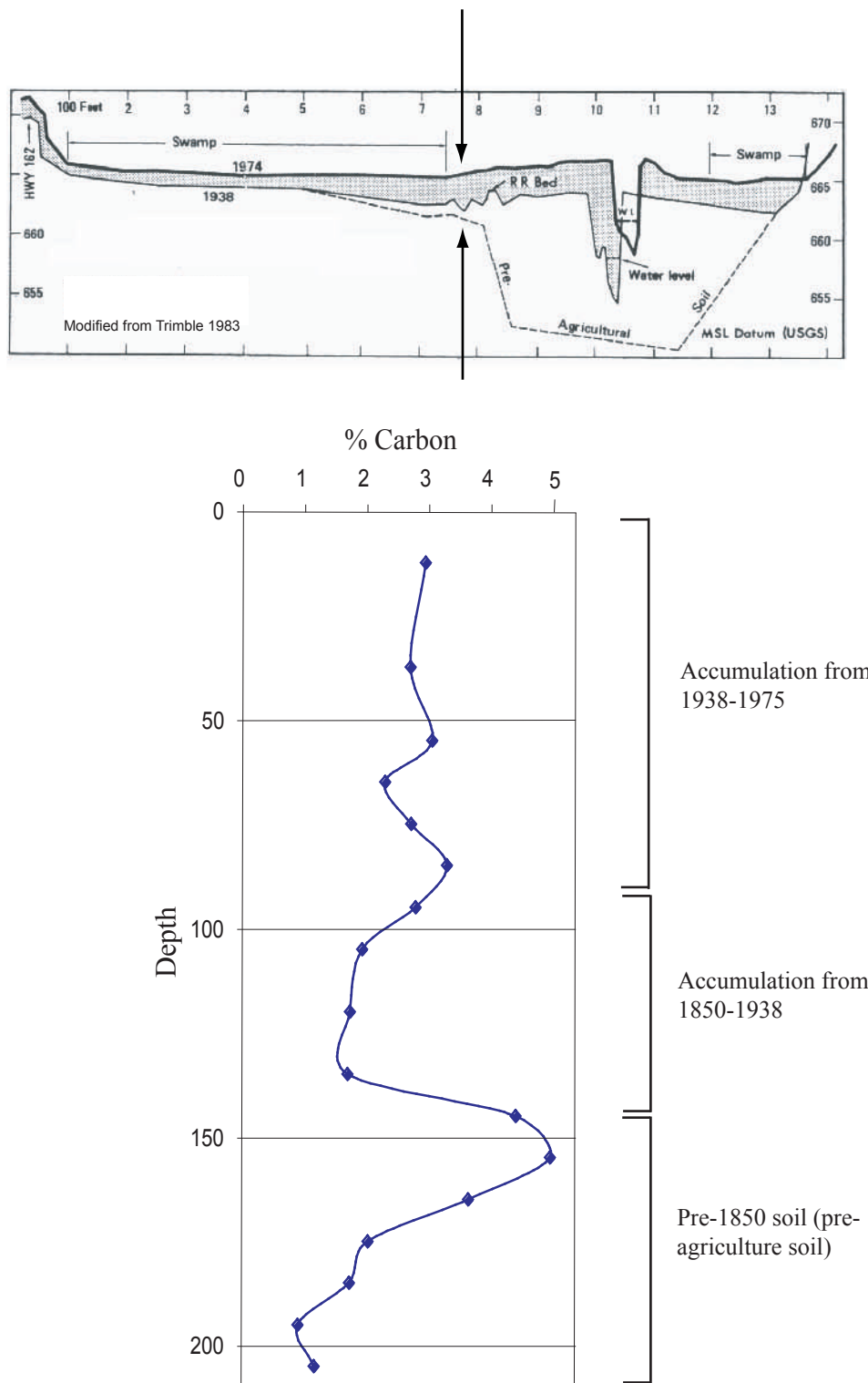


Figure 6: Site F profile location and carbon percentages with depth. Arrows indicate specific location of Site F profile on Trimble's cross-sectional profile. Modified from Trimble, 1983.

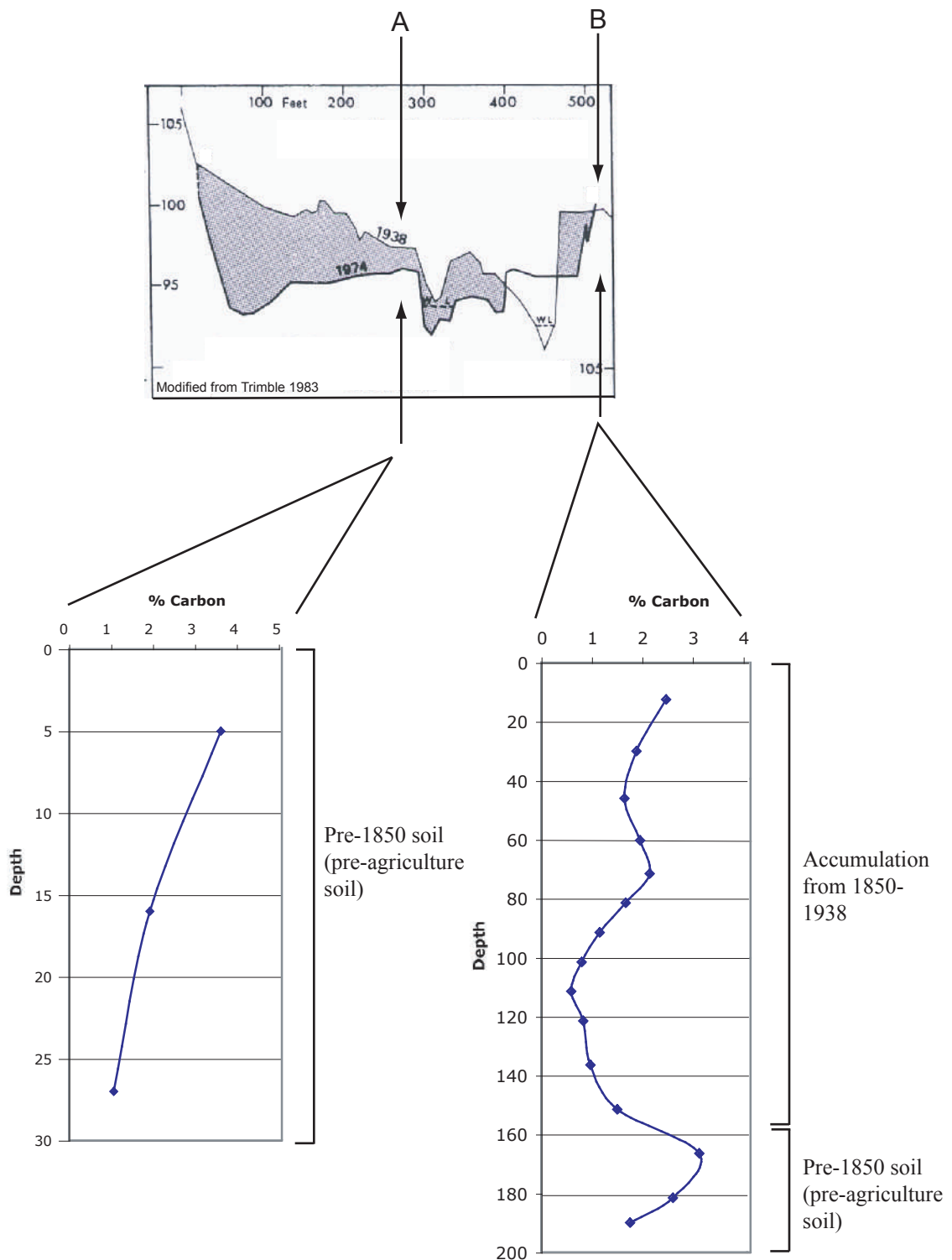


Figure 7: Location of profiles A and B in Trimble's cross sectional transects. Profile B is on an older flood terrace while profile A is on the current flood terrace and has been eroded down to pre-agriculture levels.

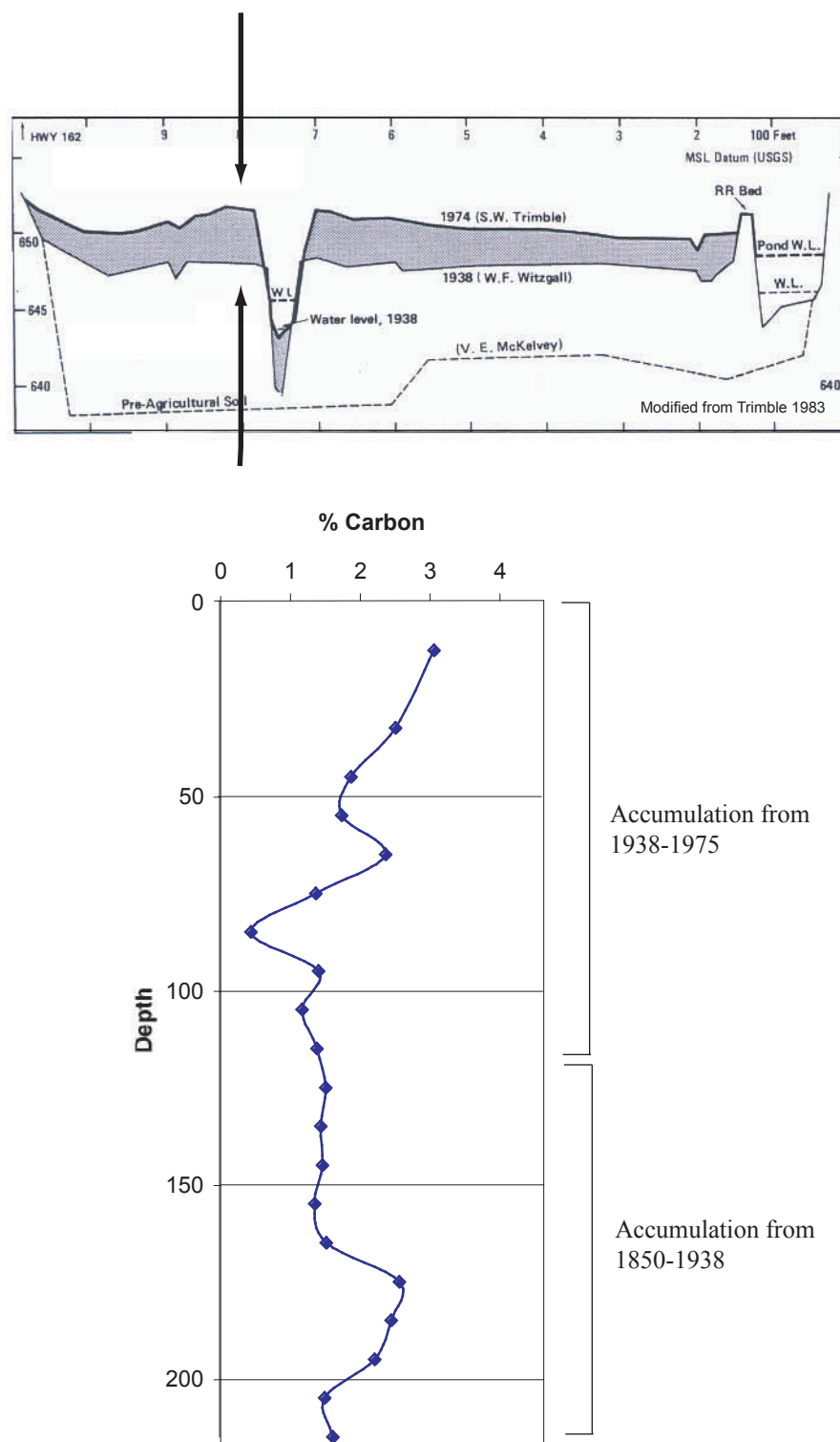


Figure 8: Site G profile location and graph illustrating carbon content with depth.

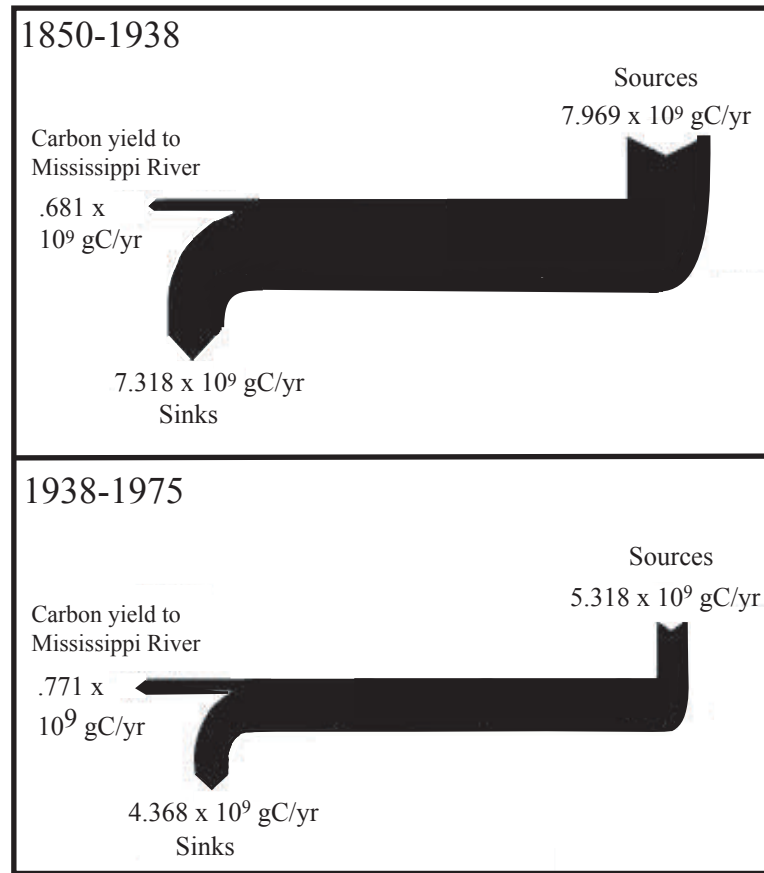


Figure 9: Carbon budgets for Coon Creek Watershed, 1850-1975. The basin has an area of  $360 \text{ km}^2$ . Numbers are in  $10^9$  grams of carbon per year. Annual amount of carbon stored in basin (sinks) has decreased since the beginning of conservation measures in 1933. Regardless, the period 1850-1975 experiences severe carbon burial. Modified from Trimble 1999.

Table 2: Table of grams of carbon that accumulated in basin for each time period along with the grams of carbon per square meter in the basin for each time period. Note the reduction of carbon accumulation and grams of carbon per square meter in later years.

Time period	Number of years	Average grams of C that accumulated in basin per year	Grams of C that accumulated in basin	Grams of Carbon per square meter in basin
1850-1938	88	$7.318 \times 10^9$	$6.439 \times 10^{11}$	13700.0
1938-1975	37	$4.368 \times 10^9$	$1.616 \times 10^{11}$	3438.3
Total (1850-1975)	125	$6.445 \times 10^9$	$8.056 \times 10^{11}$	17140.4

47 km<sup>2</sup>, the total grams of carbon per square meter in the Coon Creek basin is 17140.4 g/m<sup>2</sup>.

The total amount of carbon dioxide emitted to the atmosphere during the period 1850-1975 globally is approximately 137 Gt of carbon (Marland and Boden, 2003). The missing sink is roughly 18% of current yearly emissions (Meyer, 2002). If this percentage reflects how the carbon cycle was operating since 1850, then calculating 18% of total yearly emissions for the period 1850-1975 should give us the amount of missing carbon. This amount is 24.67 Gt (Marland and Boden, 2003). To bury 24.67 Gt of carbon during the period 1850-1975, the sink or carbon-sequestering process would have to occur over  $1.4392 \times 10^{12}$  m<sup>2</sup> (approximately 0.9% of total global land). Approximately 33% of land on earth is capable of sequestering carbon (area of active upland alluvial and colluvial storage plus lake and reservoir area) (Stallard, 1998). Only 3.0% of that sequestering-capable land is needed to sequester the amount of carbon found in this study.

## **Discussion**

### *Sedimentation history*

In an average Midwest soil profile, the majority of the carbon is contained in the top 25 cm of soil (Birkeland, 1974). Below 25 cm, carbon content decreases dramatically, averaging below 1% carbon in soils at 75 cm depth (Birkeland, 1974). Clearly, the carbon and nitrogen percentages in this study are not indicative of typical soil profiles. Frequent carbon and nitrogen fluctuations within the profiles suggest that this watershed has experienced a complex sedimentation history. A comparison with Trimble's cross-sectional transects coupled with the discovery of pre-settlement soil indicates that a large

amount of accumulated sediment still remains in the Coon Creek valley. Excluding profiles A and C, every valley site has a significant amount of accumulated sediment residing on its pre-settlement soil (Figures 6, 7, 8). Where did this sediment come from? According to Trimble, this sediment is eroding from somewhere upstream or uphill from its site of deposition. Graphing profile carbon and nitrogen percentages along with the C/N ratio helps in determining the origin of sediments. High carbon and nitrogen content in a layer of accumulated sediment suggest that it is either an eroded A-horizon from a cultivated field or eroded sediment from a forested and/or uncultivated field (topsoil in both cases). An accumulated sediment layer with low carbon and nitrogen percentages is most likely eroded subsoil from surrounding cultivated fields. As ridgetop carbon contents indicate, agricultural practices and the resulting erosion are able to wipe out the entire topsoil of a field. With the topsoil gone, the subsoil is left extremely vulnerable to erosion. Characteristically, subsoil has low carbon and nitrogen percentages. However, it is extremely important to note that subsoil, like any other soil horizon eroding off of cultivated fields, must travel from the site of erosion in the uplands to the site of accumulation in the valley. Thus, this subsoil most likely picks up other organic matter (possibly humus) along the way, significantly raising the carbon content of the eroded soil. Therefore, when using carbon percentages to determine the origin of accumulated sediment, we must take into account the fact that these carbon percentages might be elevated due to transport (Macalady, 2004).

When attempting to understand a complex sedimentation history, it is helpful to identify the pre-settlement soil. Soils that formed on forested areas typically have C/N ratios around 20 while soils that formed on prairies or grasslands tend to have C/N ratios



around 13 (Bauder, 1999). Two profiles (B and F) reached buried pre-settlement soil (Figures 6, 7). Both sites reached this boundary around roughly 160 cm depth. The sharp pulses indicate that this soil was rich in carbon and nitrogen. The C/N ratio (around 20 for both) (Figure 4) suggests that this soil was formed in a forest. A pre-settlement vegetation map of the watershed (Figure 10), confirms that the pre-settlement soil for both sites was indeed forest vegetation. If that layer 160 cm down in the profile is the A horizon of the pre-settlement soil, then 160 cm of sediment has accumulated on top of this land since 1850. Low carbon percentages for the accumulated soil between the depths of 90-150 cm in site B suggest that this sediment was subsoil derived from surrounding cultivated fields (Figure 7). The simultaneous carbon and nitrogen pulses further up in the profile (around 70 cm) may represent eroded sediment derived from a forested and/or uncultivated area or it may represent an eroded A-horizon from a cultivated field. Similarly, site F's accumulated soil is also characterized by an interval of low carbon and nitrogen followed by a strong carbon pulse around 90 cm in depth, suggesting a similar sedimentation history to site B (Figure 7). The unusually sharp increase in carbon and nitrogen levels in site B's surface soil may be due to the fact that the land is now used for grazing.

Sites A, B and C are profiles taken from upstream in the watershed. According to Trimble (1982), successful conservation measures (aimed at decreasing erosion) have caused most upstream accumulated sediment to erode away, moving downstream. The landscapes of these sites strongly support this argument. Sites A and C are just about level with the stream, implying that they are no longer accumulating or holding any eroded sediment. In addition, high carbon and nitrogen percentages in A and C strongly

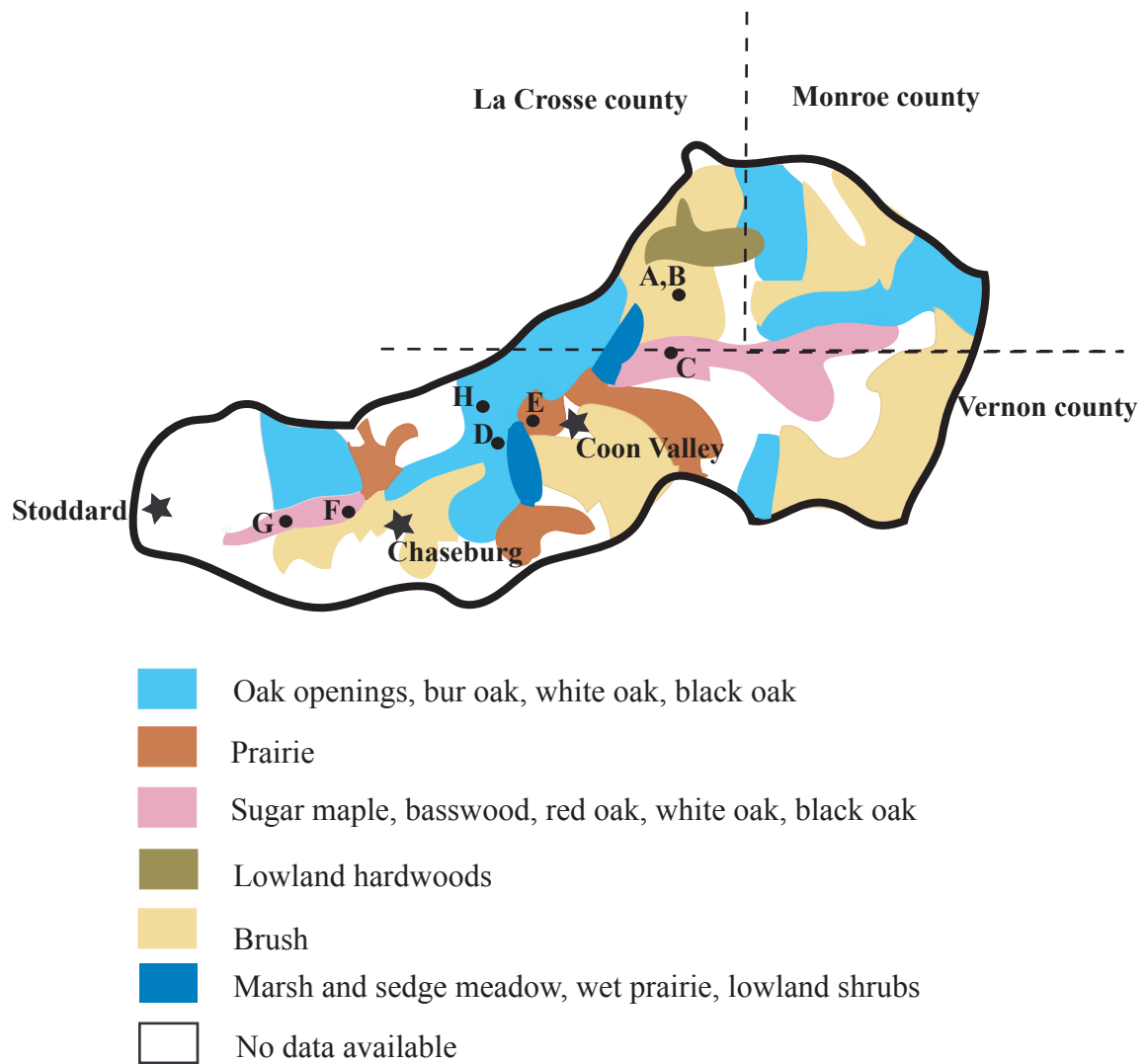


Figure 10: Pre-agriculture vegetation for Coon Creek Watershed. Modified from Wisconsin DNR webview.

resemble those of forest soils. These characteristics, along with pre-settlement vegetation data, suggest that the soil found in sites A and C is pre-settlement soil. Site B also displays a pre-agriculture surface (as noted above); however this soil is covered by 160 cm of accumulated sediment. The stream running near sites A and B has recently meandered (Figure 11). Site B is actually an older flood terrace formed at the time of intense erosion and sediment accumulation. Since then, the stream has meandered away from that terrace and formed a new flood terrace (which A is located in). Therefore, when conservation measures began take effect and streams successfully started to erode this accumulated sediment and transport it downstream, the stream was unable to reach and erode sediment off of the older terrace. For that reason, site B is not characteristic of profiles taken from upstream in the watershed.

The “fulcrum” of the watershed is the point in the stream where the carrying capacity is reached, preventing erosion of downstream sediments. Sites D and E were taken close to this “fulcrum,” which is approximately at the town of Coon Valley. Carbon percentages at both sites decrease with depth but contain pulses of high carbon content within each profile (Figure 4). Neither profile reaches the pre-settlement soil, although site E is estimated to have been within centimeters. Therefore, the entire profile of both sites consists of accumulated sediment. Low carbon percentages suggest that the sediment is most likely eroded subsoil from cultivated fields; however, high carbon pulses in each profile indicate that some layers of sediment must have been eroded from forested areas or A-horizons from agricultural fields.

Similar to sites D and E, accumulated sediment in site G consists of subsoil derived from fields as well as carbon-rich soil originating in forested areas. However, a

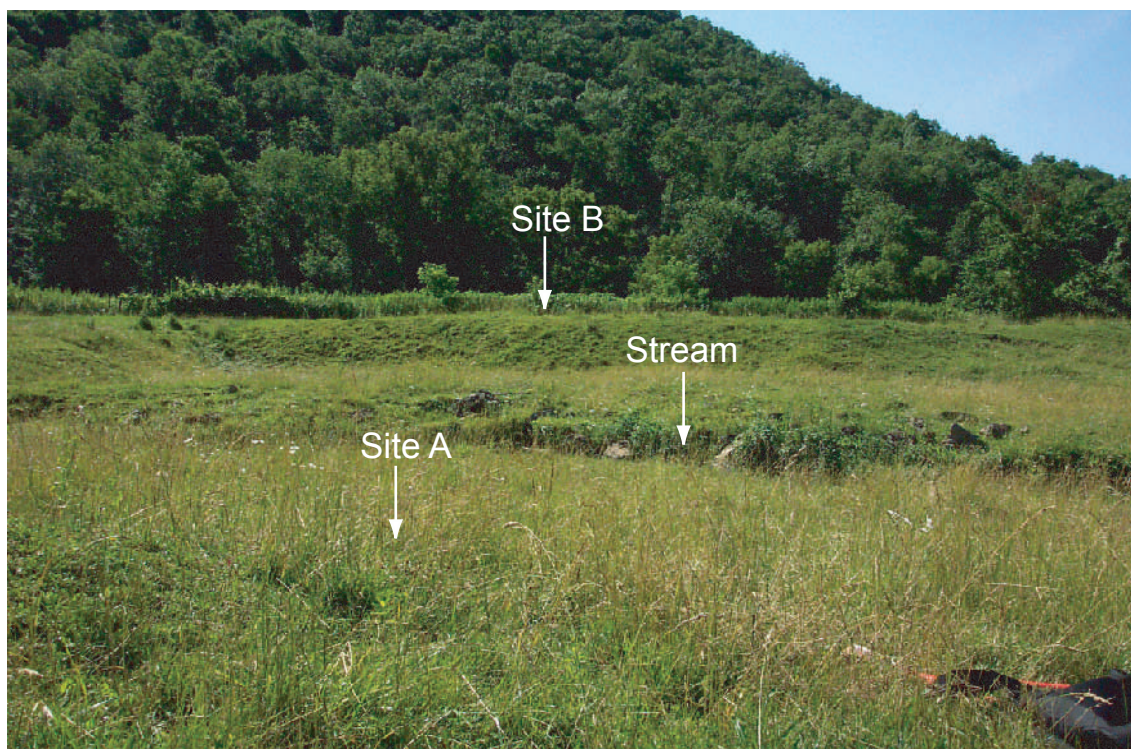


Figure 11: Location of sites A and B in area photograph. Site B is located on an older terrace, while site A is located on a newer terrace. Photo by Katja Meyer.

pulse of extremely low carbon percentages near 80 cm in depth most likely is indicative of eroded subsoil from cultivated fields that, for some reason, has not gathered a significant amount of organic material or humus on its journey down to the valley (Figure 8).

The ridgetop location (site H) has extremely low carbon and nitrogen values, characteristic of subsoil. Ridgetop soil carbon percentages are consistent with other studies of abandoned agricultural fields which show an average of 0.04% N and 0.42 % C. According to Knops and Tilman (2002), these percentages imply a loss of 75% of original nitrogen and 89% of original carbon in the top 10 cm. Agriculture in Coon Creek has clearly stripped the topsoil from the land, often leaving farmers with no choice but to cultivate on the subsoil. Subsoil cultivation leaves the carbon deficient soil exposed to the air. Photosynthetic uptake of carbon in this less developed soil removes carbon dioxide from the air and is a net sink for carbon. Thus, the ridgetop subsoil has formed a local sink (Harden et al., 1999; McCarty and Ritchie, 2002; Schlesinger, 1997; Stallard, 1998). Erosion has set soil development back in time, effectively adding new fixed carbon to the uncovered, less developed, and carbon-poor soil. The high carbon content in the top 10 cm of the soil in site H is a sign of this recovery (Figure 4). The C/N ratio for site H is also extremely low, emphasizing the lack of carbon in the soil as well as the soil's set-back in soil development.

### *The Carbon budget*

For each time period, spatial distribution of carbon throughout the watershed appears to be fairly constant across the landscape; no patterns were found (Figure 12).

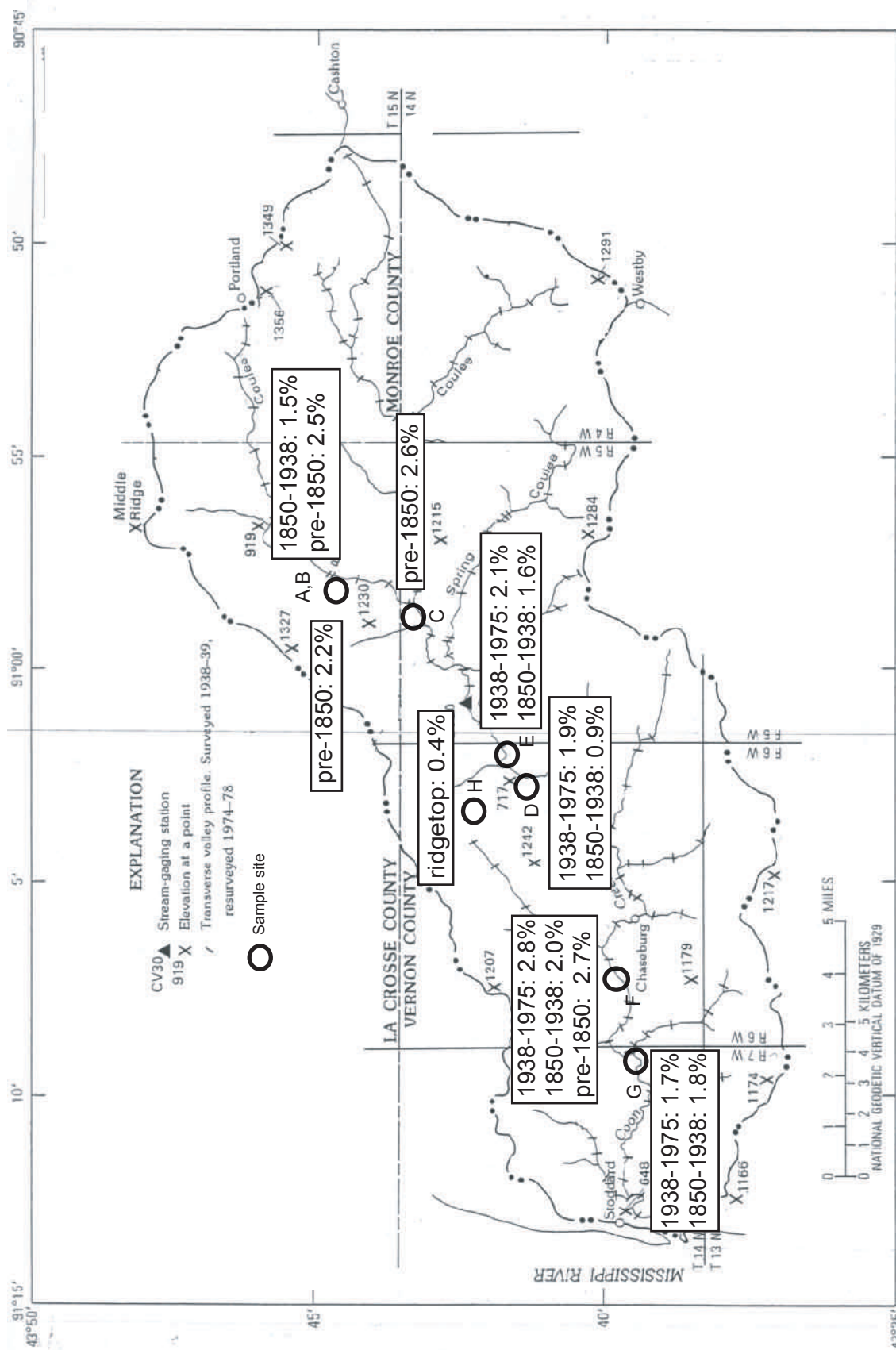


Figure 12: Spatial distribution of carbon percentages in the Coon Creek basin. Spatial distributions reveal no variability patterns with depth. Modified from Trimble 1982.

However, carbon budget results clearly reveal a large variation in the amounts of carbon per square meter in the basin from 1850-1938 (13700.0 g C/m<sup>2</sup>) and 1938-1975 (3438.3 g C/m<sup>2</sup>) (Table 2). This difference is most likely due to the lack of A-horizons left on agricultural fields after 1938. With only subsoil left to erode and collect on valley floors, accumulated sediments for 1938-1975 would clearly contain smaller amounts of carbon per square meter. This variation in carbon content effectively indicates that large amounts of carbon rich topsoil as well as carbon deficient subsoil have eroded from agricultural fields and accumulated on valley floors.

#### *Accounting for the missing carbon sink*

For the period 1850-1975, the global “missing sink” is calculated to be roughly 24.67 Gt of carbon (Marland and Boden, 2003). To sequester this amount of missing carbon on land, the terrestrial sink process would have to occur over 3.0% of the global land capable of this form of sequestration. Given these percentages, it is very plausible that erosion and accumulation of carbon-rich sediments in terrestrial basins can account for the missing carbon sink.

The U.S. Geological Survey (USGS) has calculated carbon storage in Mississippi River basin sediments to be in the range of 10,000-24,000 gC/m<sup>2</sup>. Through an examination of soil variations and carbon storage characteristics for each soil type, the USGS claims that the Mississippi river basin stores an average of 10,000 g C/m<sup>2</sup> (Markewich, 2001). Based on these calculations, the average carbon distribution in the Coon Creek basin, 17140.4 g C/m<sup>2</sup>, seems to be a reasonable value. However, the calculations in this study did not account for subsoil carbon sequestration on cultivated

fields such as the ridgetop sample. Even though the ridgetop sample did not contain much carbon, incorporating this potential sink into calculations would further increase the probability that terrestrial carbon sequestration can account for the missing sink.

### *Successful conservation measures*

Profiles A and C are evidence that the Coon Creek Watershed is returning to its pre-settlement condition. Although the sediment cycle is still far from a steady-state, conservation measures have been effective in decreasing the amount of accumulated sediment on upstream valley banks and in the upper reaches of streams. It follows that if accumulated sediment is sequestering this missing amount of carbon and conservation measures are decreasing this built-up sediment, then the missing carbon sink must be decreasing as a result of successful conservation measures. However, most watersheds do not have conservation success stories like the Coon Creek watershed does. Therefore, a noticeable reduction in the carbon sink might take more than 100 years. It is also important to realize that a reduction in the carbon sink due to successful conservation measures means that atmospheric carbon dioxide levels will increase. This forms a strange paradox in which conservation measures may eventually end up increasing atmospheric carbon dioxide, escalating the greenhouse effect.

### **Conclusion**

Profile results indicate that accumulated sediment in the Coon Creek Basin has varying layers of carbon and nitrogen content, demonstrating a complex sedimentation history. Recurring periods of comparatively low carbon percentages indicate that most



sediment eroded from heavily cultivated areas. High carbon and nitrogen content in upstream sites suggest that the current land surface is close to the pre-settlement soil, confirming Trimble's hypothesis that upstream sites have returned to pre-settlement levels due to successful conservation measures. Sediments that accumulated during 1938-1975 had less carbon per square meter than sediments accumulated during 1850-1938 because they contain a higher proportion of eroded subsoil. Despite relatively low carbon percentages for eroded subsoil, this accumulated sediment contains considerable amounts of carbon. The total amount of carbon sequestered in the basin for the period 1850-1975 is  $8.056 \times 10^{11}$  grams. When extrapolated globally, this amount of carbon sequestration is sufficient to account for the missing carbon sink, supporting Stallard's hypothesis.

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