Net Primary Production (NPP) estimates with resource to Forest-BGC and Krikagem methodologies

Previous work and research lines

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Outline

Motivation

- Collaboration with Prof. Domingos Lopes and Prof. Leonia Nunes from the Universidade de Trás-os-Montes e Alto Douro, Dept. Forestal, Vila Real, Portugal.
- Monitoring climate change impact on natural ecosystems.
- Net Primary Production (NPP) is the key variable for a wide range of ecological studies.
- Results will allow to apply the studied methodologies at a regional/global scale studying the impact of climate change on the forest ecosystems.

Work overview

- Compare methodologies for NPP estimates in Eucaliptus stand by:
  - Conventional method.
  - Forest-BGC.
- Error analysis to better understanding in order to provide a correction method and get even more accurate NPP estimations.

Outline

Greenhouse effect

- The carbon content of the atmosphere is less than the cumulative input from fossil fuel combustion and any additional sources as a result of carbon exchanges between the atmosphere and other reservoirs (oceans and terrestrial ecosystems).
- The "greenhouse effect" may lead to significant changes in the earth's climate if there is a substantial increase in the concentrations of CO_2 and other greenhouse gases.

Climate change prediction

- In order to be prepared for climate changes we need some means to predict how different ecosystems will be affected.
- The only practical means of making this estimate on a global scale would be the regular coverage of world vegetation by satellite.
- The net flux of carbon between the atmosphere and terrestrial vegetation can be expressed on an annual basis in terms of net biomass accumulation or Net Primary Production (NPP).

Remote sensing (RS) and ecophysiology

- The linkage of RS and ecophysilogy provides a spatially explicit means to monitor short-term variations in photosynthetic capacity.
- It also will largely expand the applications of ecophysiological models, capable of estimating NPP.
- These kind os studies, implying global phenomena, can only be analysed at these scales by means of RS data.

Outline

NPP Definition

- NPP can be defined as the time integral of the positive increments to plant biomass.
- NPP is the central carbon related variable summarizing the interface between plant and other processes.
- In a local scale, it can be measured in terms of either biomass or CO_2 exchange.

Measurements based on biomass data

Measurements based on biomass data

$$NPP = b_{t+1} - b_t + L_{t+1}$$

- where:
  - b_t and b_{t+1} are the plant biomass at the beggining and end of the measurement interval.
  - L_{t+1} is the new litter produced during the interval.
- Litter production, in adidition to the shedding of leaves and branches, should include root turnover and exudation.
- This approach should also consider consumption of organic matter by hervibory (generally less than 10% in forest, can be about 50% durig insect out break).

Measurements based on terms of gas exchange

Measurements based on terms of gas exchange

$$NPP = GPP + R_a$$

- where:
  - GPP (Gross Primary Production) is the carbon fixed during photosynthesis.
  - R_a is the autotrophic respiration.
- GPP and R_a have opposite signs.
- Measurements based on gas exchange are complicated by the fact that it is very difficult to measure either GPP or R_a in isolation.

NPP variables

- NPP is sensitive to a many controls, including aspects of climate, topography, soils, plant and microbial characteristics, disturbance regime and anthropogenic impacts.
- In forest ecosystems, NPP is usually higher in young stands that are accumulating biomass than in mature stands near steady state.

Outline

Ecofisiological models

- Models are an important tool for both, understanding ecosystem function and predicting responses to global change, and they can summarize the results of many experiments by incorporating hypotheses and conclusions into a quantitative framework.
- Understanding how climate and vegetation influence the biogeochemistry of ecosystems will allow us to make predictions about how global change will affect forests.

Ecofisiological models (cont.)

- Models differ in time scale, linkages between C, N and H_2O, representation of heterogeneity, and detail of photosynthesis, allocation, and descomposition submodels.
- These simulation models can be thought of as different syntheses of our understanding of what controls element cycling within ecosystems, and it can be used to explain and predict plant responses to the environment.

The Forest-BGC model

- The Forest-BGC (Bio Geochemical Cycles) was developed by Running and Coughlan on 1998.
- Forest-BGC calculates key processes involved in the carbon, nitrogen and water cycles in forest ecosystems.
- The model treats variable link: canopy interception and evaporation, transpiration, photosynthesis, growth and maintenace respiration, carbon allocation above and below ground, litter fall, decomposition and nitrogen mineralization mechanistically, but incorporating minimal species-specific data.

Model's inputs

- The model has a mixed time resolution, with hydrologic, photosynthetic and maintenance respiration processes computed daily, and the other carbon and all nitrogen processes computed yearly.
- It was conceived to be completed with inputs of remote sensing.
- There are a hundred variables of input required for the functioning of the model.

Leaf Area Index (LAI)

- The leaf area index (LAI), which represent the ratio of leaf area per unit ground area, is probably the most important independent variable used by the model for measuring vegetation structure over large areas.
- It's related to energy and mass exchange and for calculating canopy interception, transpiration, respiration, photosynthesis, carbon allocation and litter fall.
- Most ecosystems process models that simulate carbon and hydrologic cycles require LAI as an input variable.

LAI measure

- In the Forest-BGC, LAI is calculated by the following equation:

$$LAI = \frac{specific\ leaf\ area * leaf\ carbon}{ground\ surface\ area}$$

- Another approach is to obtain it by remote sensing data.

Aim of the study

Forest-BGC study target

The aim of this study was to develop a method for quantifying the NPP in forests ecosystems at regional/global scale, using the Forest-BGC, a very important ecophysiological model, using as input the Leaf Area Index (LAI) estimated by LANDSAT TM images.

Outline

Study area

- 31 samples of Eucalytups globules where established in the localities of Amarante.
- The results are related to general measurements, wich include structural variables.
- The dendrometric measurements were taken in order to characterise each stand in terms of density with the actual stock (volume per hectare) and also individual parameters (average diameter, height and volume).

NPP Estimation

- NPP values were estimated by two methods:
  - From a traditional inventory method, using allometric equations used as reference values ("observed NPP").
  - From the ecophysiological model Forest-BGC ("Forest-BGC NPP").

Observed NPP

- Observed NPP was estimated using allometric equations, using data from field measurements and adding the individuals NPP calculations for stem, crown (leaves and branches), roots, litterfall and shrubs.
- All trees inside each sampling plot were measured at two different moments in time, and shrubs biomass and litterfall were also measured between the same gap of time.
- Direct estimates of LAI and NPP can be obtained by harvesting individual plants, developing allometric equations or using equations already adjusted to stand diameter data, aplying these equations to all individuals in the stand.

Forest-BGC NPP

- Forest-BGC requires daily climate data and also one input file with data from each study site.
- For this study, the input file with data from each stand was kept constant changing only the LAI for each sample plot.
- The model should be run as many times as sampling plots we have.
- The annual output of this model gives us the Gross Primary Production (GPP) and the autotrophic respiration (R_a) values to get the NPP values.

Forest-BGC problem

The problem

The major limitation of this approach is that we need to repeat the commands for each sampling plot, changing the LAI value for each in the input file. One of the major goals of the entire research will be the automation of the procedure in order to obtain a more practical methodology and to get automatic NPP maps.

Summary

- Net Primary Production (NPP) is a key variable for measuring climate change impact on forest ecosystems.
- Reliable models are needed for estimating NPP over regional/global areas.
- Remote sensing should be need for regular coverage of global vegetation.

- Outlook
  - Implement an automatic NPP estimation process by the use of Forest-BGC.
  - Use of Krigaggem techniques to estimate NPP maps by the use of a few observed NPP data.

For Further Reading I