A Global Database of Ecosystem Root Profiles (ERP)

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Abstract

A global database of root profiles was assembled from the primary literature in order to characterize the belowground structure of global vegetation types and to study relationships of belowground vegetation structure with climate, soil characteristics, and aboveground vegetation structure. Variables used to characterize belowground vegetation structure include the depths above which 50% of all roots and 95% of all roots are located in the profile. For each root profile, recorded are latitude and longitude, elevation, soil texture, depth of organic horizons, type of roots measured (e.g., fine or total, live or dead), sampling methods, units of measurements (root mass, length, number, surface area), and sampling depth. Some profiles lack information on one or more of these variables. Also recorded are presence and dominance of plant life forms (including succulents, forbs, grasses, semi-shrubs, shrubs, and four categories of trees: needle-leaved vs. broadleaved, evergreen vs. deciduous) and whether the vegetation was relatively "natural" or altered by humans (e.g., forest plantations and pastures). The database also includes data on mean annual precipitation and on the seasonal distribution of precipitation.

The 50% and 95% rooting depths were calculated by fitting a non-linear smoothing function (a logistic dose-response curve) to each cumulative root profile and interpolating the 50% and 95% rooting depths. Less than 10% of all profiles in the database were sampled to the maximum rooting depth, which means that more than 90% of these interpolated rooting depths are underestimates of the true 50% and 95% rooting depths at the respective sites. To correct for this sampling error, incompletely sampled profiles (those not sampled to the maximum rooting depth or to at least 3 m depth) were extrapolated using the same mathematical function used to interpolate completely measured profiles. To avoid excessive errors, extrapolations were restricted to a maximum sampling depth of either twice the sample depth or to 3 m depth, whichever

was smaller. Profiles for tundra and wetlands were also not extrapolated beyond the measured depth. For extrapolated profiles, both the 50% and 95% rooting depths based on interpolating to the maximum sampling depth and the 50% and 95% rooting depths based on extrapolating the profiles are included in the database.

Methods used to compile the database

The global database of root profiles described in Jackson et al. (1996) and Schenk and Jackson (2002) was expanded to more than 550 root profiles for more than 300 geographical locations, with data sets included if root samples were taken in at least four depth increments. For each root profile, we recorded latitude and longitude, soil texture (coarse, medium, or fine), depth of organic horizons, type of roots measured (e.g., fine or total, live or dead), sampling method, units of measurements (root mass, length, number, surface area), and sampling depth. We also recorded the presence and dominance of plant life forms as described in the publications (including succulents, forbs, grasses, semi-shrubs, shrubs, and four categories of trees: needle-leaved vs. broadleaved, evergreen vs. deciduous). Semi-shrubs were treated separately from shrubs because many studies made this distinction and because previous studies found differences in rooting depth between shrubs and semi-shrubs. We also noted whether the vegetation was relatively “natural” or altered by humans (e.g., forest plantations). Where unavailable, geographic coordinates were estimated based on geographic information in the publications. The precision of these estimates varied from a few kilometers in the majority of cases to no more than 0.5° latitude or longitude in a few (mostly for sites in unpopulated areas in boreal or tropical zones).

Mean annual precipitation was recorded from each publication or, where unavailable, was estimated from the nearest available weather station. The seasonal distribution of precipitation was estimated from 1961-1990 long-term monthly means for 0.5° grid cells recorded in the CRU Global Climatologies (IPCC Data Distribution Center).

Most profiles included roots from different species and life forms. Where data were given separately for species or life forms they were averaged to generate an estimated profile for the community, but the individual data were retained for the life-form analyses. Data for both late- and early successional vegetation were included. Root profiles for crops and from fertilized or ploughed soils were excluded because root distributions in such systems can be strongly influenced by management practices, a factor that we were unable to include in our analyses.

Interpolation of root profiles to estimate 50% and 95% rooting depths

The goal of interpolations and extrapolations was to estimate the depths above which 50% of all roots (D_{50}) and 95% of all roots (D_{95}) were located in the soil. Root profiles differed in the number and depth of intervals sampled, which made standardizing them necessary so that statistical analyses could weigh each profile equally. To achieve this, profiles were interpolated by fitting a non-linear smoothing function to each profile. The model used in this study for interpolation of profiles was a logistic dose-response curve (LDR), which was fitted to cumulative root profiles:

$$r(D) = \frac{R_{\max}}{\left[1 + \left(\frac{D}{D_{50}}\right)^{c}\right]} \qquad (1)$$

In this equation, $r(D)$ is the cumulative amount of roots above profile depth D (in cm, including organic layers), $R_{\max}$ is an estimate for the total amount of roots (i.e. total biomass, length, number etc.) in the total profile (incl. sampled and un-sampled parts), D_{50} is the depth (cm) at which $r(D) = 0.5\ R_{\max}$, and c is a dimensionless shape-parameter.

The LDR-model was fitted to all profiles, allowing R_{max} ,D_{50}, and c to vary to obtain the best fit. Tests of the accuracy of interpolations are discussed by Schenk and Jackson (2002).

To interpolate the depths within the sampled part of the soil profile above which 50% of all sampled roots (D_{S50}) and 95% of all sampled roots (D_{S95}) were located, the following equations were used:

$$D_{S50} = D_{50} * \left(\frac{R_{\max}}{0.5\ R_{S\max}} - 1 \right)^{\frac{1}{c}} \tag{2}$$

and

$$D_{S95} = D_{50} * \left(\frac{R_{\max}}{0.95\ R_{S\max}} - 1 \right)^{\frac{1}{c}} \tag{3}$$

where R_{Smax} is the total amount of roots (i.e. total biomass, length, number etc.) within the sampled profile. Several other interpolation methods, including the β-function of Gale and Grigal (1987) that was used by Jackson et al. (1996), as well as simple linear interpolations between sample intervals, were also tested for their accuracy of calculating 50% and 95% rooting depths. However, the LDR model was found to be superior (Schenk and Jackson 2002).

The 50% and 95% rooting depths listed in the ERP database can be used to calculate vertical root distributions by using equation (1), setting Rmax = 100%, and calculating the shape parameter c from:

$$c = \frac{-1.27875}{\left(\log_{10} D_{95} - \log_{10} D_{50}\right)} \tag{4}$$

Extrapolation of root profiles to estimate 50% and 95% rooting depths

Interpolated rooting depths tend to be under-estimates of the true 50% and 95% rooting depths, because less than 10 % of the root profiles in the database were sampled to a depth at which no further roots were found, with few studies sampling root profiles to depths of 3 m or more (Schenk and Jackson 2002). These incompletely sampled profiles (those not sampled to the maximum rooting depth or to at least 3 m depth) were extrapolated using the same mathematical function used to interpolate completely measured profiles. All extrapolations of profiles were restricted to a maximum depth of 3 m, because this should be sufficient for most vegetation types (Canadell et al. 1996) and because our limited data set of deep profiles did not allow us to test the accuracy of extrapolation to greater depths. Details about extrapolation methods and tests of their error rates may be found in Schenk and Jackson (2002). The model used in this study for extrapolating profiles was the LDR model, the same as that used for interpolations (equation 1).

For extrapolations, the LDR-model was fitted to the profiles, allowing R_{max} to vary to obtain the best fit. To avoid excessive errors, extrapolations were restricted to a maximum sampling depth, D_{max}, of either twice the sample depth or to 3 m depth, whichever was smaller, and the cumulative amount of roots at D_{max} was set to 100%. Profiles sampled to the apparent maximum rooting depth or to ≥ 3 m were not extrapolated. Profiles for tundra and wetlands were also not extrapolated beyond the measured depth.

It is important to note that it is not possible to estimate errors for extrapolations of individual profiles. On average, the extrapolation method outlined above has a slight tendency towards underestimating mean rooting depths by about 1 to 3% (Schenk and Jackson 2002), but individual extrapolations may be highly inaccurate. However, extrapolated rooting depths for individual profiles can be averaged to compute mean rooting depths for vegetation types or profiles that share climatic or edaphic characteristics. In this case, total errors (including interpolation and extrapolation errors) of estimated mean rooting depths for vegetation types decrease with the number of profiles used to derive the estimate. In our analyses (Schenk and Jackson 2002), errors decreased from ± 40 % of the mean for samples of 10 profiles to less than ± 10 % of the mean for samples of 60 profiles or more (i.e., the more profiles, the smaller the error).

References

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