Net Primary Production (NPP) measures of forest ecosystems in the North of Portugal

Collaboration project with Universidade de Tras-os-Montes e Alto Douro (Portugal)

Miguel A. Veganzones

Grupo Inteligencia Computacional
Universidad del País Vasco

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Outline

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Greenhouse effect

- 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 ecophysiology 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.

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 outbreak).

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

Ecophysiological 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.

Ecophysiological 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 1988.
- 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.

Model's inputs

- The model has a mixed time resolution:
  - Daily: incoming short-wave radiation, air temperature, dew point, precipitation.
  - Annually: other carbon and all nitrogen processes.
- 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) represents the ratio of leaf area per unit ground area.
- It 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.
- Key simplification for regional/global-scale applications.

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 (i.e: MOD15 product).

Spatial scales

- Many of the most pressing ecological questions address ecosystem processes at regional to global scales:
  - Global climate change.
  - Global CO_2.
  - Regional air pollution.
  - Regional shifts in vegetation cover.
- Most ecosystem process models have been built from and used to simulate the dynamics of study plots.

Advantages

- Calculate key processes involved in the C, H_2O, N_2 cycles for forest mechanistically but incorporating minimal species-specific data.
- Compromise allowing it to be implementes for regional/global-scale ecological research.
- Designed to be driven ultimately by RS inputs of surface climate and vegetation structure.

Final objective

- Evaluate the relative importance of general enviromental factors in explaining the regional variations in hydrologic and carbon partitioning, predicted for forests in different environments.

Outline

Departamento de Ciências Florestais e Arquitectura Paisagista

http://home.utad.pt/~floresta/

- Universidade de Trás-os-Montes e Alto Douro (Vila-Real).
- Team: 25 people (17 PhDs).
- Grads:
  - 1º Ciclo: Engenharia Florestal: Arquitectura Paisagista.
  - 2º Ciclo: Engenharia Florestal: Arquitectura Paisagista e Sistemas de InformaÇao Geográfica.
  - Collaborations: grads of Ecología Aplicada, Engenharia Ambiental, Engenharia Zootécnica, Engenharia Agronómica, Turismo.

Departamento de Ciências Florestais e Arquitectura Paisagista I

http://home.utad.pt/~floresta/

- Research:
  - Qualidade dos Produtos Florestais, Dendroclimatologia e Biocombustíveis.
  - Melhoramento genético de plantas florestais com recurso a técnicas tradicionais e biologia molecular.
  - Estudo das espécies florestais, sua selecção e adaptação às alterações climáticas.
  - Inventário e Planeamento florestal e Ordenamento florestal.
  - Protecção florestal com a monitorização por detecção remota de pragas e doenças.
  - Ecologia do fogo; Modelação de combustíveis e do comportamento do fogo; Prevenção florestal activa aos fogos florestais; Fogo controlado; Resilência dos ecossistemas.

Departamento de Ciências Florestais e Arquitectura Paisagista II

http://home.utad.pt/~floresta/

- Relações entre Floresta, Fogo e Pastoreio; Efeitos do Pastoreio na Gestão do Coberto Vegetal, Biomassa, Prevenção de Incêndios e na Regeneração Natural Arbórea.
- Inventários faunísticos; Caracterização ecológica; Avaliação de prejuízos; Estudos de reprodução.
- Monitorização ambiental; Ordenamento piscícola; Recuperação de habitats fluviais; Estabelecimento de índices e modelos que integram e prevêm os efeitos antropogénicos cumulativos.
- Vegetação em Arquitectura Paisagista; Jardins Terapêuticos.
- Planos Regionais de Ordenamento do Território; Projectos de Recuperação de Áreas Verdes.

Contact with UTAD

- Prof. Dr. Domingos Mendes Lopes (Assistant Professor in UTAD).
- Prof. Leonia Nunes (Assistant Professor in IPV).

Other contacts

- Prof. Dr. Stith Tom Gower:
  `http://forestecology.forest.wisc.edu/gower.html`
  - Professor of Forest Ecosystem Ecology, University of Wisconsin-Madison.
  - Part of MODIS team.
- "Pensar (e investigar) os Povamentos Mistos em Portugal" group.
  - PTDC/AGR-CFL/68186/2006.
  - Margarida Liberato (UTAD).
  - Margarida Tomé (ISA).
  - Maria do Sameiro Patrício (IPB).
  - Paulo Godinho (INRB).
  - ...

Other contacts

Outline

Motivation

- Estimate Net Primary Production (NPP) for forest ecosystems in the North of Portugal using remote sensing (RS) data.
  - NPP is directly related to Carbon fixation -> Climate Change (Kyoto protocol).
  - Regional (LandSat ETM+) / Global (MODIS) scales.
- Current approaches:
  - In-field meassures: accurate, high cost, impossible for large areas.
  - Ecophysiological models (i.e.: Forest-BGC): well defined but complex, lot of variables (some of them given by RS data), suitable for large areas.
- New approach:
  - Infer NPP values directly from RS data using computational intelligence methods: suitable for large areas, "simple" approach (few data needed).

Specific goals

- Compare:
  - Ecophysiological models respect to in-field data (groundtruth):
    - Forest-BGC.
    - Biome-BGC.
    - Direct inference.
  - Sensor spatial resolutions:
    - MODIS: 1km^2.
    - LandSat ETM+: 30-60m^2.

NPP estimates I

- NPP_1: using MODIS Net Primary Production product (MOD-17).
  - Coarse spatial resolution ($1km^2$).
  - Uses Biome-BGC.
- NPP_2: using MODIS Leaf Area Index (LAI) and Fractional Photosynthetically Active Radiation (FPAR) product (MOD-15) as input to Forest-BGC model.
  - Coarse spatial resolution ($1km^2$).
  - Uses Forest-BGC.
- NPP_3: infer NPP values directly from LandSat ETM+ data using in field meassurements as training data for computational intelligence methods.
  - Medium spatial resolution ($30m^2$).

NPP estimates II

- Uses computational intelligence methods.

- NPP_4: using LandSat ETM+ data to calculate Leaf Area Index (LAI) values as input to Forest-BGC model.
  - Medium spatial resolution ($30m^2$).
  - Uses Forest-BGC.

- NPP_5: using LandSat ETM+ data to calculate Leaf Area Index (LAI) values as input to Biome-BGC model.
  - Medium spatial resolution ($30m^2$).
  - Uses Biome-BGC.

Important dates

- 10 Oct.: Jornadas Inteligencia Computacional - Vitoria'09.
  - Forest-BGC and Biome-BGC review.
  - Project specification document.
- 15 Oct.: Silva Lusitana journal deadline (Portuguese national journal).
  - Forest-BGC reimplementation paper.
- 30 Oct.: NPP_1, NPP_2, NPP_3 estimates.
- 30 Nov.: NPP_4, NPP_5 estimates and preliminary results.
- 15 Dec.: Final results and paper draft.

Current projects

- Kriging biomass data:
  - Prof. Helder Viana (PhD. Student), Prof. Dr. Domingos Lopes.
- Forestry image classification:
  - Mr. Pedro Gomes, Prof. Dr. Domingos Lopes.

Future projects

- Use of hyperspectral imagery.
- Work with mixed stands.
- Climatology aspects.
- International conference in Portugal (2010).
- European project.

¿Preguntas?

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- Contacto:
  - Miguel Angel Veganzones
  - Grupo Inteligencia Computacional
  - Universidad del País Vasco (UPV/EHU)
  - E-mail: miguelangel.veganzones@ehu.es
  - Página web: http://www.ehu.es/inteligenciacomputacional