**ESU22001 Climate Science**

**Practical 2**

**Ecosystem carbon dynamics**

**Aim**

The carbon balance of the terrestrial biosphere is primarily controlled by two different processes – photosynthesis and respiration. In turn, both processes are affected by environmental drivers such as temperature, CO2 and light, but in different ways. In this practical you will explore how different climate factors affect photosynthesis and respiration through a simplified model. This model is a version of what is normally used in the real climate models so while it might seem like it’s missing a lot of variables and interactions that would make it more biologically realistic, it will give you a good idea of the tools we use to predict future climate.

**Workflow**

Go to <https://drive.mathworks.com/sharing/a1c5b4ed-76f6-4360-9bac-e9dbd6187147> then add the folder to your MATLAB Drive add the folder to your files: click the Add to my Files button and select Copy Folder. MATLAB Drive adds the folder to your files and opens the Files view. You must be logged in with your MathWorks account to add a shared folder to your files. If you now go to the MATLAB Online window you should be able to see the files on the left hand side. Here, you will find two .m scripts associated with the tasks below and a photosynthesis.m and respiration.m that contain the respective models themselves. As with the Daisyworld practical, you do not need to modify the code in the model itself, but you should look inside to understand what is going on. Remember, you work, edit and run the \_task files and if you try to run photosynthesis.m or respiration.m on its own it will give you an error.

The workflow follows the one in the previous practical – the first questions in each task asks you to think about the model behaviour as shown by the figures, then subsequent questions ask you to modify parameters in the task .m files and interpret what those changes do. You might want to try out a few different values for those parameters to get an idea of what’s going on.

Don’t hesitate to ask questions, both if MATLAB gives you errors and if you are usure about the scientific interpretation.

|  |
| --- |
| **Task 1: Understanding the plant model** |
| What are the input variables? What are the output variables? What are their units? |
| Are these biologically realistic? Do you think there are things missing? |
| **Task 2: Effect of air temperature on ecosystem carbon fluxes** |
| Run practical2\_task2.m. How is the response of photosynthesis and respiration to temperature different? How does this reflect in the net carbon flux? |
| Try changing the atmospheric CO2 concentration. Are the response curves different? What is the effect on the net flux? Have a look at the resources below for realistic values of what we might expect in the future. |
| Try changing the biological parameters. Have a look at the papers below for realistic values for each parameter. V25 is the photosynthetic capacity, higher values mean more efficient plants. How does this affect the response to temperature? |
| SLA or specific leaf are is how dense a leaf is, higher values mean less dense leaves so it is a reflection on different plant types e.g. broadleaf vs. evergreen trees. How does this affect the response to temperature? |
| LAI or leaf area index is how many leaves there are per square metre of ground so for example the difference between a closed forest and a sparse, young forest. How does this affect the response to temperature? |
| **Task 3: Effect of atmospheric CO2 on ecosystem carbon fluxes** |
| Run practical2\_task3.m. How do photosynthesis and respiration vary with CO2. Why are they different? What are the implications for the future terrestrial carbon sink? |
| Change the air temperature – does the response to CO2 change? What are the implications for future high temperature, high CO2 conditions? |
| Change some of the biological parameters. If these parameters correspond to different places on the globe, what are the implications for global ecosystems under future conditions? What kind of plant will be able to store more carbon? |

Biologically realistic ranges for parameter values

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Broadleaf evergreen tropical forest | Broadleaf deciduous temperate forest | Needleleaf evergreen boreal forest |
| Vcmax25 (micro mol /m2 /s) | 39 | 39 | 80 |
| SLA (m2/g) | 0.009 | 0.015 | 0.01 |

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Young, open forest | Old, temperate forest | Old, tropical forest |
| LAI (m2/m2) | 1-3 | 3-5 | 5-8 |

**Resources**

Here are a couple of papers that might help you during this practical:

* The original description of the photosynthesis model: Farquhar, G. D., von Caemmerer, S., & Berry, J. A. (1980). A biochemical model of photosynthetic CO2 assimilation in leaves of C 3 species. *Planta*, *149*(1), 78–90. <https://doi.org/10.1007/BF00386231>
* A paper about plant properties (traits), some of which are used in this practical. Check table 4 for different values for different plant types. Kattge, J., Diaz, S., Lavorel, S., & Prentice, I. C. (2011). TRY–a global database of plant traits. *Global Change Biology*, *17*, 2905–2935. <https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2486.2011.02451.x>
* Future CO2 and temperature projections. Have a look at figure 3. O’Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.-F., Lowe, J., Meehl, G. A., Moss, R., Riahi, K., & Sanderson, B. M. (2016). The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. *Geoscientific Model Development*, *9*(9), 3461–3482. <https://doi.org/10.5194/gmd-9-3461-2016>