Land-use options for carbon sequestration in reclaimed mined lands

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Abstract

The sequestration of plant-derived carbon (C) in soils is a viable option to reducing the rate of carbon dioxide (CO_2) accumulation in the atmosphere. This report presents C pools and soil properties of grasslands established on reclaimed mined lands. Plant biomass (above- and below-ground), intact cores and composite soil samples were collected in 2002 from: (1) undisturbed grassland (no grazing, hay production), (2) meadow (no grazing and no grass cutting for hay), (3) grazing land, (4) old pasture converted into meadow, (5) Austrian pine (*Pinus nigra*), and (6) Black locust *(Robinia pseudoacacia*) stands. The meadow was established on land reclaimed in 1982. The other sites were reclaimed in 1978 and used as grazing land until 1993 when conversion to the current land use occurred. Comparison of SOC pool in a recently-reclaimed site with that of nearby undisturbed grassland and forest sites suggests that a C sequestration potential of 18 - 30 Mg C ha^{-1} exists in the reclaimed grasslands. Root biomass contributed 60 - 80 % of the total biomass returned to soils. The contribution of leaf fall was minor (< 5 %). A negative relationship was noted between bulk density and below-ground biomass. This trend is best illustrated by the observation that the site (site 3, grazing land) with the longest grazing history (24 years) had the highest bulk density and lowest biomass production. Inorganic C (IC) pools averaged 0.7 Mg C ha^{-1} under A. pine, and was comparable to the amounts recorded in the meadow (0.74) and undisturbed grassland (0.13) soils. At all other reclaimed sites, IC ranged between 4.6 and 17.3 Mg C ha^{-1}. Organic C pools (0-40 cm) in the meadow was the highest (63.1 ± 4.1 Mg C ha^{-1}) among the reclaimed sites and compared well with SOC pool in the undisturbed grassland ($53.6_{\text{depth: 0-40 cm}}$; $67.7_{\text{depth: 0-60 cm}}$ Mg C ha^{-1}). SOC pools under the A. pine and black locust stands were 48.5 and 40.7 Mg C ha^{-1}, respectively. More SOC accumulation is expected in the A. pine and black locust plantations given the large biomass production with these land-use systems.

1. Introduction

Carbon (C) sequestration in terrestrial ecosystems is one of the proposed strategies to reduce the rate of carbon dioxide (CO_2) accumulation in the atmosphere. The strategy involves the transfer of photosynthetically-fixed CO_2 (plant biomass) into stable soil C pools. Research has shown that C tend to rapidly accumulate when restorative measures are implemented in degraded lands (Bayer, 2000; Akala and Lal, 2001).

In the US, more than 30 thousands hectares are affected by surface mining annually (OSM, 1998). Every year, mining activities add an estimated 3,040 ha (OSM, 1998) to the 0.3 million ha occupied by mined and barren lands in Ohio (AMLSF, 2000). Coal mining operations result in drastic landscape disturbances manifested by deterioration of important physical and biochemical properties of soils. Ashby and Vogel (1993) noted that soil compaction and salinity are the most common problems limiting tree growth in mined lands. However, with adoption of proper restoration and management techniques, these disturbed lands could be returned to productive use. In an assessment of C sequestration potential in Ohio minesoils, C accumulation rates ranging from 0.7 to 3 Mg C ha^{-1} y^{-1} in reclaimed forest and pasture were reported (Akala and Lal, 2001). These rates are several fold higher than normally recorded in croplands.

During the last 30 years, several hundred hectares of forests and grasslands have been established in Ohio on land previously strip-mined for coal. A study was initiated in 2002 to document C pools in selected reclaimed sites. This report presents an assessment of biomass production and soil C pools at these sites in relation to post-reclamation land-use and soil properties.

2. Material and Methods

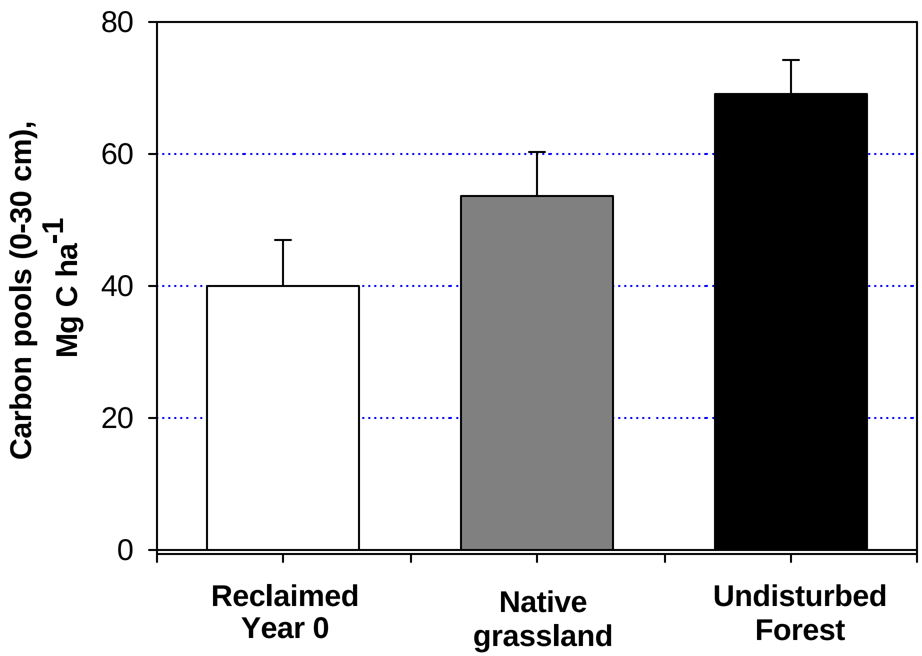
Six sites were selected for this evaluation, including (1) undisturbed grassland (no grazing, hay production), (2) meadow (no grazing and no grass cutting for hay), (3) grazing land, (4) old pasture converted into meadow, (5) Austrian pine (*Pinus nigra*) and (6) Black locust *(Robinia pseudoacacia*) stands. Site 2 was reclaimed in 1982. Sites 3 to 6 were reclaimed in 1978, used as grazing land, and converted to the land-use described above in 1993. These reclaimed sites, owned by the American Electric Power (AEP), are located in Muskingum, Noble and Morgan counties in Ohio. A recently-reclaimed area (owned by B&N coal company) was also included in the evaluation.

Above ground biomass (grass clippings and leaf fall) was measured during the summer to fall of 2002. Composite soil and core samples were collected each site for physical and chemical analyses including: soil bulk density (core method), root mass density (dry weight of roots per soil volume), pH (1:1 soil:water ratio), electrical conductivity (EC, 1:5 ratio), inorganic C (acid dissolution of carbonates and determination of CO_2 by gas chromatography) and organic C. Total C (TOC) was determined by dry combustion (CN analyzer at 900 ^{o}C). Soil samples were treated for 8-12 h with a mixture (55 ^{o}C) of $K_2Cr_2O_7$ (0.5M) and H_2SO_4 (9M) to remove oxidizable C. The C remaining after this treatment was taken as coal-derived C and was subtracted from TOC to determine SOC concentration.

3. Results and discussion

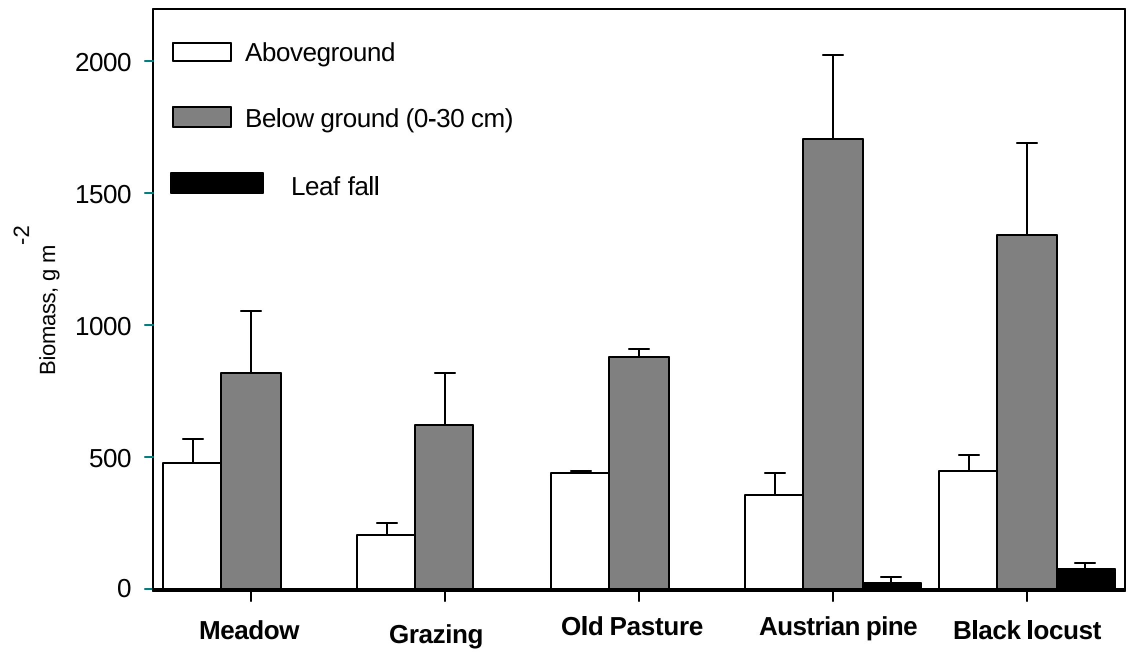
Major findings of this work are presented in Fig. 1-7.

Fig. 1. Comparison of C pools in recently-reclaimed mined land and (adjacent) undisturbed grassland and hardwood forest. No grazing occurs at the native grassland site but has been harvested for hay.



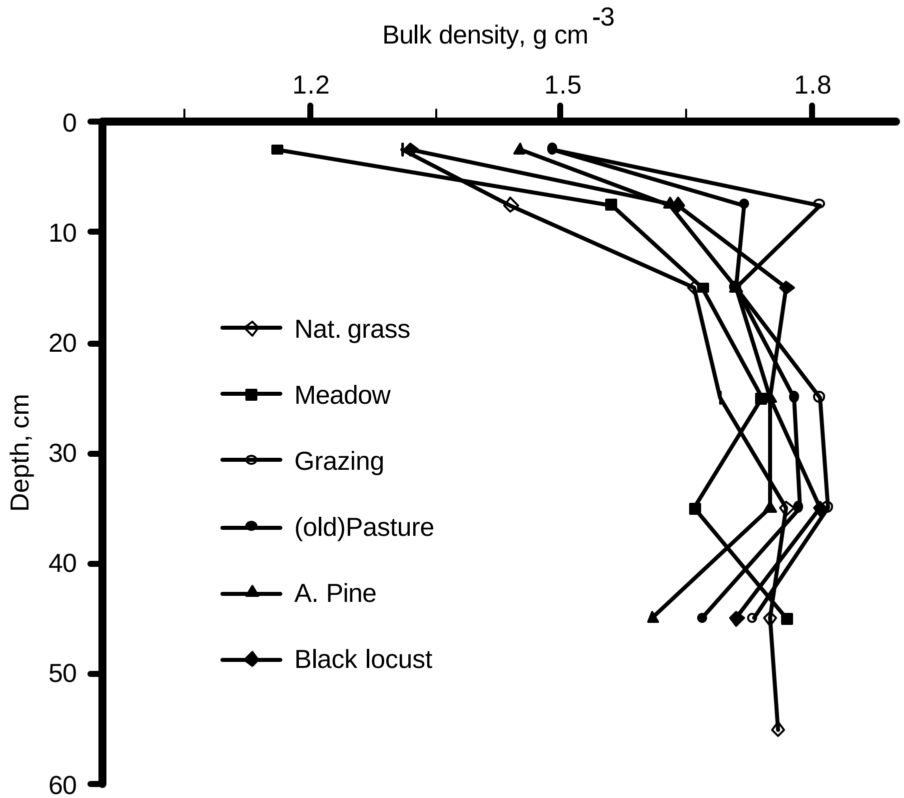
Data suggests that a C sequestration potential of 18-30 Mg C ha^{-1}

Fig. 2. Above ground and root biomass (0-30 cm) at time of sampling (June-August 2002).



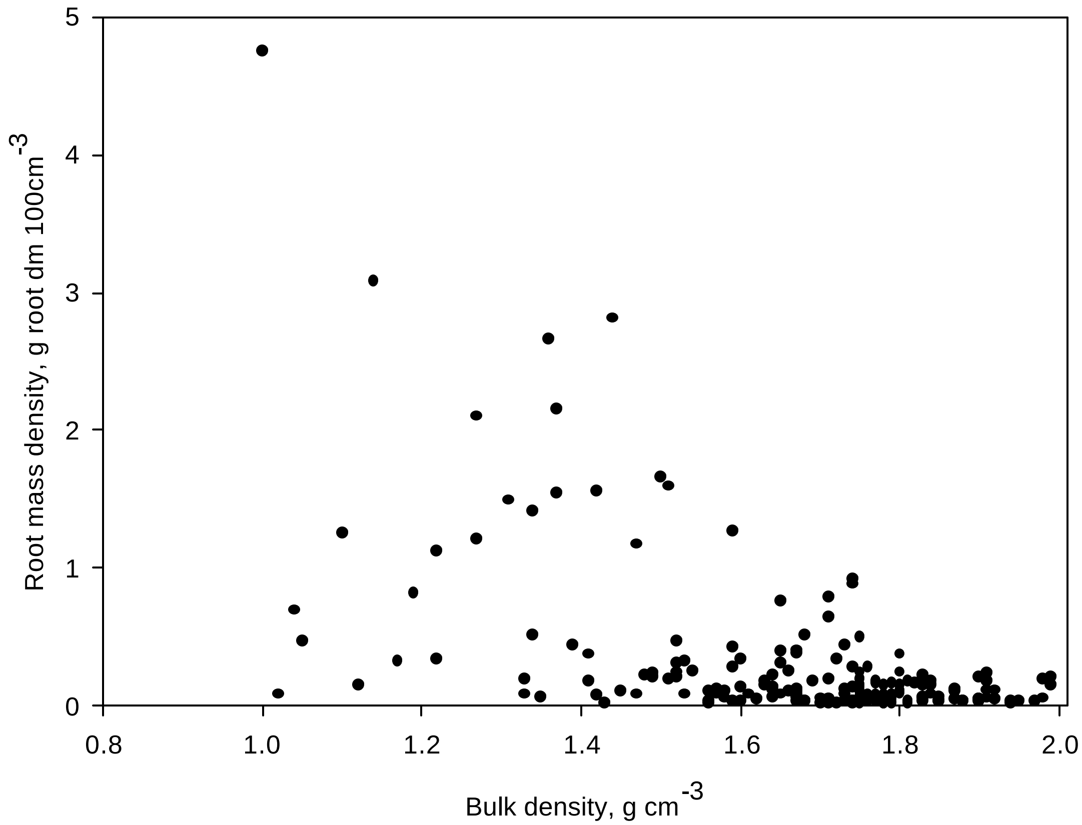
Reported root biomass includes live and dead roots (0.5 - 2 mm). Biomassproduction was lower in the grazing area compared to the other sites. Below ground biomass was the largest input (60 - 80 %) of C into soils. Nine years after introduction of A. pine and black locust into the grassland, leaf fall remains a minor contributor (1 - 5 %) to biomass input.

Fig. 3. Soil bulk density.



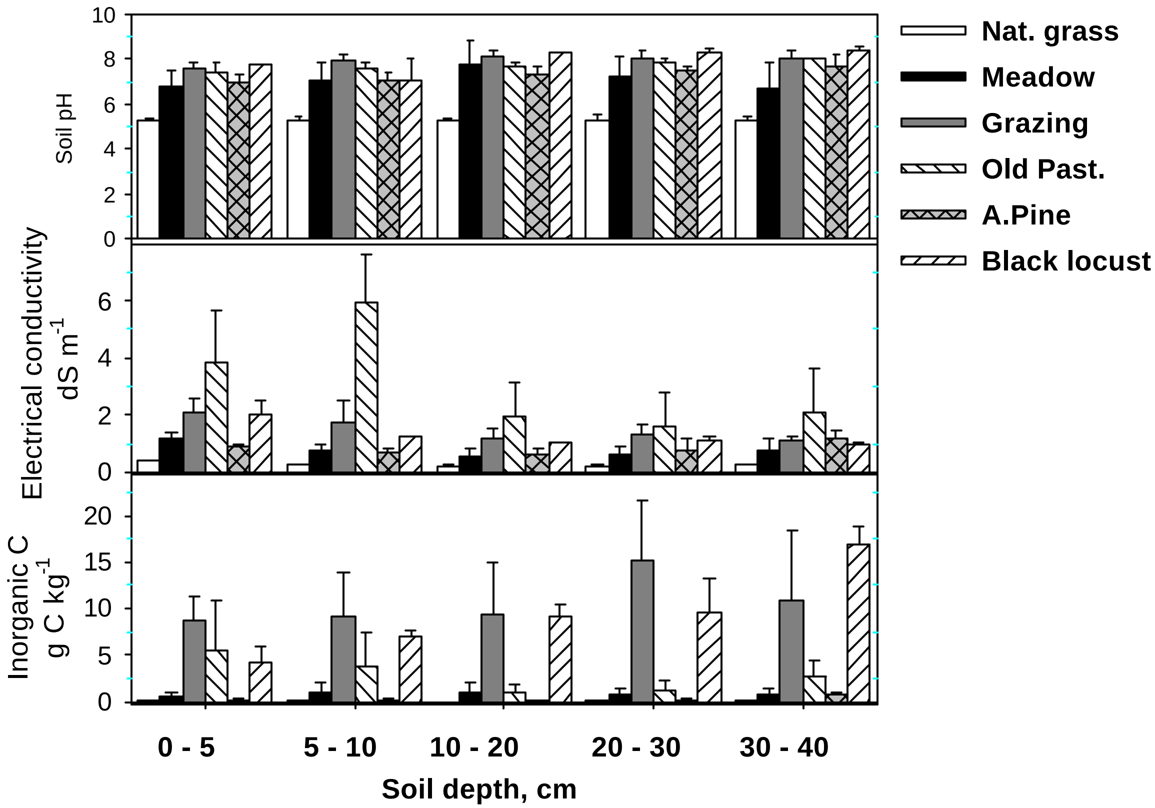
Soil compaction is indicated by the high bulk density values in the top 20 cm layer. Bulk density profile of the meadow was similar to that of the undisturbed grassland. The absence of compaction at the meadow suggests that grazing is a important contributor to soil compaction in reclaimed mined lands.

Fig. 4. Relationship between soil bulk density and root mass density.



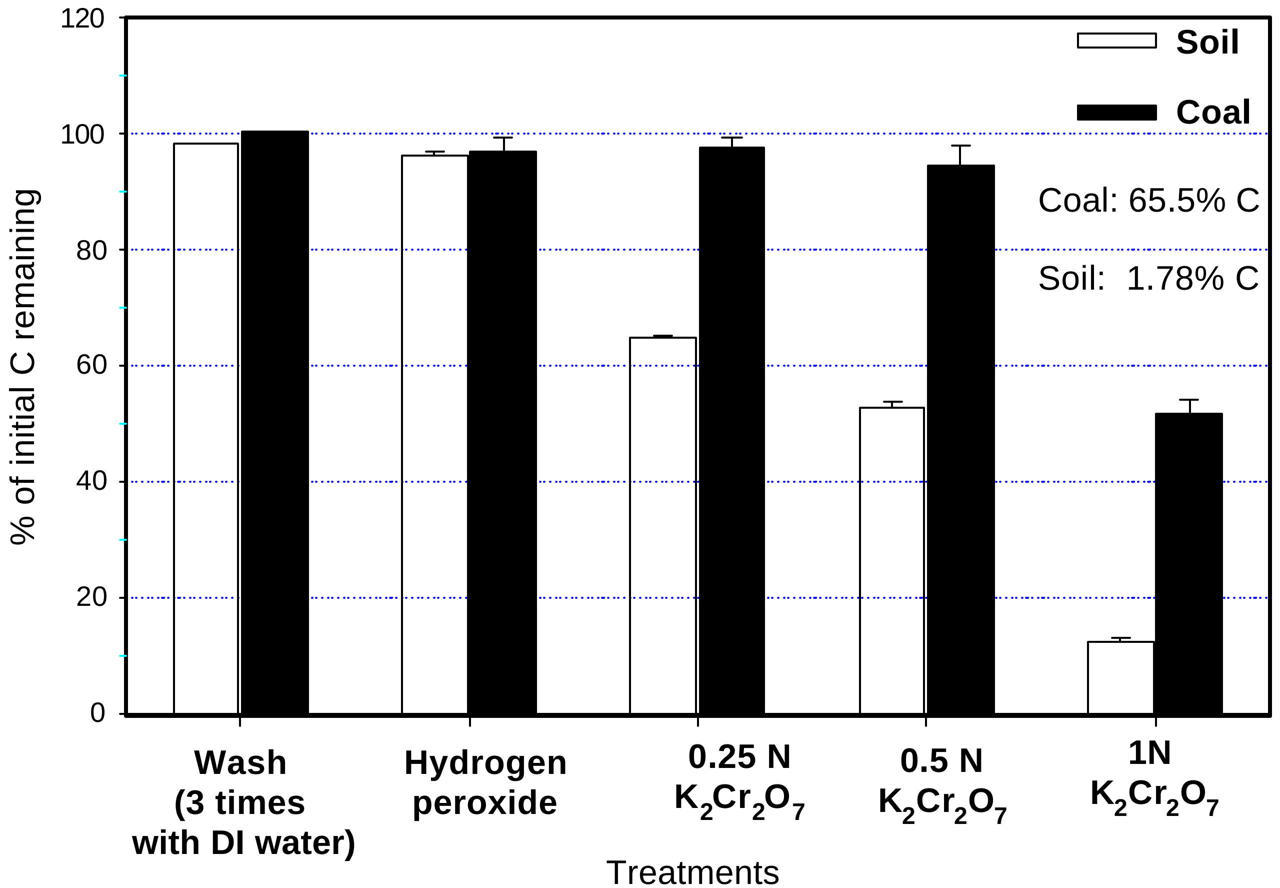
The negative trend displayed here suggests that soil compaction limits root penetration and deposition at depth of root-derived C. Deeply- deposited C is better protected from oxidation.

Fig. 5. Chemical Properties of Soils



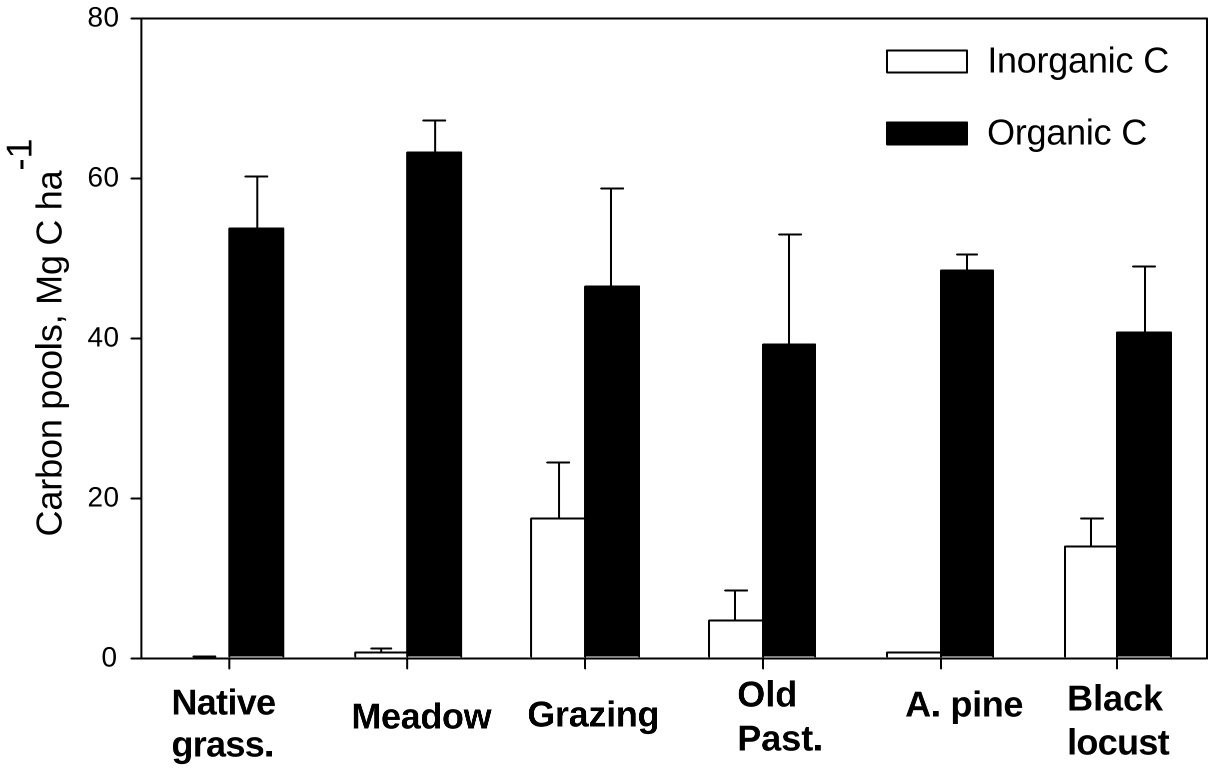
At all soil depths, soil pH, EC and inorganic C were higher at the reclaimed sites compared to the native grassland. Inorganic C content was significantly lower in the reclaimed area converted to A. pine stand compared to the other sites (Black locust, old pasture and grazing) with similar (prior to 1993) land use history.

Fig. 6. Percent of soil- and coal-C remaining after treatment with different oxidizing agents.



The dichromate (> 0.5 N) treatment removed biomass-derived C and coal-derived C. The data suggest that the chemical stability/resistance of some biomass-derived C fractions overlap with that of coal-derived carbon

Fig. 7. Inorganic and organic C pools (0-30 cm).



Reported organic C pool in the native grassland soil is slightly under-estimated since only the top 30 cm of soil was considered to allow comparison with the reclaimed sites. SOC pools to a depth of 60 cm totaled 67.7 Mg C ha^{-1} in the undisturbed grassland. Among the reclaimed sites, organic C pools was highest in the meadow as no export of plant biomass(e.g. as hay) occurs in this system during the last 20 years.

4. Summary

- C sequestration potential in reclaimed mined land could range between 18-30 Mg C ha^{-1};

- Soil compaction and accumulation of soluble salts (EC > 1.5 dS m^{-1}) at depth could limit root growth at the reclaimed sites;

- Root biomass contributed to most (60 - 80 %) of the residue-C returned to soils;

- After 9 years on conversion to A. pine plantation, soil inorganic C (IC) concentrations and pools were 7 to 24 times lower than in adjacent reclaimed fields with similar (prior to 1993) land use history;

- Although the largest SOC pool was recorded in the meadow, it is uncertain that the average farmer can afford this land use option. The large biomass production in the A. pine and black locust stands suggests that these systems are poised for significant accumulation of SOC in the future.

5. Acknowledgments

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6. References

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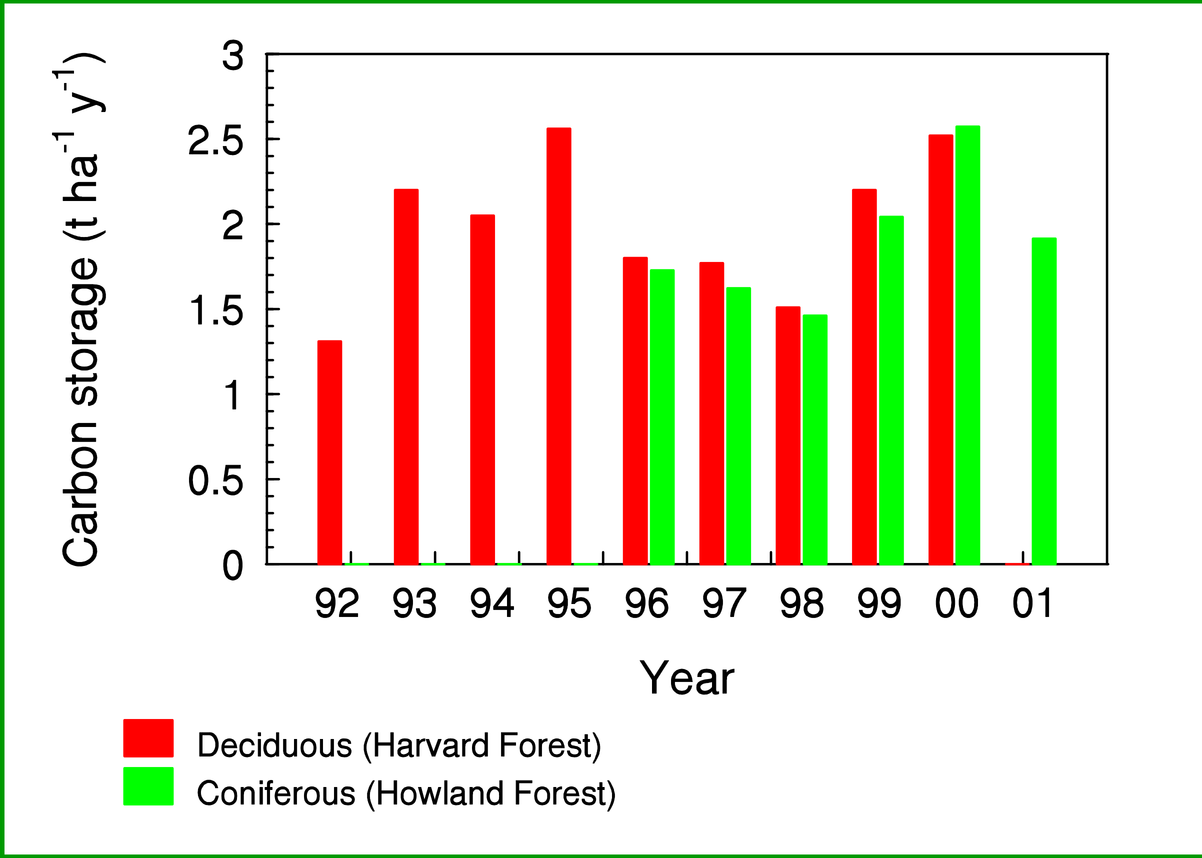
Contribution of northern hemisphere forests to carbon budgets

Atmospheric inversions indicate the N. Hemisphere is accumulating carbon (Gurney et al. 2002)

Annual net ecosystem C exchange by eddy covariance at 2 Ameriflux sites



(Deciduous forest data courtesy S. Wofsy)

Forest area of New England
(acres)

State	Total Land Area	Total Forest Total Land	Timberland	Productive/ Reserved
CT	3,101,000	1,819,000	1,768,000	21,000
ME	19,753,000	17,533,000	16,987,000	278,000
MA	5,016,000	3,203,000	2,960,000	101,000
NH	5,740,000	4,981,000	4,760,000	74,000
RI	669,000	401,000	371,000	8,000
VT	5,920,000	4,538,000	4,429,000	64,000
Total	40,199,000	32,475,000	31,275,000	546,000