EEOS 465 / 627 – Environmental Modeling with Raster GIS

Project:

•The final project will **simulate a real-world setting** by establishing a **GIS consulting firm**.

•The **CEO** of the firm is the **instructor**, who will be **responsible for helping** the project teams **complete their work** in a **timely and professional** manner.

•The CEO will also **review team performance** and the **quality of their output**.

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Project, Continued:

- Students may **conduct the project in a team** consisting of **no more than 3 members**.
- Each team will have an **elected team leader**. This team leader is **responsible for communications** between the CEO and individual team members. In other words, the team leader is the **‘point person’** for **project management**.

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Project, Continued :

- The classroom time allocated for **lab sessions** will provide **a common time** for project teams to **meet each week**.
- During **certain phases** of the project, **additional team meetings** will need to be scheduled.
- From the **9th week**, each team or individual will give a **5-to-10 minute report** on that week's **progress** either to the entire class or to the instructor.

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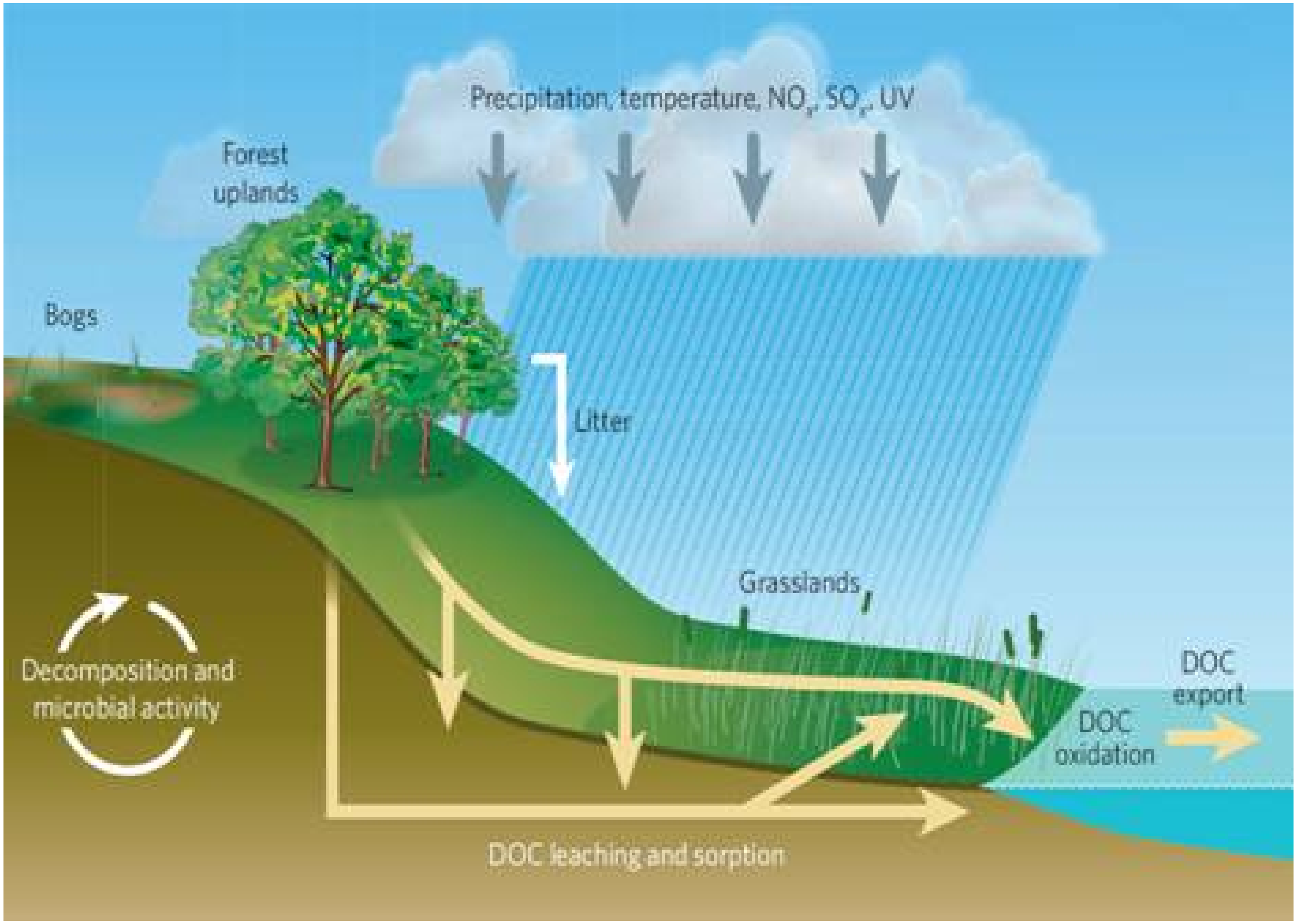
Project, Continued :

- Team members will **take turns** to **presenting** your project progress each week.
- This **'staff meeting'** will allow **everyone** to follow the **progress of the group as a whole**, and should **eliminate duplication of effort** during the data collection phase of the project.
- **All members** should **feel free** to **offer comments and suggestions** to other teams.

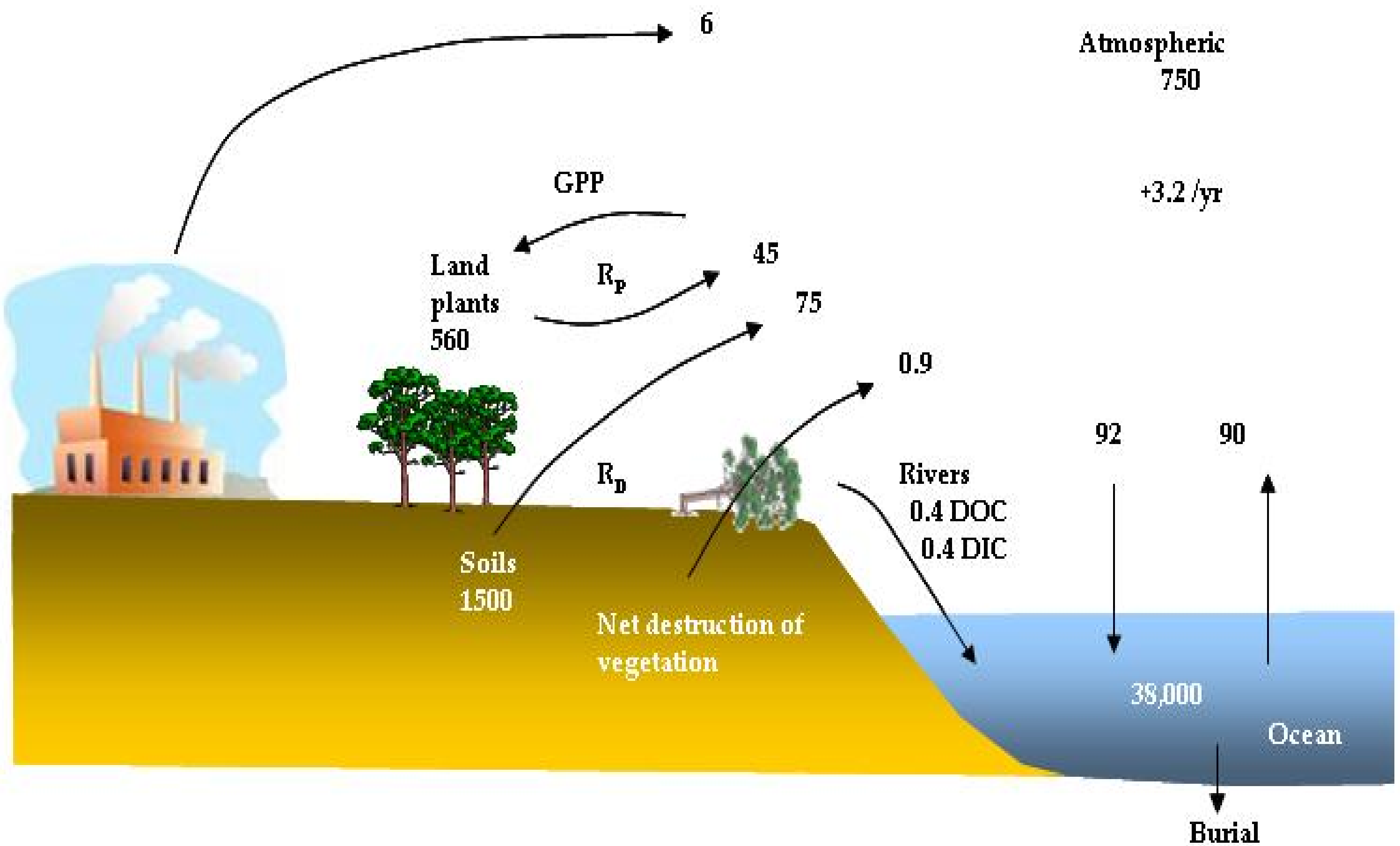
Date	Topic	Background Material	Lab / Project Work
PROJECTS USING ENVIRONMENTAL MODELING WITH RASTER GIS			
03/25/09	Group Formation and Proposal Creation	•Project Outline	•Preliminary Project Work
04/01/09	Project Design and Document Preparation	•Project Implementation	•Progress Report 1, Discussion, and Collaboration
04/08/09	Formulation and Implementation I	•Graduate Reading Assignments	•Graduate Presentations
04/15/09	Formulation and Implementation II	N/A	•Progress Report 2, Discussion, and Collaboration
04/22/09	Verification and Validation	N/A	•Progress Report 3, Discussion, and Collaboration
04/29/09	Document and Presentation Preparation I	N/A	•Progress Report 4, Discussion, and Collaboration
05/06/09	Document and Presentation Preparation II	N/A	•Progress Report 5, Discussion, and Collaboration
05/13/09	Project Presentations	N/A	•Project Presentations

Modeling Riverine Monthly Carbon Flux from the Neponset River Watershed to the Ocean



Passage of dissolved organic carbon through the landscape (Roulet & Moore, 2006, *Nature*)

The Global Carbon Cycle



Schlesinger, W.H. 1997. Biogeochemistry: An Analysis of Global Change. Harcourt, Brace and Co., USA: p.359.

The Global Carbon Cycle

- Living tissue is **primarily composed of carbon**, so estimates of the disposition of carbon globally (like NPP) give us a good sense of the extent to which ecosystems are thriving or struggling
- Carbon is **abundantly available** in the **atmosphere** as two gaseous species, $\mathbf{CO_2}$ and $\mathbf{CH_4}$
- Carbon is withdrawn from the atmosphere and added to organic biomass through **photosynthesis**, and vice-versa occurs through the process of **respiration**
- Over the past billions of years, the **concentration of atmospheric $\mathbf{CO_2}$ has diminished** as its removal from the atmosphere has exceeded its addition, demonstrating organisms' ability to change the planet

The Global Carbon Cycle

Units are Pg (10^{15}) rather than Tg (10^{12})

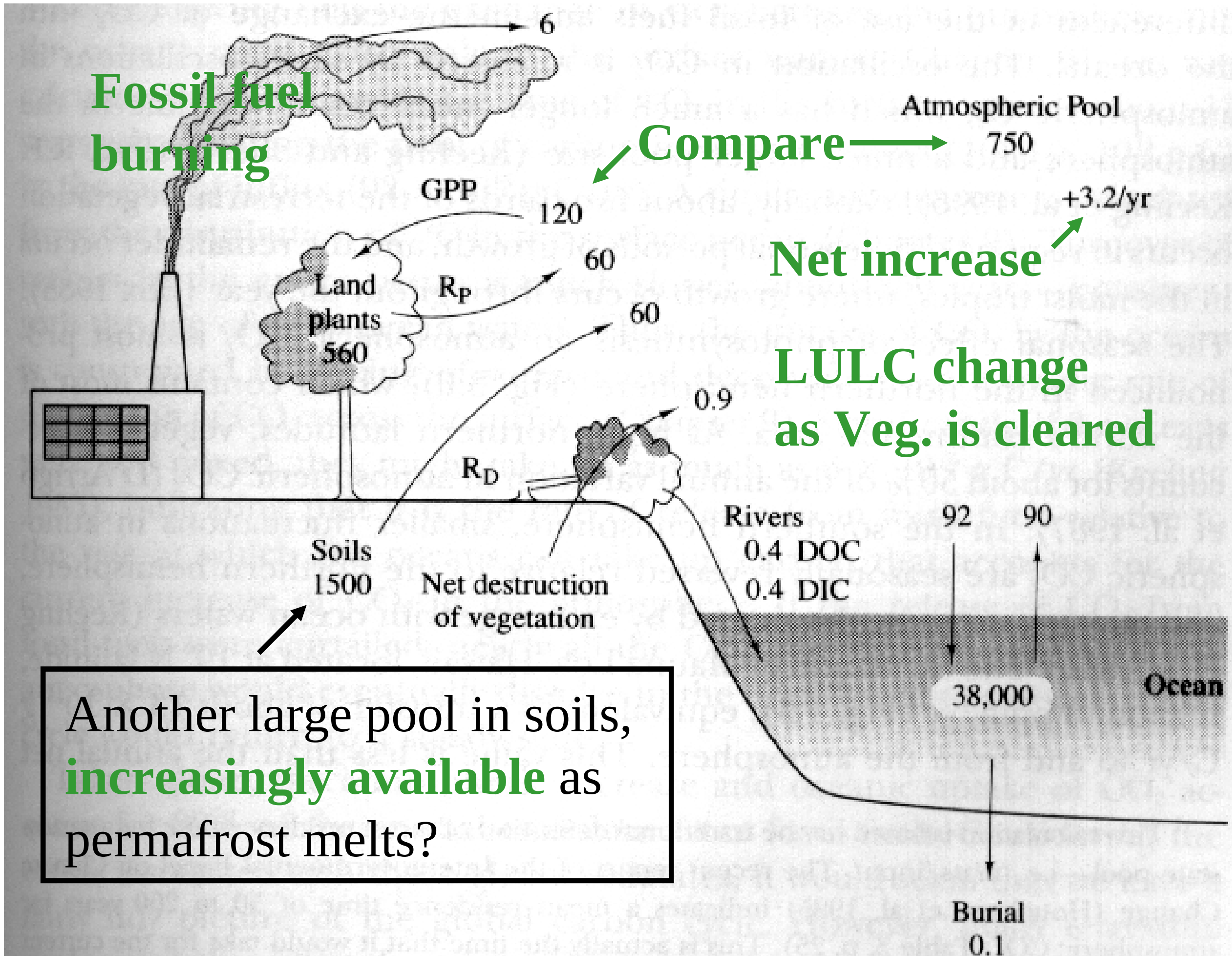


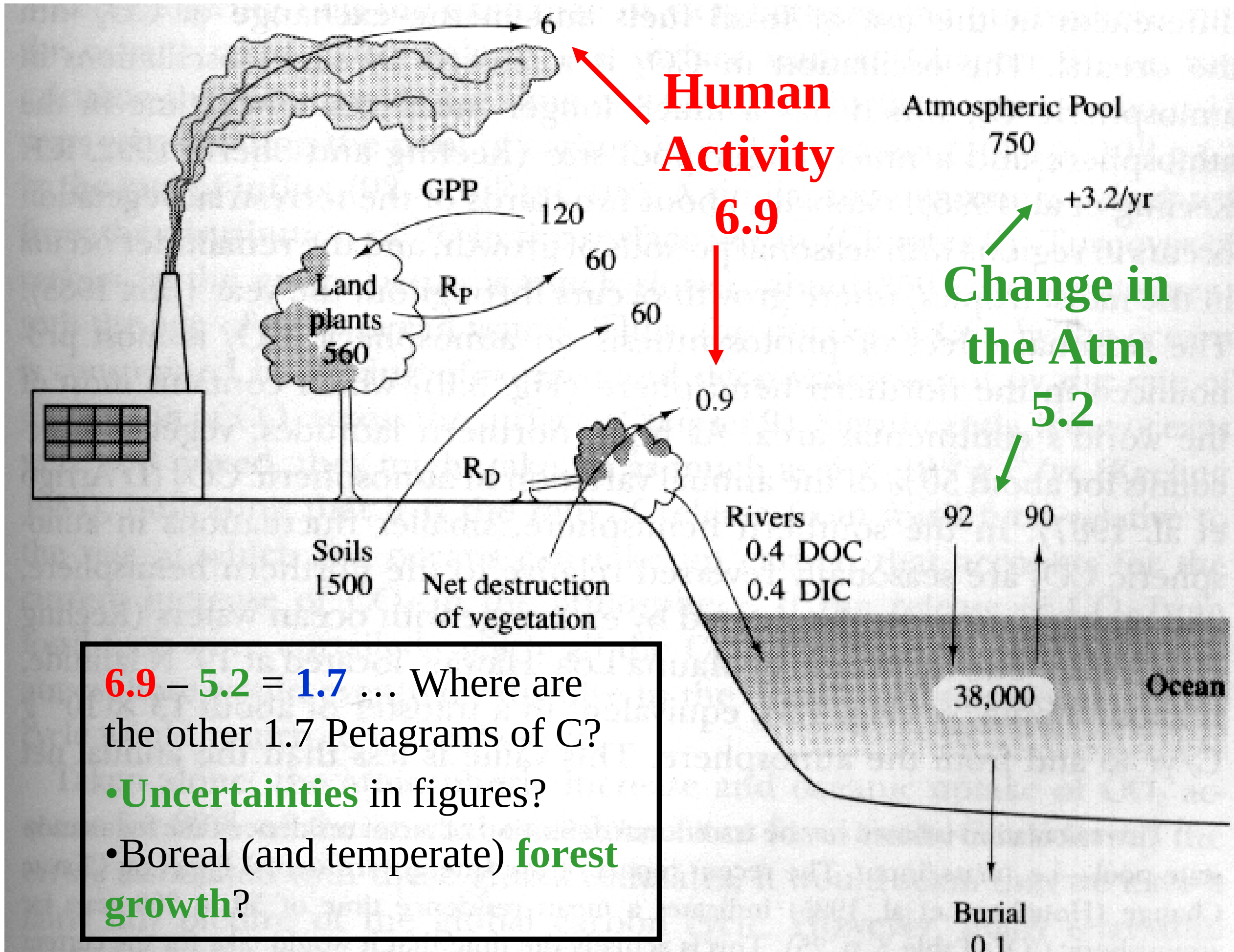
Figure 11.1 The present-day global carbon cycle. All pools are expressed in units of 10^{15} g C and all annual fluxes in units of 10^{15} g C/yr, averaged for the 1980s. Most of the values are from Schimel et al. (1995); others are derived in the text.

~15% of the atmospheric pool is taken by terrestrial organisms

Schlesinger, W.H. 1997. Biogeochemistry: An Analysis of Global Change. Harcourt, Brace and Co., USA: p.359.

The Global Carbon Cycle

Units are Pg (10^{15}) rather than Tg (10^{12})



$\color{red}{6.9}$ – $\color{green}{5.2}$ = $\color{blue}{1.7}$ … Where are the other 1.7 Petagrams of C?

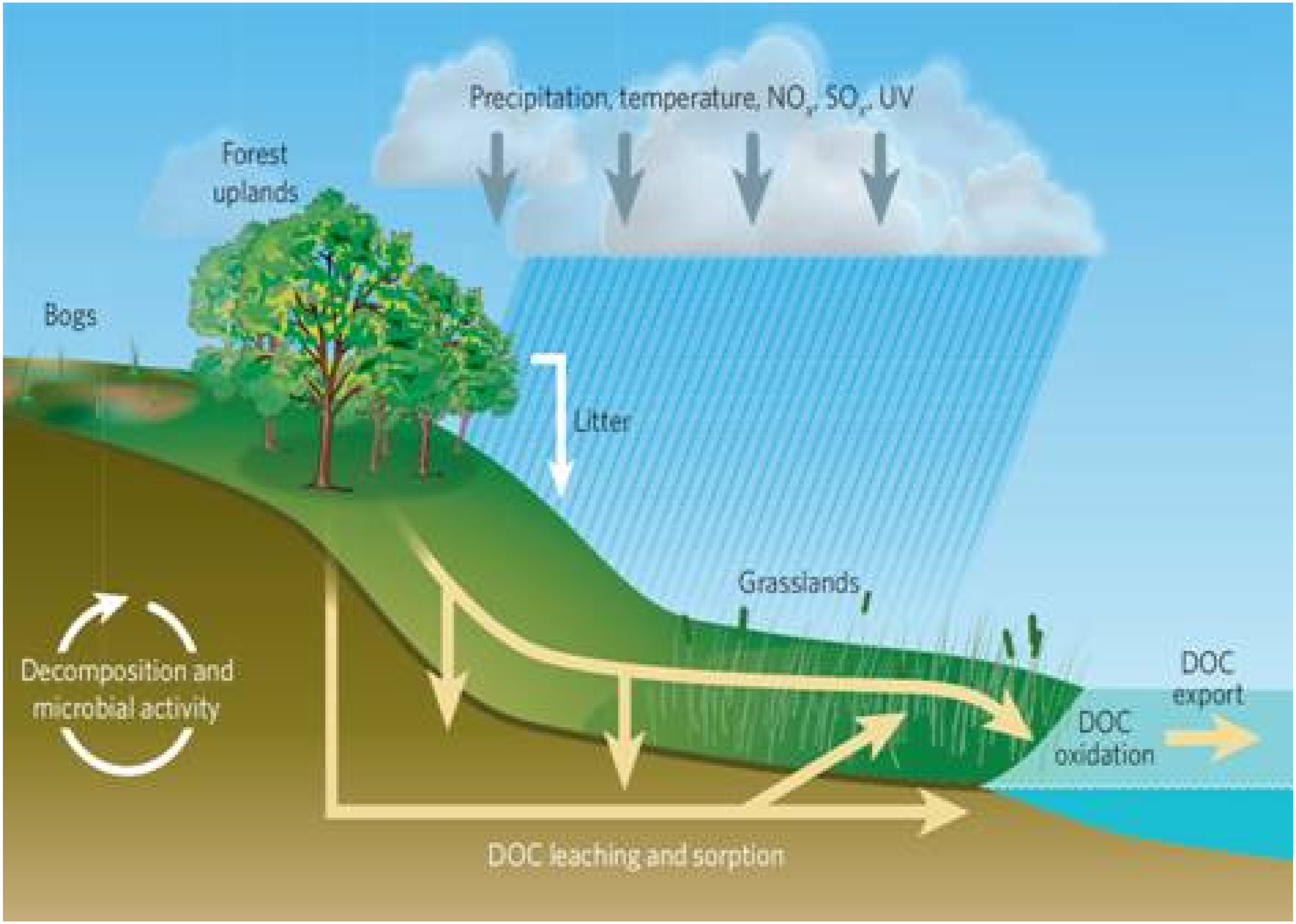
- **Uncertainties** in figures?
- Boreal (and temperate) **forest growth**?

Figure 11.1 The present-day global carbon cycle. All pools are expressed in units of 10^{15} g C and all annual fluxes in units of 10^{15} g C/yr, averaged for the 1980s. Most of the values are from Schimel et al. (1995); others are derived in the text.

Potential feedbacks:

- As $[CO_2]$ increases, plant uptake increases
- As global climate changes, vegetation distribution changes, and $[CO_2]$ … changes?

Schlesinger, W.H. 1997. Biogeochemistry: An Analysis of Global Change. Harcourt, Brace and Co., USA: p.359.

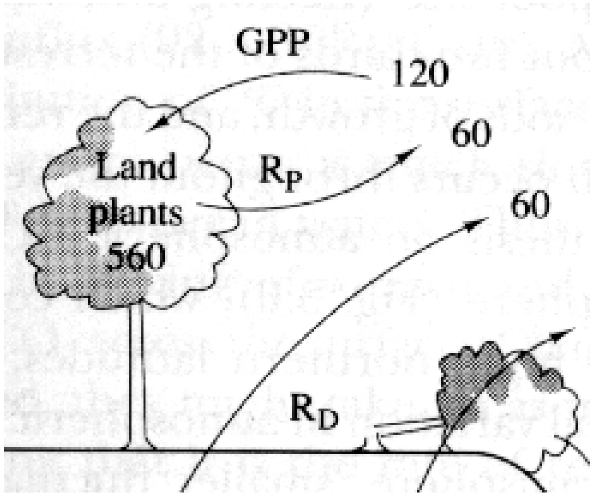


Passage of dissolved organic carbon through the landscape (Roulet & Moore, 2006, *Nature*)

Carbon Cycle of Terrestrial Ecosystems

- To understand what is happening in ecosystems, we can track the **movement of carbon**, from the point of view of a few key processes and concepts:

1. Photosynthesis
2. Respiration
3. Net Primary Production
4. Heterotrophic Respiration
5. Net Ecosystem Production



- Modeling these processes is going to require us to **combine our understanding** of how the abundance of **energy, water, and nutrients** all are factors here

1. Photosynthesis

$$CO_2 + H_2O \xrightarrow[\text{light}]{\textbf{chloroplasts}} CH_2O + O_2$$

- This actually happens in **two** steps
- First, the **chloroplasts absorb the light energy** and break the water into molecular oxygen, electrons and protons:

$$2H_2O \rightarrow 4H^+ + 4e^- + O^2 + \text{Energy} \longrightarrow \begin{matrix}\text{ATP} \\ \text{NADPH}\end{matrix}$$

- Later, these products are used in further reactions to produce carbohydrate in **gross primary production**:

$$\begin{matrix}\text{ATP} \\ \text{NADPH}\end{matrix} \xrightarrow[CO_2]{\text{RUBP}} C_6H_{12}O_6$$

1. Photosynthesis

- There are several **factors** that influence the **rate of photosynthesis**:

1. CO_2 concentration in the atmosphere
2. H_2O availability in the soil
3. Stomatal aperture
4. Nutrient availability (as N, P and others are essential components of the enzymes required)
5. Amount of light absorbed by the leaves

- We can take $[CO_2]$ as **reasonably constant**, and stomatal aperture as a **complex, biologically-mitigated response**, but the other factors depend on resources being available and **used efficiently**

2. Respiration

- **Respiration** is the process that is **opposite** to photosynthesis in plants
- Like any other organism, the **plant metabolism requires energy to function**, and this energy can be obtained through respiration, where **stored carbohydrate is broken back down** to release energy:

$$C_6H_{12}O_6 + O^2 \rightarrow CO_2 + H_2O + \text{Energy}$$

- In general, about **50%** of the carbohydrate produced by photosynthesis is eventually used for plant respiration
- This is also termed **autotrophic respiration (R_A)**, to distinguish it from other types of respiration

3. Net Primary Production

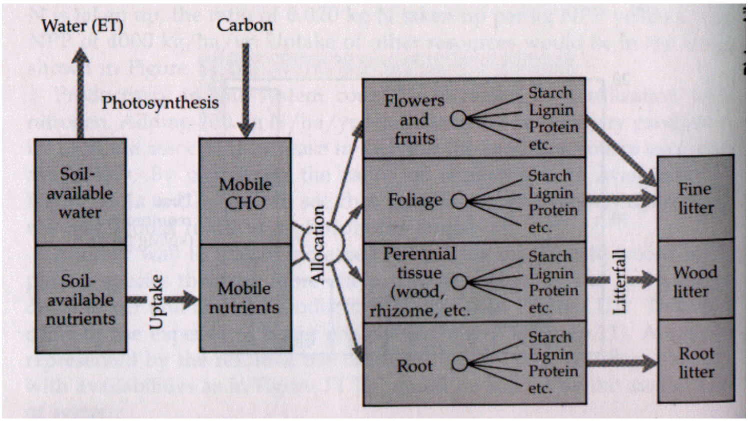
- We can take the **difference** between the **gross primary production (GPP)** that creates carbohydrate through photosynthesis and the amount consumed by **autotrophic respiration (R_A)** to calculate **net primary production (NPP):**

$$NPP = GPP - R_A$$

- Net primary production is not quite a quantity that can be measured directly in the field (by farmers or foresters), because a certain amount of NPP is also **lost through means not accounted for above**, such as through the action of herbivores and death of plant tissues; these factors in models are usually referred to collectively as **litterfall**

3. Net Primary Production

- Terrestrial ecosystem models often concern themselves with figuring out where NPP goes in a plant, i.e. how is it **allocated**:
  - Leaves
  - Trunk and stems
  - Coarse roots
  - Fine roots
  - litterfall



- From an observational point of view, its much **easier to learn about above-ground allocation** of carbon than that below-ground (to gain access to the root mass, you have to disturb the system, so like soil this is a bit of a mystery that is hard to study…)

3. Net Primary Production

- In general, the **allocation of NPP varies** with vegetation type, age of the plant, and availability of nutrients and water in the soil … quite a few factors that plants can respond to in complex ways, but we can make **a few generalizations**:

1. Allocation of **NPP to leaves** is generally greater in shrublands than in forests
2. **NPP to woody tissue** ratios are greater in boreal regions than in the tropics
3. Annual **growth and turnover of root tissues** account for a significant fraction of NPP in most ecosystems

4. Heterotrophic Respiration

- **Litterfall** transfers organic carbon from vegetation to the soil, making it available to other organisms in the ecosystem
- Some of this carbon accumulates in the soil through time, but another portion of it is **consumed by through decomposition** by soil organisms, returning it to the atmosphere as CO_2 through **heterotrophic respiration (R_H)**
- Also produced are H_2O , nutrients, and organic compounds known as **humus**, which comprises the bulk of soil organic matter
- The soil pool of carbon undergoes **rapid turnover** at the **surface**, and **slow turnover** of humus **at depth**

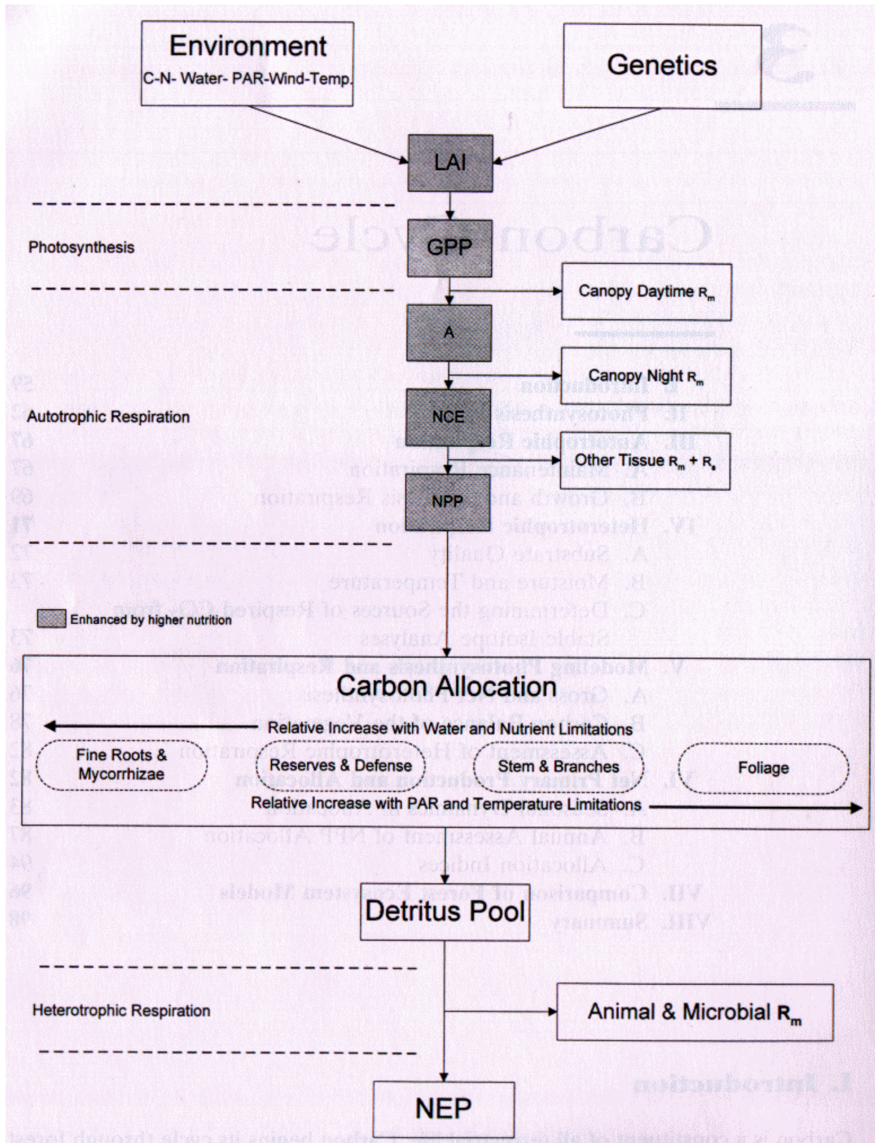
5. Net Ecosystem Production

- We can take the action of heterotrophic respiration into account by taking the **difference** between the **net primary production (NPP)** and **heterotrophic respiration (R_H)** to calculate **net ecosystem production (NEP):**

$$NEP = NPP - R_H$$

- Presuming we have **all the required information** (energy and matter inputs, organism characteristics etc.) we now have covered the **basic concepts** that we would need to construct a model that would simulate NEP, and give a sense of the overall productivity of an ecosystem under a certain set of conditions:

5. Net Ecosystem Production



Waring, RH, Running SW. 1998. <u>Forest Ecosystems: Analysis at Multiple Scales</u>. Academic Press, USA. p. 60.

Project Objectives

- **DOC concentration or flux** to runoff **varies** according to the land's physical biological, climatic and hydrological characteristics, including seasonal productivity and soil properties

1. To investigate what **land surface factors** affect the **variability** of the **DOC runoff rate**?
2. To **accurately estimate DOC flux** at the **sub-basin scale**?
3. To **integrate DOC flux** from the sub-basin scale to the **entire watershed's scale**, and to **route fluxes** to the receiving coastal waters by **considering transport processes**

Applications of the Model

- To examine **seasonal trends** of DOC flux to coastal waters in the last two decades
- To examine percent changes of total annual DOC flux **due to land cover type changes** in the past decade (i.e. the impact of human activities)
- To examine **impacts of climate change** on DOC flux to coastal waters

Components of the Model

SIP: **Mean monthly carbon flux at Milton Dam**

Compartments:

- **Photosynthesis** of land biota (f(x) of veg., LULC)
- **Respiration** of land biota (f(x) of veg., LULC)
- **Soil respiration** (soil types)
- **Plant roots** to the soil (soil types and LULC)

Scenarios:

- Deforestation, clearing, litter fall
- Human activities and natural events

Topographic and Location Factors

- Slope
- Aspect
- Distance (from stream)
- Size (of land-use proportion in sub-basin)

Hydrological Factors

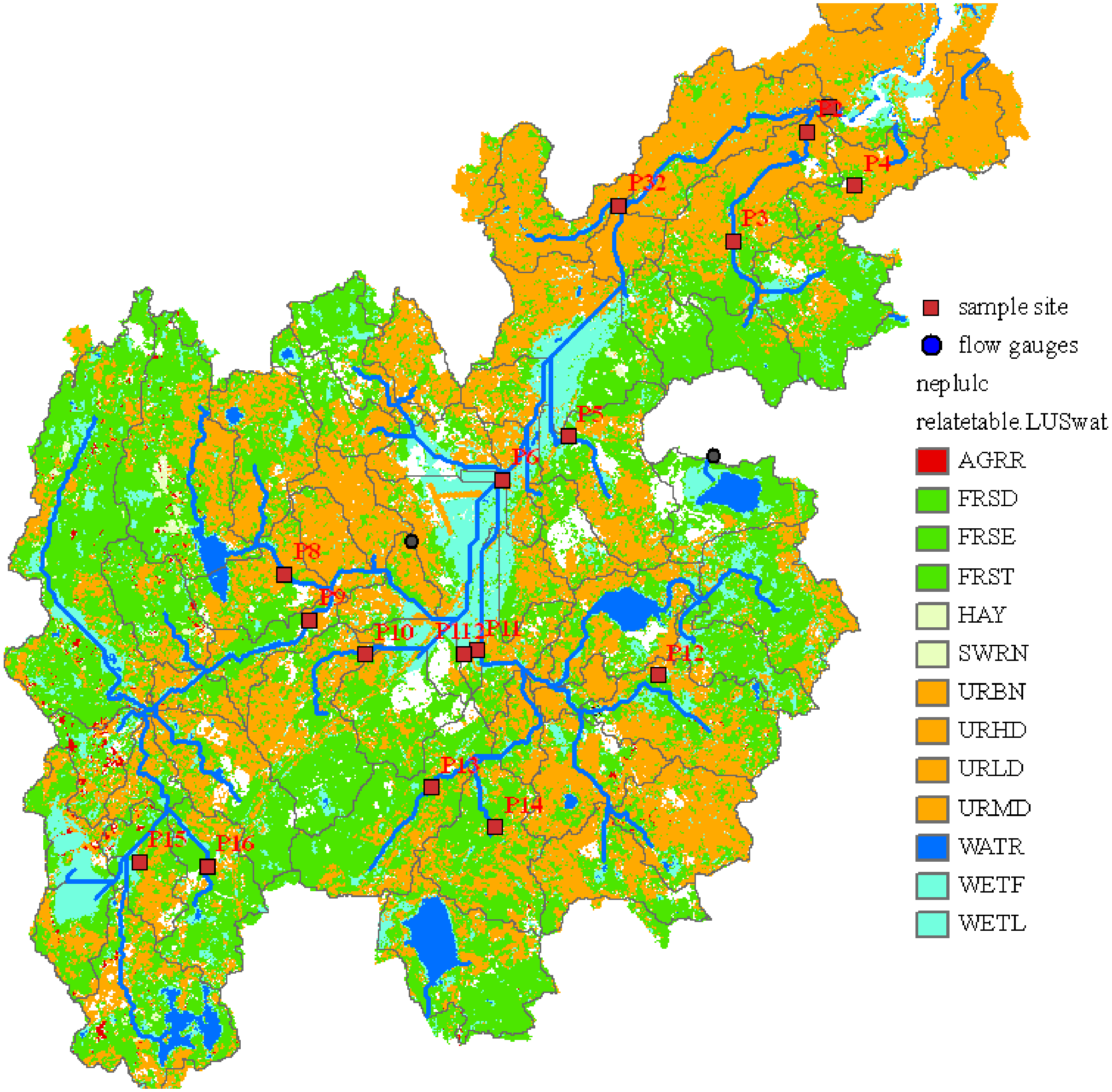
- Precipitation
- Surface runoff production (as volumes)
- Surface flow rate (for routing)
- Sediments

Other Relevant Factors

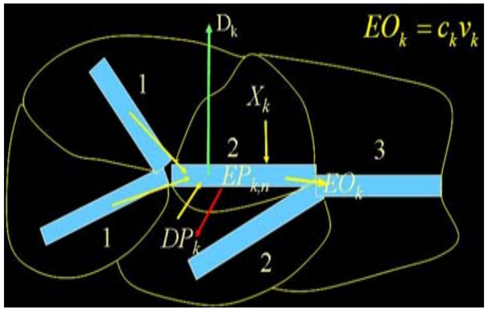
- Climate (in particular, temperature)
- Seasonal Characteristics

Land Cover 2001

- Recalculate % LULC on **sub-basin** basis
- Incorporate **new data** for associated areas
- Use **leaf area index** (LAI) from remote sensing to take into account **seasonal effects**



Productivity?
Decomposition?



DOC flux/mons — flow * mean concentration

Transport processes

DOC flux at sub-basin — flow * mean concentration

Land cover | Seasons | Hydro | Soil | Topo

- Land cover ← Wa, F, A, B, D, Wet
- Seasons ← LAI ← Climate
- Hydro ← Flow/volume
- Soil ← Windsor, Woodbridge, Montauk, Rock outcrop, Urban land, Water
- Topo ← Size, Distance, Slope, aspect

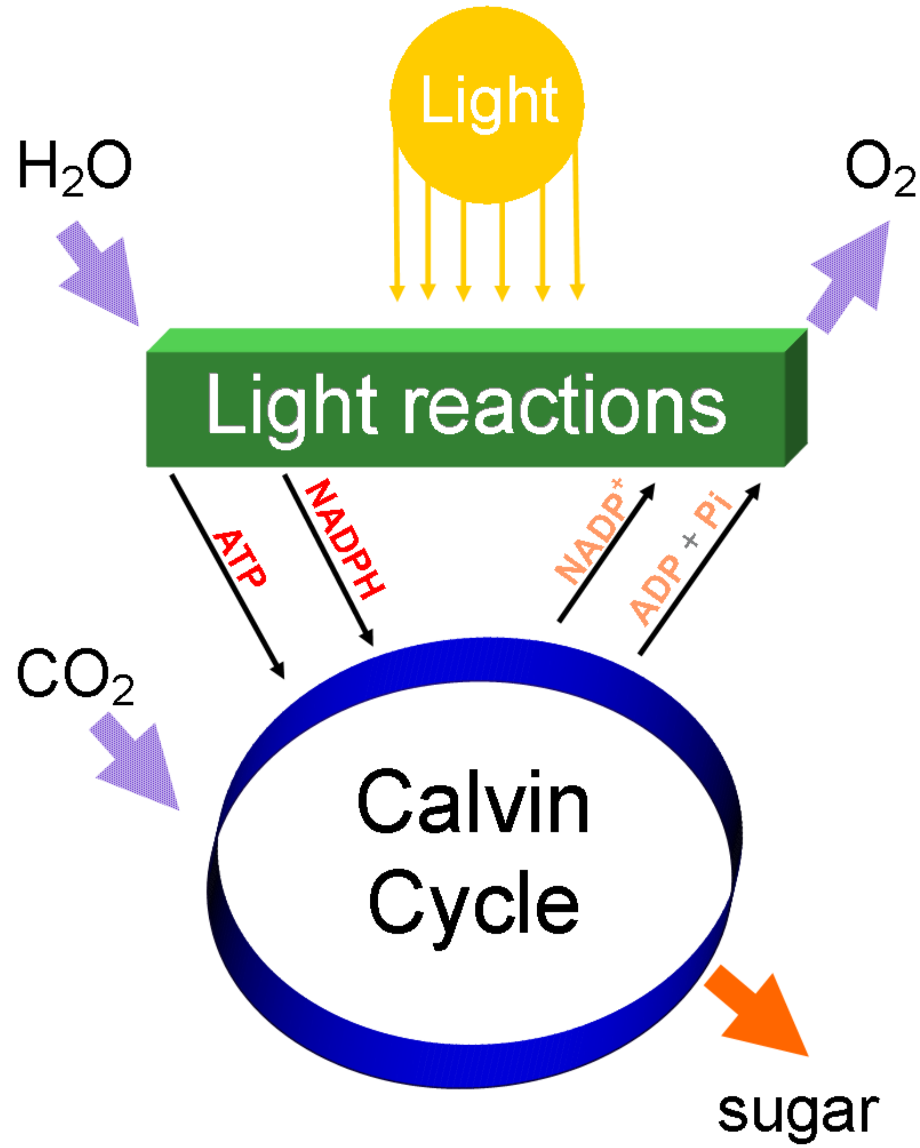
flux is defined as the amount that flows through a unit area per unit time

http://www.epa.gov/mrlc/definitions.html

LAI is the ratio of total upper leaf surface of vegetation divided by the surface area

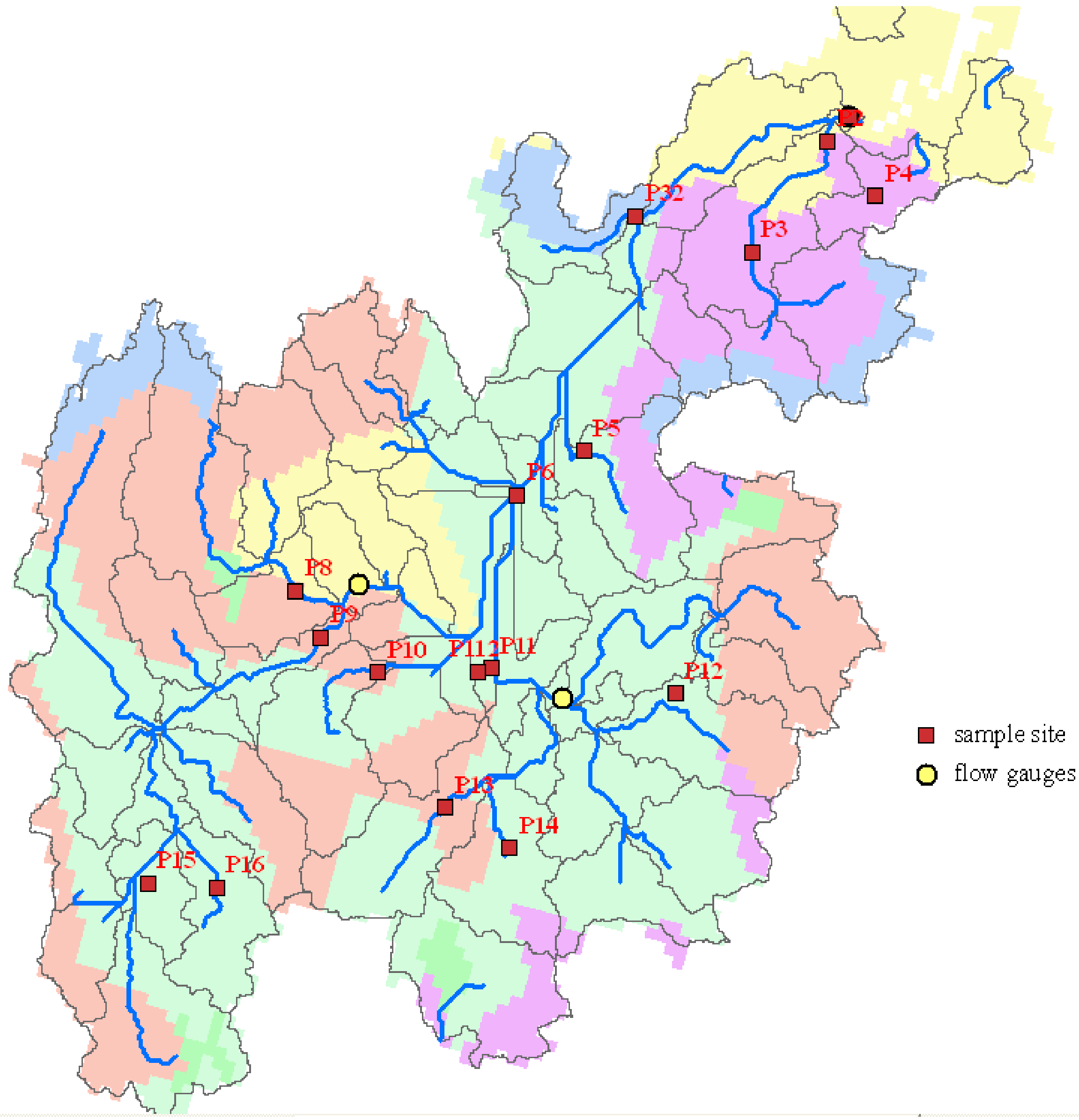
Photosynthesis

- The **conversion** of **light energy** into **chemical energy** by living organisms
- The **raw materials**:
  Carbon dioxide and water (plus sunlight)
- The **end-products**:
  Oxygen and (energy rich) carbohydrates



Soil Types

- **Correlate** soil with DOC samples
- Identify the **dominant and %** of soil types **per sub-basin**
- Also identify **adjacent** soil types



Explore Other Important Variables

- Hydrological processes
- Soil types
- Distance to outlet
- Dominant land cover
- LAI
- Scale (size) of the sub-basin
- Sediment

Some Definitions of C

- **Total Carbon (TC)** – all the carbon in the sample, including both inorganic and organic carbon
- **Total Inorganic Carbon (TIC)** – often referred to as inorganic carbon (IC), carbonate, bicarbonate, and dissolved carbon dioxide; a material derived from non-living sources.
- **Total Organic Carbon (TOC)** – material derived from decaying vegetation, bacterial growth, and metabolic activities of living organisms or chemicals.
- **Non-Purgeable Organic Carbon (NPOC)** – commonly referred to as TOC; organic carbon remaining in a sample after purging the sample with gas.
- **Purgeable (volatile) Organic Carbon (POC)** – organic carbon that has been sparged or removed from a sample.
- **Dissolved Organic Carbon (DOC)** – organic carbon remaining in a sample after filtering the sample, typically using a 0.45 mm filter.
- **Suspended Organic Carbon** – also called particulate organic carbon (PtOC); the carbon in particulate form that is too large to pass through a filter.

Further Investigations

- Search for information on **factors** affecting **DOC losses in runoff**
- Search for information on DOC **concentration / ratio / weight factors** in runoff from **different land covers**