Modelling ecosystem responses to climate change

Introduction and aims

In this exercise you will pose a question regarding potential future changes in vegetation patterns and ecosystem functioning in a biome or climate zone of your choice. You will then attempt to answer, or at least shed further light on, your question by performing simulations with a dynamic global vegetation/ecosystem model. You may use your results as the basis for a discussion of possible implications of change in terrestrial ecosystem functioning for coastal areas affected by runoff from your system.

Questions, resources and approach

- Work in groups of 2-3 students
- The model, LPJ-GUESS, is able to simulate the potential natural vegetation composition and ecosystem biogeochemical exchange anywhere on Earth under present climate conditions and under a simple future climate+CO_2 scenario. **Formulate a question** that can be approached by 2-3 simulations with the model in a biome or climate zone of your choice. Examples:
  - How will climate change affect carbon cycling in the northern boreal region compared with the southern temperate region of the Baltic Sea catchment area?
  - What are the independent and combined effects of rising temperature and atmospheric CO_2 concentrations on net primary production in my home region?
  - How will increasing rainfall affect heterotrophic respiration and runoff (the main drivers of DOC export) compared with decreasing rainfall?
- **Scenarios:** Your question probably requires you to define one or two scenarios in terms of changing mean temperature, precipitation and/or atmospheric CO_2 concentrations over the coming 100 years. You may define your own scenarios on a "best guess" basis. Current GCM projections agree on increasing temperature trends in most areas of the world, while precipitation change is less certain in sign and magnitude. Percentage changes in CO_2 concentrations under the SRES-era emission scenarios are as follows: A1FI = 190, A2 = 150, A1B = 110, B1 = 60.
- **Ecosystem model:** An installer package for model for Windows may be downloaded from **http://www.nateko.lu.se/lpj-guess/education**. An icon (called the LPJ-GUESS Windows Shell) will appear on the desktop. Double-click to initiate a graphical user interface (GUI) for running the model. Instructions for setting up and running a simulation are available in the User's guide, accessible from the Help menu (an online version is also provided at the URL above)**.** A brief summary is also given under **Technical Details** below.
- Note that this version of LPJ-GUESS does not simulate biogeochemical (including DOC) exports in runoff.
- **Output and analysis of results:** The output appears as graphics on the screen, and in output files which can be opened, for example in Excel, to explore relationships between different variables, relationships to the driving climate and CO_2 data, and changes through time. You can also use the graphics tools in Excel to visualise your results.
- **Conclusions and implications:** Discuss in your group the results in relation to the question you posed. Bear in mind that the model might generate misleading results and think about the potential sources of error in the model but also the input data entering your analysis. Try to distinguish "robust" and "uncertain" aspects of your results. Consider and discuss the implications of your findings for coastal ecosystems affected by runoff from the grid cell you simulated, for example:
  - Are the simulated changes significant/large?
  - Considering the simulated changes in hydrological cycling (runoff, evapotranspiration) and carbon cycling (respiration, net primary production) what effects might be expected for DOC export to watersheds?
  - What are the possible consequences for land-sea biogeochemical fluxes and how might these influence the biogeochemistry or ecology of coastal seas?

Technical details

1. The model along with some necessary input files and documentation should be installed on a Windows computer. Sorry, this “educational” version is not available for Linux or Mac. The model can be set up and run via the user interface called the **LPJ-GUESS Windows Shell**.

2. When you first start the LPJ-GUESS Windows Shell you will be prompted to create a folder to work in, we will call this your **workspace.**

3. For *each climate and CO_2 scenario at each location* you need to create an input file containing climate and other environmental driver data for the model run. This is done using the program **GetClim** which you can access from within the LPJ-GUESS Windows Shell by choosing the menu item **File | Generate environmental driver file with GetClim**.

   - Under ”Output file to generate,” enter the name of a file that will contain climate input data for the scenario. The path (folder hierarchy) should be such that the file is written to your workspace (the folder you created in Step 2). Choose a file name that describes the location to be simulated and the scenario, e.g. ”climate_estonia_increased_precip.txt”.

   - Under ”Location,” enter the latitude and longitude of the location to simulate (you can also enter the location by clicking on the map). Make sure that you specify the correct compass direction (E or W, N or S).

   - The ”Simulation protocol” section specifies the number of years for the initialisation and scenario phase of the simulation. The initialisation phase corresponds roughly to the present climate. Enter **500 years** for the initialisation and **100 years** for the scenario (this means that the year number given in the output from the model will correspond approximately to the calender year minus 1700; e.g. simulation year 400 corresponds to calender year 2100).

   - Under “Scenario,” you should specify the temperature, precipitation and CO_2 concentration changes to be applied over the scenario phase of the simulation. Note that the precipitation and CO_2 changes are in percent, not (as you might expect) mm or ppm. For example, a 100% change in CO_2 represents a doubling of the CO_2 concentration compared with the historical data used by the GetClim, which is the 1980 value of 338 ppm..

   - Press **Generate file** to create the input data file. Optionally, you can inspect the file in Excel, opening it as a file of type “tab-delimited text”.

4. Settings for the model simulation are specified in the *instruction (inz) file*. We will use the inz file **cohort.inz**. Normally, this file will be automatically copied to your workspace folder. Check the contents of your workspace folder. If it does not contain a file called cohort.inz, you will need to make a manual copy using the following procedure: (1) **Start → Programs → LPJ-GUESS Education → Instruction files**; (2) right-click on **cohort.inz**; (3) **Properties**; (4) **Find target ...**; (5) a Windows Explorer window opens – find **cohort.inz**, make a copy and place it in your workspace folder.

5. Start the simulation (for a particular location and scenario) by choosing **Model|Run.** Specify the inz file (**cohort.inz**) från Step 4 and the input data file from Step 3.

6. Output from the model appears graphically and in summarised form on the screen and is also written to output files, one file for each output variable, in your workspace folder. Output files may be opened as “tab-delimited text” in Excel. Note that, by default, results from the latest simulation are always written to the end of the output files if they already exist (the files are never overwritten): this means that you must *scroll to the bottom of the file* to find the latest results. The following variables are output by default: carbon biomass (**cmass**); annual NPP (**anpp**); leaf area index (**lai**); ecosystem carbon fluxes (**flux**). Additional output variables (monthly NPP, soil organic matter, soil water, evapotranspiration and runoff) may be specified in the inz file (this is explained in the User Guide – see next point).

7. Further technical information is available in the **User guide**.

Documentation of LPJ-GUESS

The model was introduced in the lecture. Further information is available in the document **LPJ-GUESS – An ecosystem modelling framework**, which can be accessed via the **User Guide**. Some key publications are listed in the **Bibliography**.

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