Forest Carbon Sequestration along a Mafic-Ultramafic Lithosequence

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Highlights

- Eastern deciduous forests represent an important proportion of the North American forest carbon (C) stores and geology can play a major role in forest productivity and species diversity.
- We investigated the coevolution of requisite biotic (vegetation dynamics) and abiotic (bedrock and soil properties) variables that occur over an environmental gradient in the Mid-Atlantic, USA where multifaceted drivers and mesophication are accompanying afforestation.
- The bedrock (Baltimore Mafic Complex) geochemistry as well as the fundamental bedrock structure (fracture density) functioned as a regulator of wood species productivity resulting in differential aboveground and belowground biomass and calculated carbon storage.
- Despite increased allocation to below ground biomass in soils from ultramafic parent material, forests growing on mafic bedrock store more live aboveground and below ground carbon compared to forests on serpentinite bedrock.
- Findings suggest that bedrock geology is an important factor to consider when evaluating ecosystem carbon pools at the regional level. When examining strategies for forest carbon sequestration, incorporating potential influences of lithology on forests into management plans may help in meeting carbon policy requirements.

Geoecological Background

- The field area lies in the Piedmont of Maryland within the Baltimore Mafic Complex.
- Soil properties and textures were related to bedrock. We examine the effect of soils derived from serpentinite (ultramafic) and gabbro (mafic) parent material on growth of resident (native or local) and non-resident seedlings. This was done to evaluate the root to shoot growth balance as a result of potential local adaptation.

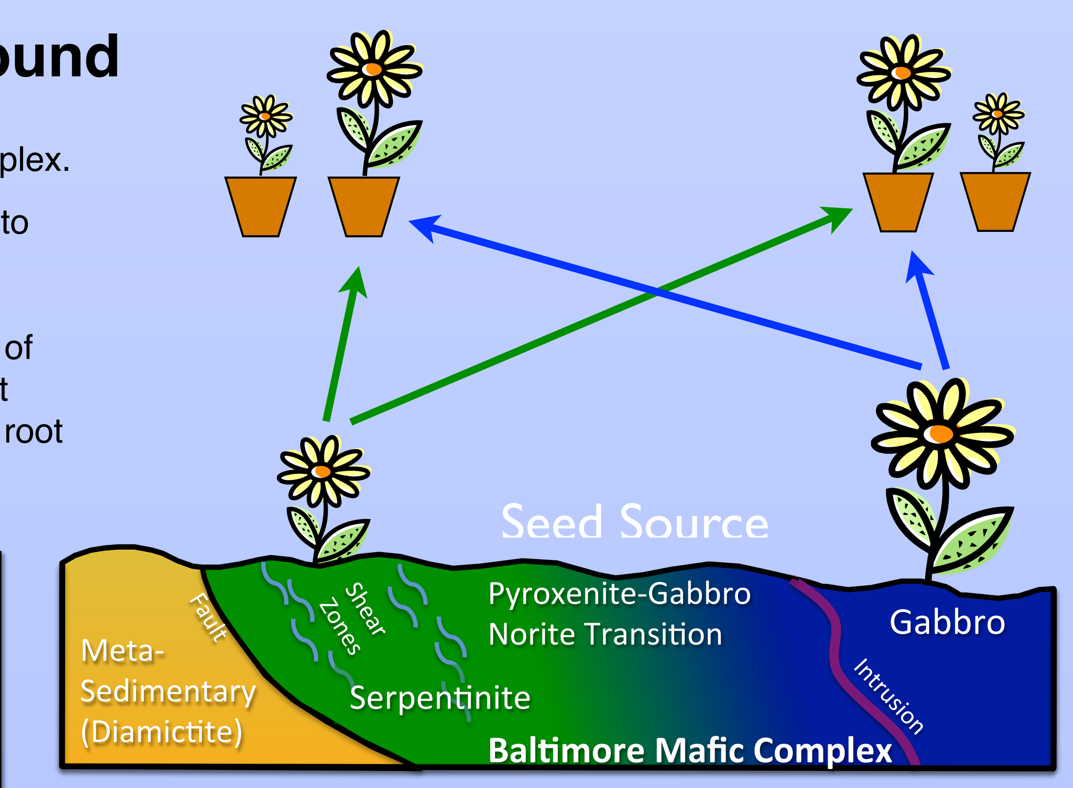


Figure 1. Simplified geological cross section showing bedrock and the reciprocal transplant set up used to derive adaptation information and root to shoot ratios for woody species.

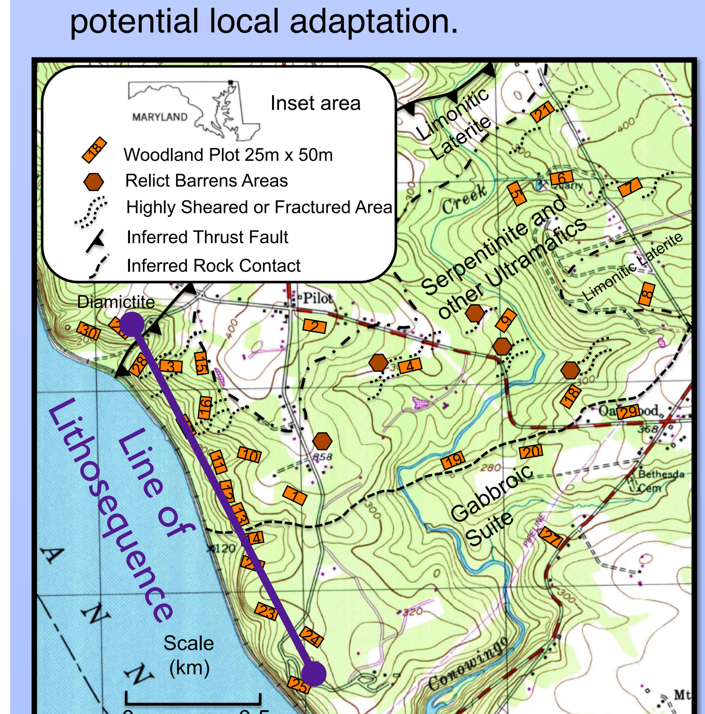


Figure 2. Sampling Plots and line of section..

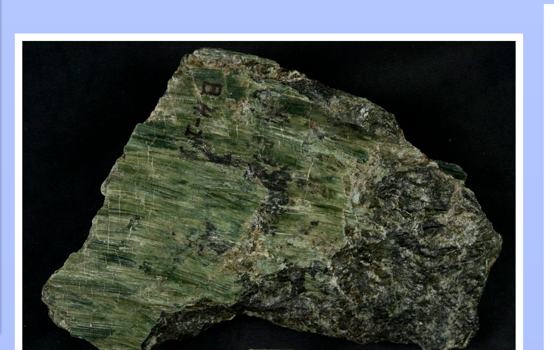


Figure 3. Slickenlines on serpentinite.

- Bedrock consists of a northeast trending group of undifferentiated serpentinite and other metamorphosed mafic-ultramafic bodies that may be an extension of the Baltimore Mafic Complex.
- Though serpentinite derived soils typically have less aboveground biomass, the greenhouse reciprocal transplant experiment was used to provide information on the below ground biomass ratios of select species common to the area.

Figure 4. Quartz bearing gabbro.

Woody Species along Lithosection

- Chemical attributes of the ultramafics include: elevated levels of heavy metals such as Cr, Ni, and Co which are toxic to many plants; and Ca: Mg ratios < 1, while those of more evolved mafic and quartzo-feldspathic materials have low heavy metal contents and Ca: Mg ratios > 1.
- Note the abundance of xeric oaks (Blackjack-Post oak forest alliance) in those areas corresponding to dryer, more sheared ultramafic substrates. Likewise, other alliances (Tulip poplar for instance) respond to the changing hydrogeologic environment.

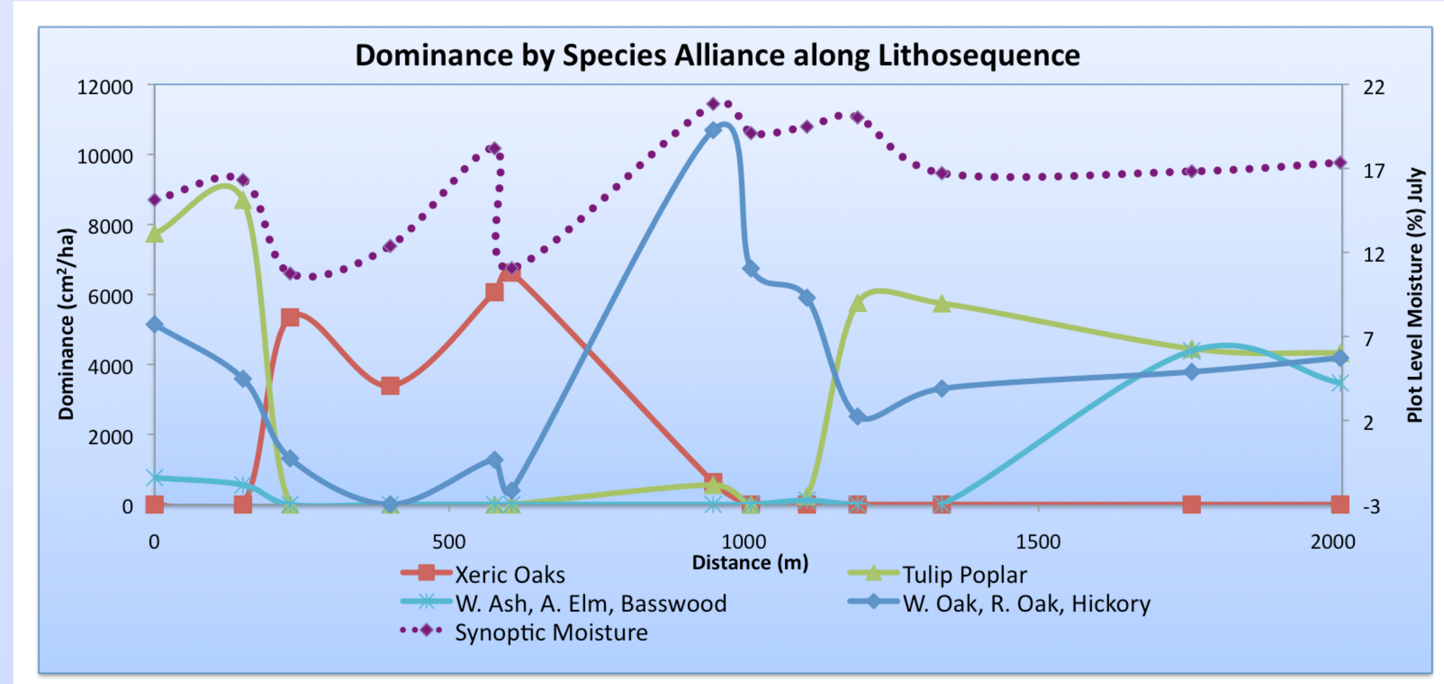
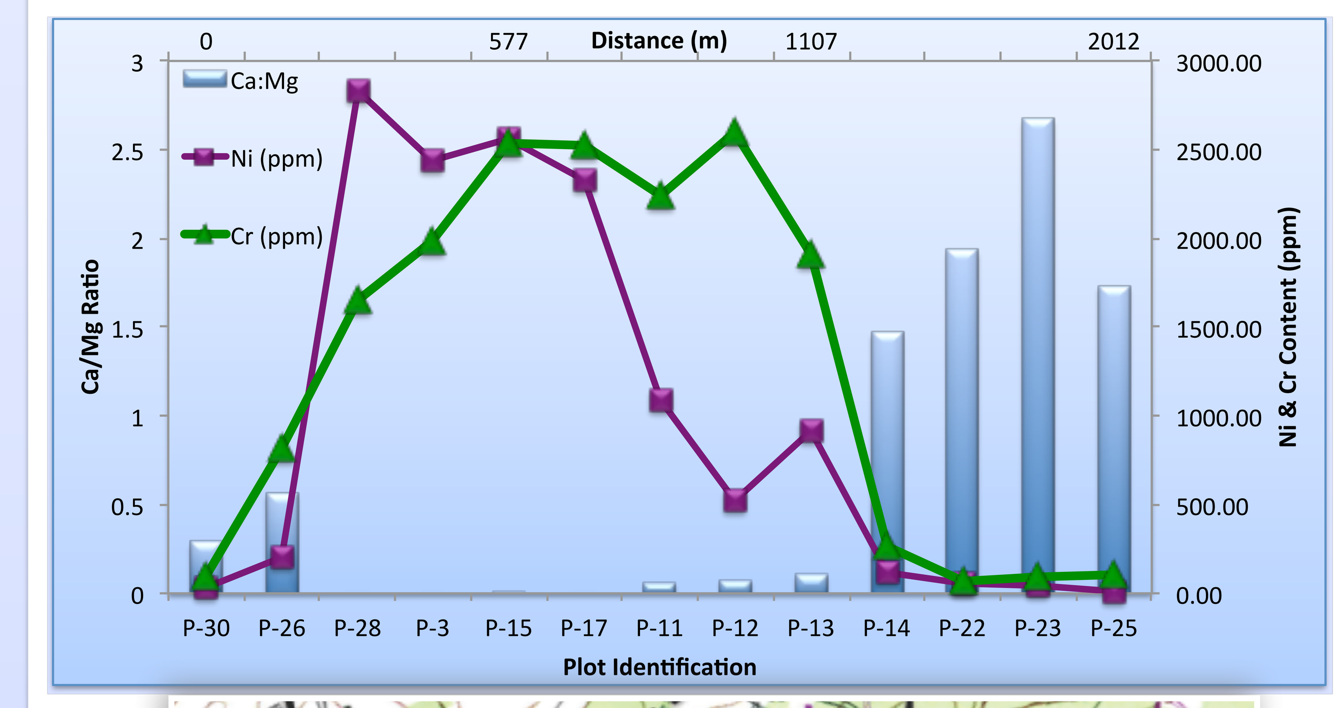


Figure 5. Woody species dominance grouped by typical Piedmont tree alliances as seen along the length of the mafic-ultramafic lithosequence.



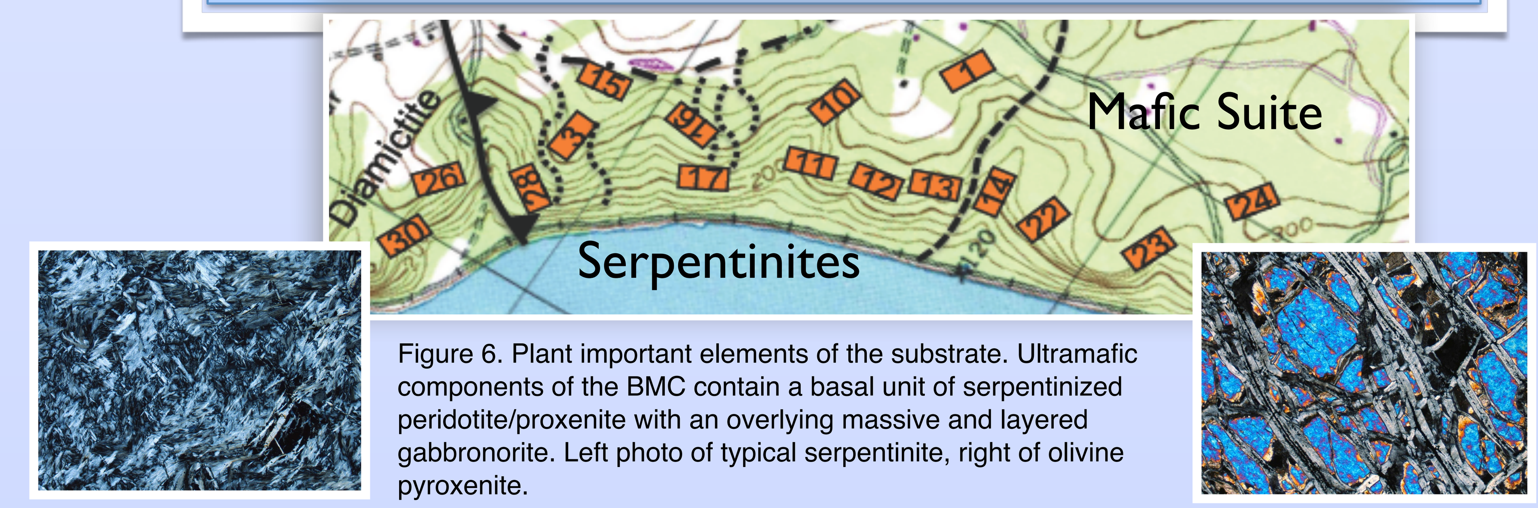


Figure 6. Plant important elements of the substrate. Ultramafic components of the BMC contain a basal unit of serpentinized peridotite/pyroxenite with an overlying massive and layered gabbronorite. Left photo of typical serpentinite, right of olivine pyroxenite.

Bedrock Type and Forest Carbon Storage

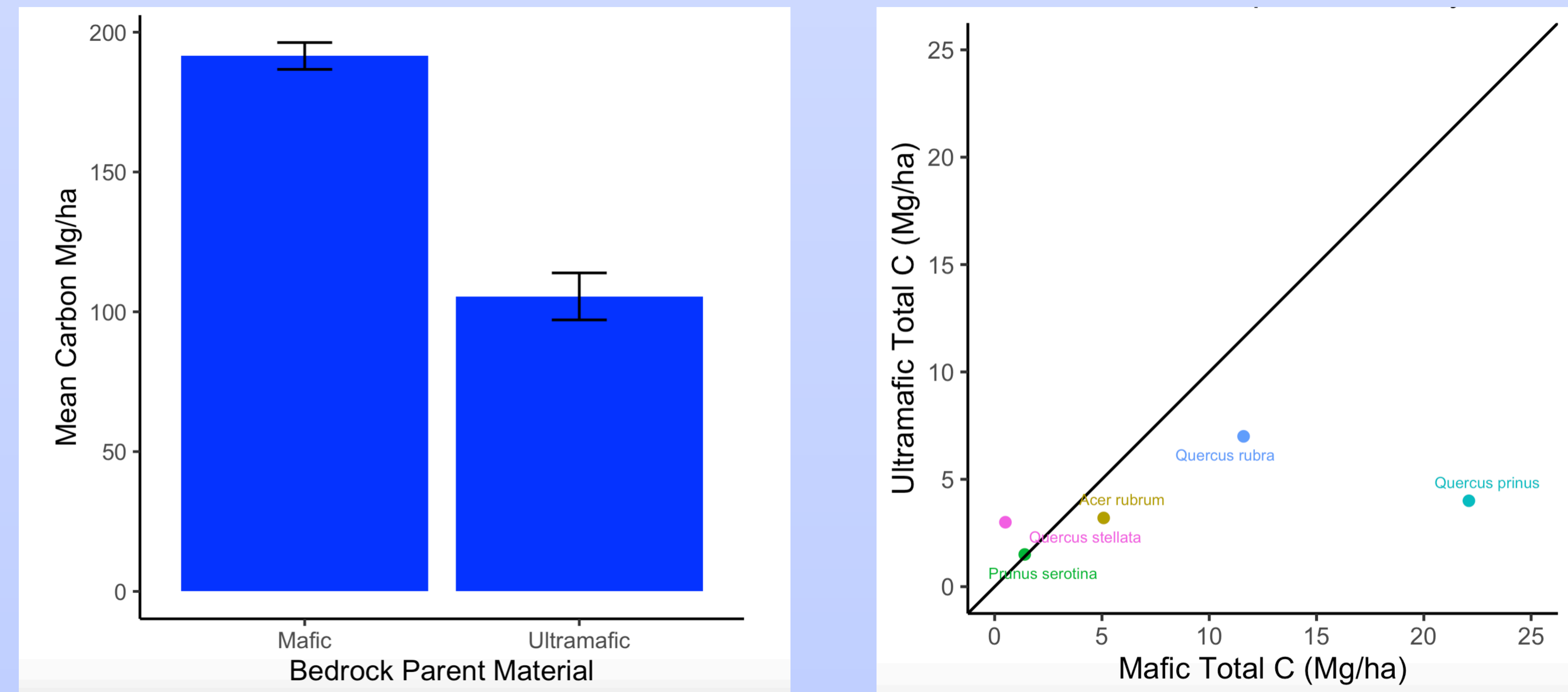


Figure 7 and b. A. Average total carbon (Mg/ha) across forests by rock type. b. Average live aboveground and below ground carbon by species and rock type. The solid 1:1 line represents the theoretical relationship of equivalent biomass on gabbroic rocks and serpentinite.

Biomass Partitioning by Species and Soil Parent Type

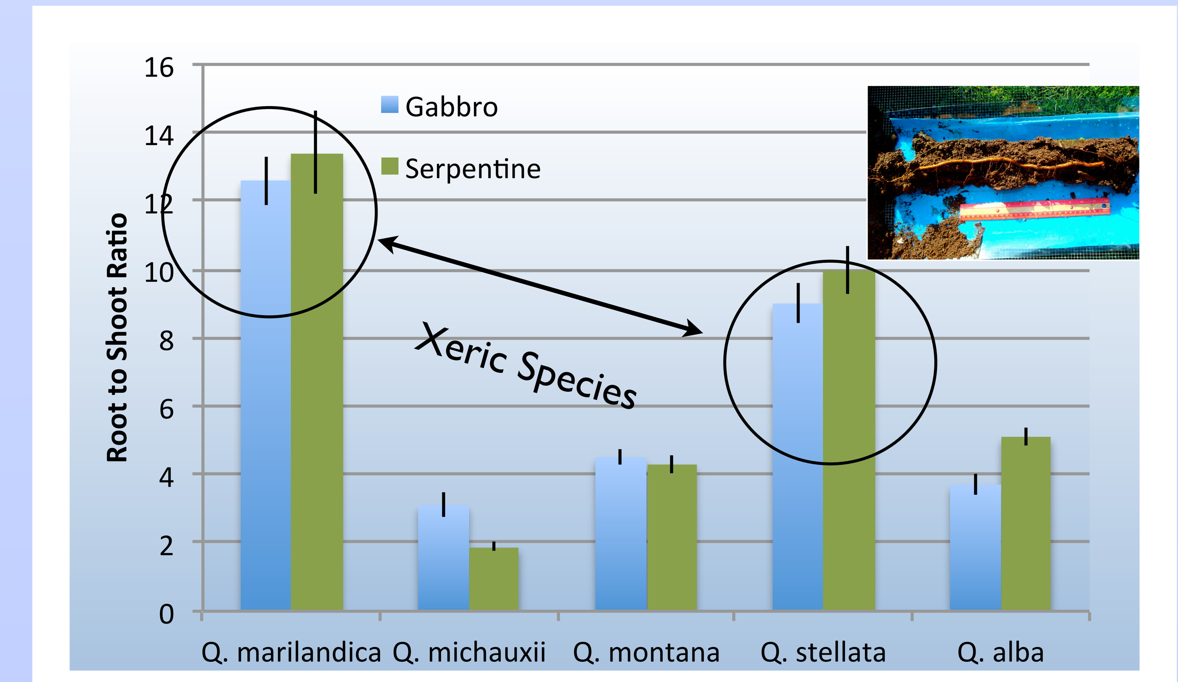


Figure 8. Interspecific differences in the allocation of carbon to root and shoot growth were observed for the oaks, but both Post Oak and Black Jack Oak serpentinite ecotypes displayed higher root:shoot ratios regardless of soil type supporting local adaptation.

- This work explored coupled forest inventory data at a local scale, where ultramafic and mafic parent material are juxtaposed, from stratified plots including measures of woody vegetation, edaphic factors, bedrock geochemistry, petrography, and outcrop fracture density to evaluate some of the community-structuring factors in an area where ultramafic and mafic bedrock are juxtaposed in the mid-Atlantic area.
- Allometric equations for calculation of tree above-ground biomass (AGB) form the basis for estimates of forest carbon storage and exchange with the atmosphere. In this study, the R package "allodb" was used to calculate the AGB based on diameter at breast height and geographic location (latitude and longitude). Citation: Gonzalez-Akre et al. (2022). allodb: An R package for biomass estimation at globally distributed extratropical forest plots.
- Belowground biomass was calculated as a percentage of AGB based on literature values as well as direction measurements from greenhouse experiments on biomass allocation (root to shoot ratios) of five typical oak species grown in chambers with field collected soils from ultramafic and mafic parent materials. Two species in particular showed local adaptation to the serpentinite soils with 25% more allocation to belowground biomass than is typical for the species in other soils. Common occurrence species showed higher allocation to biomass on mafic substrates (Fig. 7b).
- In the Piedmont province of Maryland forest carbon storage is approximately 50 % greater and annual uptake higher (all plots have similar age structure based on dendrochronology) in forests growing on gabbro bedrock compared to serpentinites and pyroxenite (Fig 7a). This difference is often overlooked despite the dominance of these rock types within a large and important carbon sink.

Species Diversity

- Serpentine has a steeper slope meaning it is dominated by a few species and the mafic plots have a slightly higher number of recorded species. A more shallow slope for the mafic woody species indicates a log-normal distribution typical of temperate forests. The KS test indicates that the two groups are significantly different.

Figure 9. Typical Forest Plot.

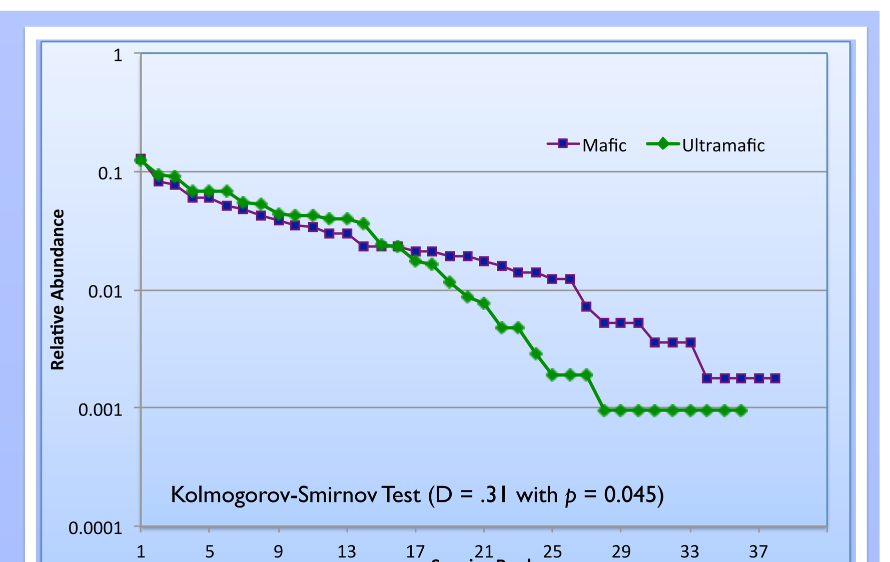


Figure 10. A rank abundance curve provide a means for visually representing species richness and species evenness. Species richness can be viewed as the number of different species on the chart.

Conclusions and Outlook

- Forest trees account for 70%–90% of the land biomass of earth (Houghton, 2008). The quantification of forest above-ground biomass (AGB) and below ground biomass (BGB) is an essential step to understand the sources, sinks and flow of carbon world-wide.
- These findings suggest that bedrock geology is an important factor to consider when evaluating ecosystem carbon pools at the landscape level. When examining strategies for forest carbon sequestration, incorporating potential influences of lithology on forests into management plans may help in meeting carbon policy targets.

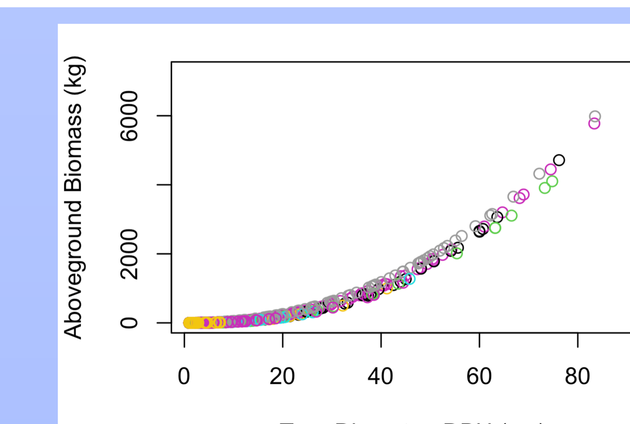
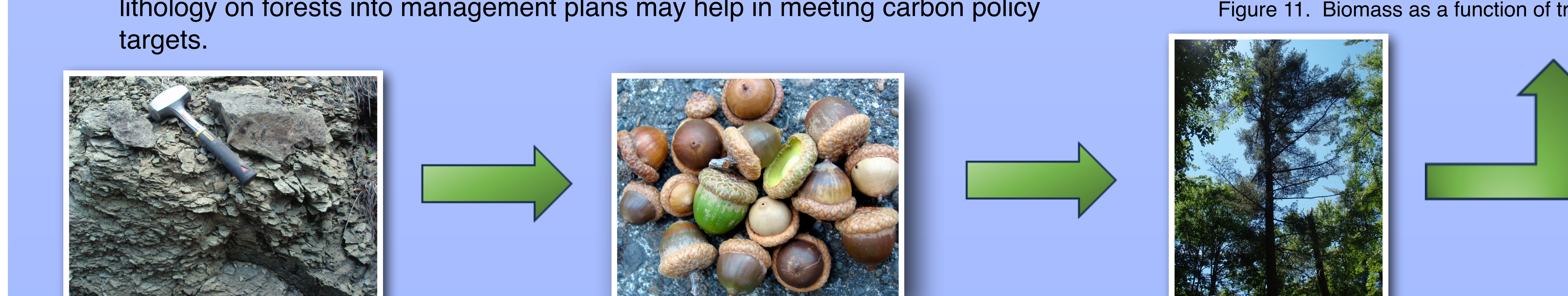


Figure 11. Biomass as a function of tree diameter



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