Response of Forests to Climate Change and the Importance of Intensive Forest Monitoring

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Importance and Justification of Long-Term Monitored Plots in Forest Ecosystem Studies

Long-term studies in ecology have some advantages that cannot be substituted with short-term approaches. A brief review of these advantages will make it more clear.

Classes of ecological phenomena for which long-term studies are recognized as essential include:

1. **Slow Processes.** Many ecological processes in forests take over relatively long time periods. Examples are population dynamics and growth of trees, changes in soil properties.

2. **Episodic phenomena.** Any ecological phenomena with a return of more than a few years falls into this category. Examples are excessive seed production or disturbance patterns like drought or wildfires. These events can be exciting for scientists but short term approaches cannot interpret their importance for ecosystem development.

3. **High variability of ecological processes**. Examples are high fluctuations in litterfall production over time. These phenomena are due to the links between biological and physical parameters.

4. **Subtle processes and complex phenomena**. Subtle processes and complex phenomena require long-term studies in order to separate pattern from "noise". Subtle processes are those that are changing over time but in which year-to-year variance is large compared to the magnitude of the trend. Examples include changes in the acidity of rainfall and changes in the level of nutrient losses of an aggrading forest ecosystem

Are the Climatic Change Effects on Forests of Such Nature that Demand Long-Term Monitoring?

The answer is an unreserved **Yes**. Over thousands of year forest trees have established complex relationships with the abiotic and biotic environment and short tem experiments or simple correlations between two variables can be of little avail.

How can the intensively monitored plots help to reveal the effects of CO_2 enrichment on forests?

Before we answer this question it is necessary to make a brief review of what science knows, what it does not and what intensively monitored plots can offer

1. **Plant Growth**. Photosynthesis is enhanced by elevated atmospheric CO_2 so as above ground growth biomass. It is not known if growth can continue or can be offset by nutrient limitations.

In the intensively monitored plots growth is measured in 5 years time or continuously with girth bands.

The soil nutrients were determined in the intensively monitored plots in 1995 and 2007 surveys. A new survey can be carried out in 10 years time. Weathering rates have not so far been calculated. This can be done through modeling. Also the budgets of cations can be calculated through hydrological modeling

2. **Nutrient Cycling**. The quantity of litterfall will increase and the N level in foliage and litter will decrease. It is not known how nutrient mineralization will change due to the higher quantity of CO_2 in soils.

In the intensively monitored plots litterfall is monitored. Also the concentrations of N in foliage and litterfall is determined.

Nitrogen (as well as C) mineralization can be measured in the future in situ with litter bags, a simple and accepted method.

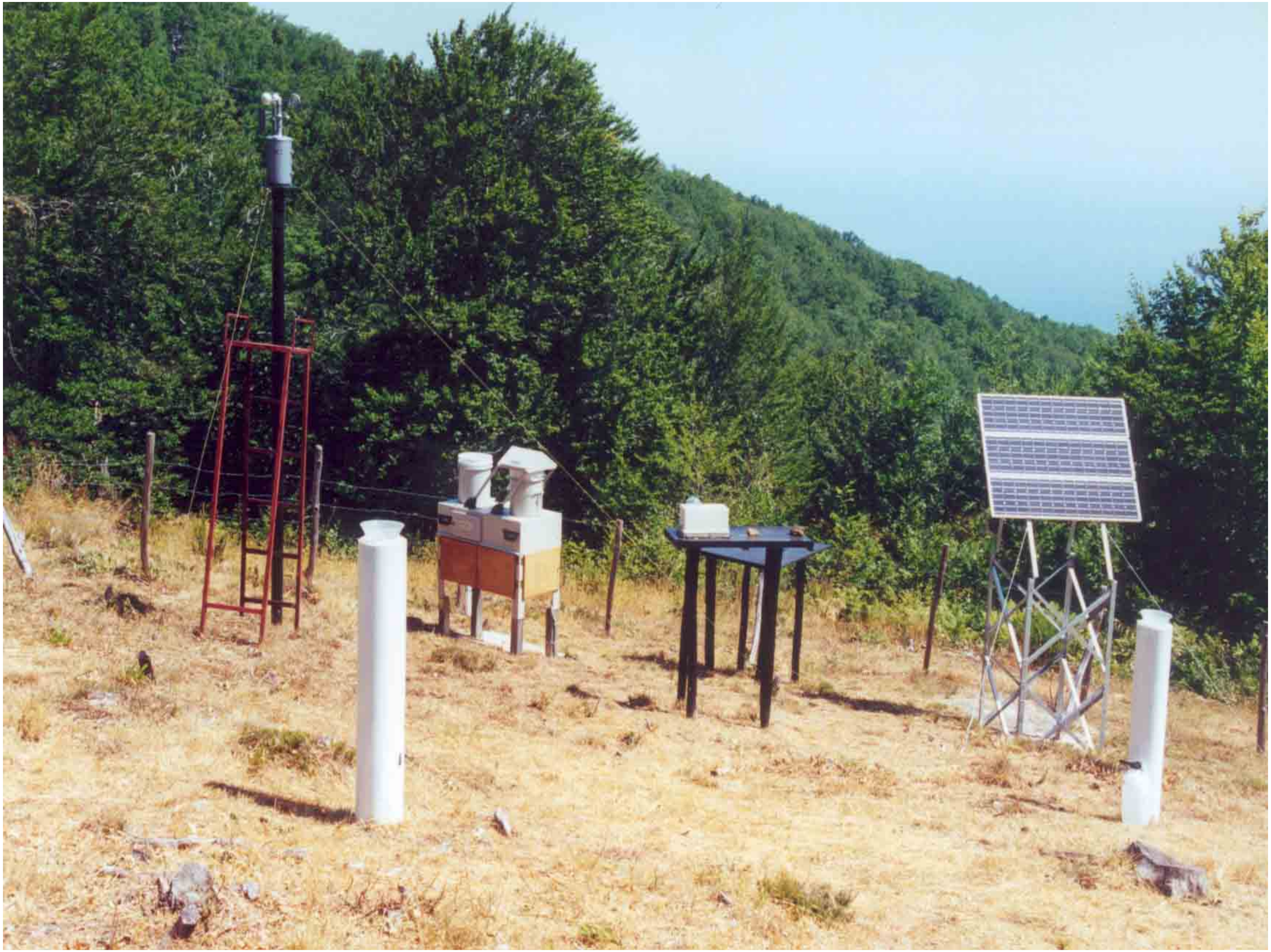
3. **Water Balance**. Long term studies of forest trees have shown a significant decrease in stomatal conductance. The question is that if tree biomass increases will the trees use more or less water even if stomatal conductance decreases.

In the intensively monitored plots the hydrological cycle is measured continuously so conclusions can be drawn in the near or long future.

4. **Phenology**. Elevated atmospheric CO_2 concentrations affect the phenology of budbreaks and bud set, flowering time, leaf senescence and drop as well as branch and shoot development rates.

Another new aspect is that climate change will alter the composition and population of mycorhizal fungi. A new phenological observation seems to be appropriate here.

The intensively monitored plots have had a quite a good record of phenological observations. The simple monitoring of mushrooms (by experts) can disclose valuable information.

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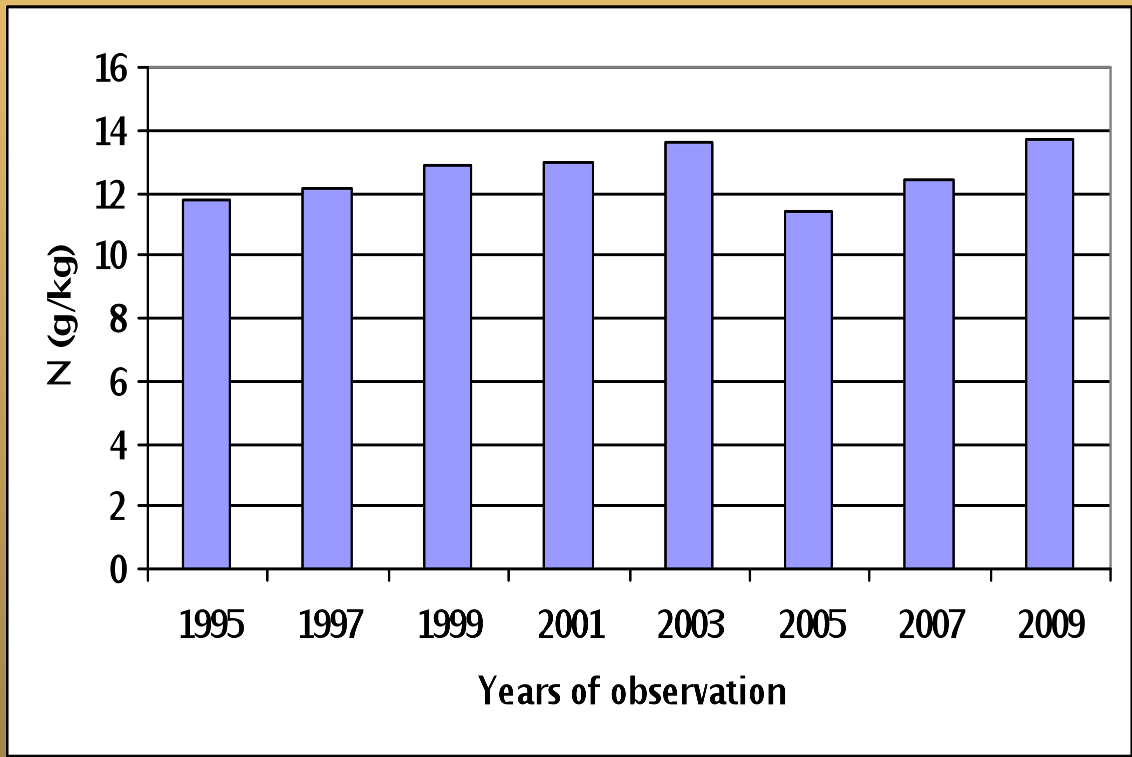
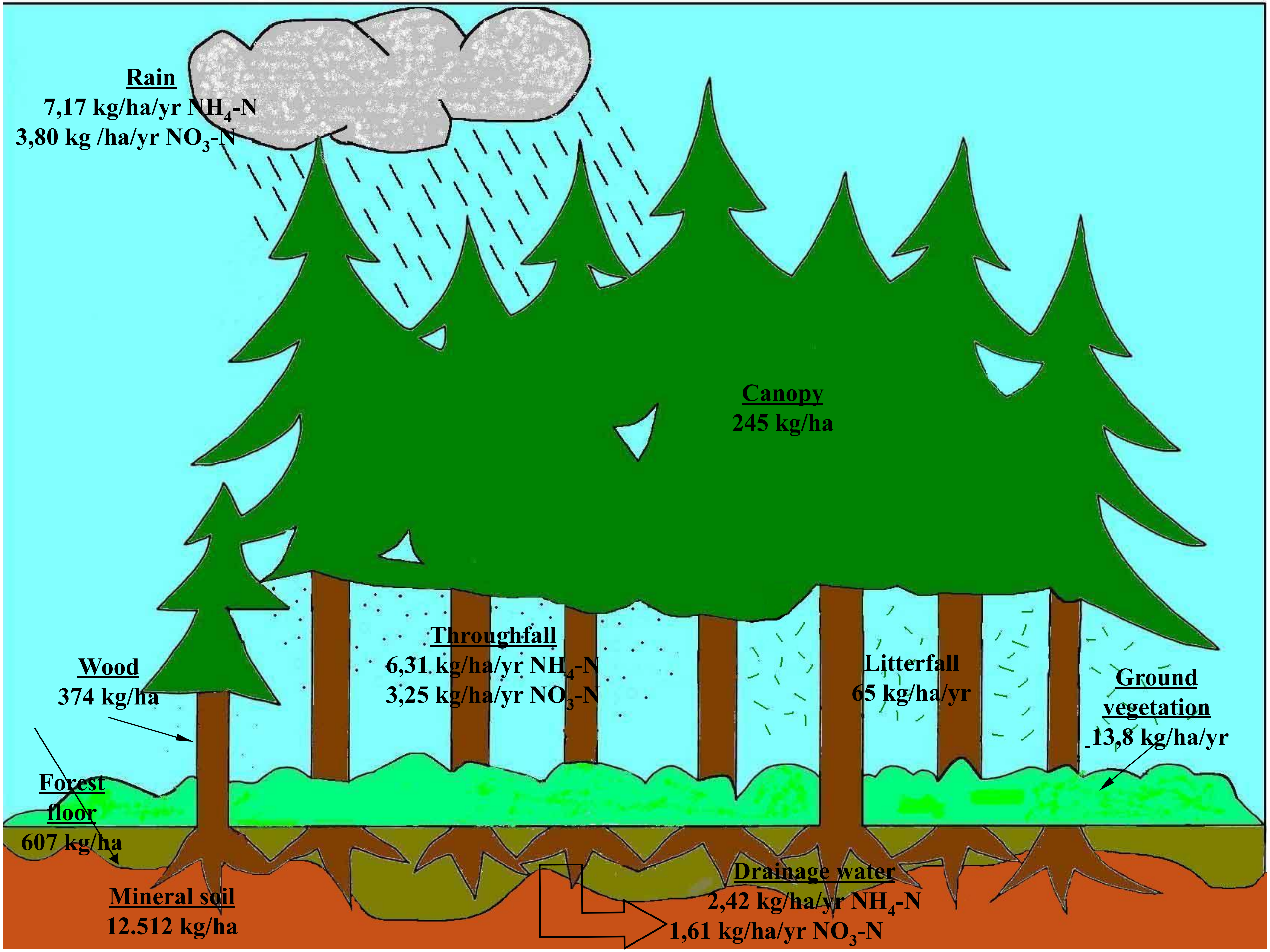
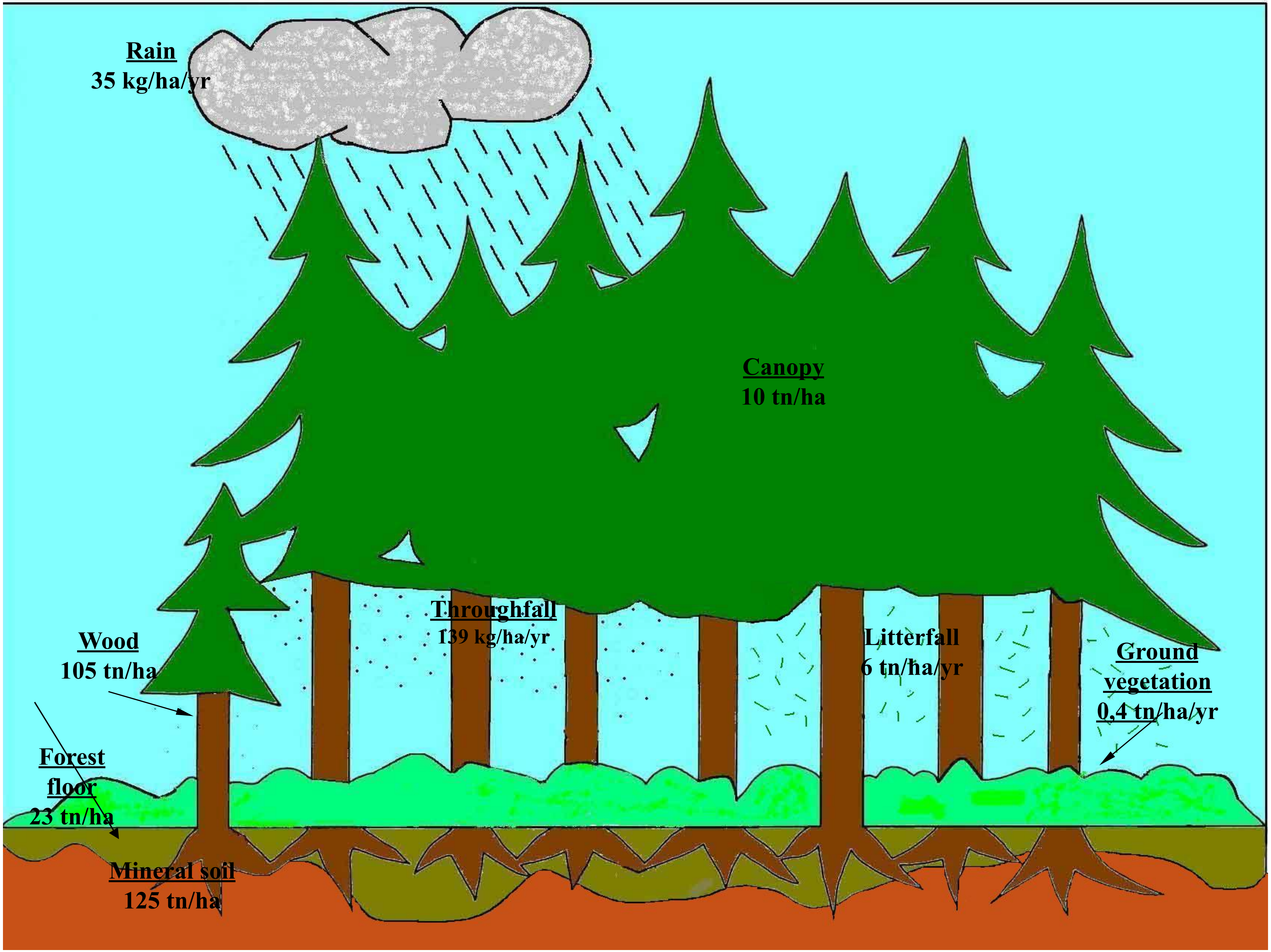
Concentrations (g/kg) of N in current year needles of fir trees in one intensively monitored plot in Greece




Rain
7,17 kg/ha/yr NH_4-N
3,80 kg /ha/yr NO_3-N
Canopy
245 kg/ha
Throughfall
6,31 kg/ha/yr NH_4-N
3,25 kg/ha/yr NO_3-N
Wood
374 kg/ha
Litterfall
65 kg/ha/yr
Ground
vegetation
13,8 kg/ha/yr
Forest
floor
607 kg/ha
Mineral soil
12.512 kg/ha
Drainage water
2,42 kg/ha/yr NH_4-N
1,61 kg/ha/yr NO_3-N



Rain
35 kg/ha/yr
Canopy
10 tn/ha
Throughfall
139 kg/ha/yr
Litterfall
6 tn/ha/yr
Wood
105 tn/ha
Ground
vegetation
0,4 tn/ha/yr
Forest
floor
23 tn/ha
Mineral soil
125 tn/ha

A Daring Suggestion

Belowground Carbon Allocation. Allocation of C to belowground plant structures often equals or exceeds aboveground litterfall-C and aboveground respiration in forest ecosystems making it the single most important fate for gross primary productivity.

Despite its importance, total belowground allocation (TBCA) remains poorly quantified because it is difficult to quantify root and mycorrhizal processes by any method.

In the absence of direct measurements of TBCA
Raich and Nadelhoffer (1989) proposed the following equation:

TBCA = Soil respiration C – Aboveground Litterfall C

Where soil respiration = Rroot + root litter C decomposition
+ aboveground litter C decomposition

A critical assumption of this approach to estimate TBCA is that that the ecosystem is at a steady state which means that the annual inputs of C below ground are equal to annual rates of decomposition

If the system is not at a steady state the previous equation becomes:

TBCA = Rsoil – litterfall C + ΔlitterC + Δsoil C+ ΔrootC + export C in soil solution

Where Δsoil C, ΔlitterC , ΔrootC are the changes in C stocks of mineral soil, forest floor and root biomass respectively and export is C loss through leaching.

From the above equation the parameters Rsoil, litterfall C and export can be measured continuously in the intensively monitored plots. Δsoil C and ΔlitterC can be measured in the following soil survey and compared with the survey in 2007.

Δroot can be calculated from a relationship between ABD (aboveground biomass density) in Mg/ha and RBD (root biomass density) also in Mg/ha.

Cairns et al. (1997) used the equation:

$$RBD = exp\{-1085 + 0.926\, Ln(ABD)\}$$

The above equation was used in 160 studies covering tropical, temperate and boreal forests.

Another important aspect is that when soil survey takes place again in 10 years time the total soil C must be split into labile a stable forms. This is very important as the incorporation of C into soil biomass depends on the form that C takes over time

CONCLUSIONS

1. The intensively monitored plots have all the qualifications to become the main sites for monitoring C dynamics in European forests. The activities carried out in the FutMon project should continue as they are.

2. Some new activities have to be added in order to have a clearer picture. Briefly these are:

   A. Calculation of soil weathering rates

   B. Nitrogen and organic C mineralization rates

   C. Soil respiration measurements (Maybe)

D. The phenological observations should include mycorrhizal fungi.

E. The soil survey must be repeated. Ten years can be the minimum time required. In the next survey the total organic C should be split into labile and stable forms provided that the same analysis is carried out in the old samples which must be kept in store.

Finally a **note** for the EU. If such projects are not funded Europe will lose a most valuable bank of information.

Every year the data derived from the intensively monitored plots are requested for various projects. Models projecting forest functions in the future can be perfected through continuous validation.


Thank you for your attention