

Calculating Net Primary Productivity



Depending on your initial research question, you may be interested in the annual carbon uptake at your sample site. This can be determined by calculating Net Primary Productivity (or NPP). **In order to calculate NPP, you will need multiple years of biomass and carbon storage data for your sample site.**

NGSS (Black- covered directly, gray- addressed, but not directly covered)

- *Disciplinary Core Ideas*
 - Gr.6-8: ESS3.C
 - Gr.9-12: ESS3.C
- *Science and Engineering Practices*
 - Analyzing and interpreting data
 - Using mathematics and computational thinking
 - Constructing explanations
- *Crosscutting Concepts:*
 - Stability and change

Background

Net Primary Productivity (NPP), or the production of plant biomass, is equal to all of the carbon taken up by the vegetation through photosynthesis (called Gross Primary Production or GPP) minus the carbon that is lost to respiration.

$$\text{NPP} = \text{GPP} - \text{respiration}$$

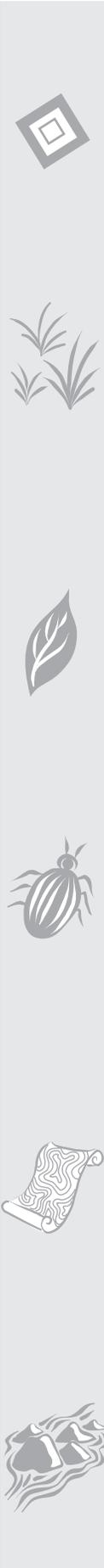
In terrestrial systems, NPP is often calculated by determining the carbon storage increment. Therefore, using the data from your sample site along with the biomass and carbon storage equations, aboveground NPP can be calculated by taking the difference in carbon storage of each individual tree between years, and summing the resulting values to get plot NPP.

NPP is one of the most frequently measured ecosystem processes, because it is central to the storage and accumulation of carbon in ecosystems, as well as the yield of usable products (lumber, etc.). From the NPP calculation, you can also calculate the annual CO₂ uptake from your sample site using the instructions at the end of this document.

What to do and How to Do it

As a class or in student groups:

1. Gather all field data entry sheets for each year.
2. Open the *NPP Analysis* spreadsheet.
3. Read through the instructions page to familiarize yourself with the tabs.
4. Follow the instructions to enter in the plot dimensions and copy in the vegetation data. *Note: This may take some adjusting to match up each tree if trees have been added to the plot, or trees have died.*

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5. If your initial research question involves calculating CO₂ uptake, see the instructions at the bottom of this document.

Why do I need to use the NPP Spreadsheet?

It is very important that you use the *NPP Analysis* spreadsheet when calculating your sample site NPP, particularly for sample sites containing trees. This is due to the difficulty of accounting for trees that have died or newly added trees in NPP calculations, as explained below.

With live trees, Tree Carbon Year2 – Tree Carbon Year1 is positive, and the resulting value contributes to the plot NPP. If a tree dies or is removed from the plot, this equation can result in a negative value. However, NPP values cannot be negative. The *NPP Analysis Spreadsheet* interprets this negative value to mean there was no growth for that tree. The NPP value for that tree is then set to zero, and it will no longer contribute to the plot NPP.

Similarly, trees don't magically appear in your sample site at 15 cm CBH (the circumference at which you start measuring them). Therefore, to get an accurate NPP value, when a new tree is added to your dataset we assume that every year prior to measurement of the tree, its CBH was 15 cm. This means that up to the first year of measurement, the tree will have a net zero impact on your NPP estimate, however in the year that you first measure the tree, the increase in biomass from the previous year will only be one year's growth.

The *NPP Analysis Spreadsheet* was designed to take these considerations into account when it calculates NPP. After you have imported your tree circumference data into the Field Data tab, click on the NPP tab. You will notice that in the rows in which you have added trees, the data has been transformed before the NPP is calculated. This insures that you get an accurate NPP value.

It is important to note that using tree biomass and carbon estimates to calculate NPP underestimates growth to some degree because any biomass a tree grows and loses (leaves, twigs, branches) in between years is missed. Lost biomass is called 'litterfall'. Scientists measure litterfall with collection baskets to account for the missing vegetation. Because of this, you'll notice that the spreadsheet uses the term 'NPPwood' when referring to tree NPP values.

For convenience, NPP calculations for shrub/sapling data are included in the spreadsheet, however because you do not keep track of individual plants in these protocols, you can get a rough estimate of NPP by finding the difference in carbon storage between years:

$$\text{NPPshrub} = \text{Carbon Stored Year2} - \text{Carbon Stored Year1}$$

Herbaceous data are not included because aboveground herbaceous vegetation dies back every year, and so does not accumulate carbon over time.

What if I collect data multiple times a year or at different times of the year?

Because NPP is calculated using the year of data collection, it is important to be sure that all of the data you enter in the NPP Analysis spreadsheet was collected at a similar time of year. For example, if you make field measurements multiple times a school year (e.g., fall semester 2012 and spring semester 2013), the spreadsheet will assume that a full year has passed between your measurements, although it

has only been a few months. This can be accounted for that by having two different spreadsheets, one for fall measurements and one for spring measurements.

What if my data set is longer than 5 years?

After 5 years of data collection, you can start a new *NPP Analysis* spreadsheet. However, it is important that in the first column of data (collection year #6), you do not record dead trees as 'd' – instead type in the circumference value for the last year the tree was alive. For the next four years, you can continue to enter the data as it is on your data entry sheet (with dead years marked as 'd').

If you are only interested in the average NPP for the entire data collection time period (and not the yearly NPP increment), then you can simply enter your first and last year of data into the spreadsheet.

If you have a dataset with 10+ years of data find an ecosystem ecologist in your area who can help you with long-term datasets. Long-term datasets are extremely valuable to the scientific community, and they may be interested in working with you and your class.

For more information on measuring NPP in the field, see Clark et al. 2001. Measuring net primary production in forests: concepts and field methods. *Ecological Applications* 11: 356–370.

How to calculate CO₂ uptake/storage from NPP data:

Annual CO₂ uptake for your sample site can be calculated using simple math and a bit of chemistry knowledge. Use (or have students develop) the equation below to calculate CO₂ uptake from NPP.

$$\text{CO}_2 \text{ Uptake (g/m}^2\text{/yr)} = \text{NPP (g/m}^2\text{/yr)} * 3.664$$

Equation Rational

A carbon dioxide molecule is made up of one carbon and two oxygen atoms.

From the periodic table we know the atomic weight of a carbon atom = 12.011 and the atomic weight of an oxygen atom = 15.999. Therefore the atomic weight of a CO₂ molecule = 12.011 + 2*15.999 = 44.009.

We then find the ratio of CO₂ to C, which is 44.009/12.011 = 3.664.

The carbon dioxide uptake of your sample site plot is equal to the carbon stored that year (i.e. NPP) * 3.664.