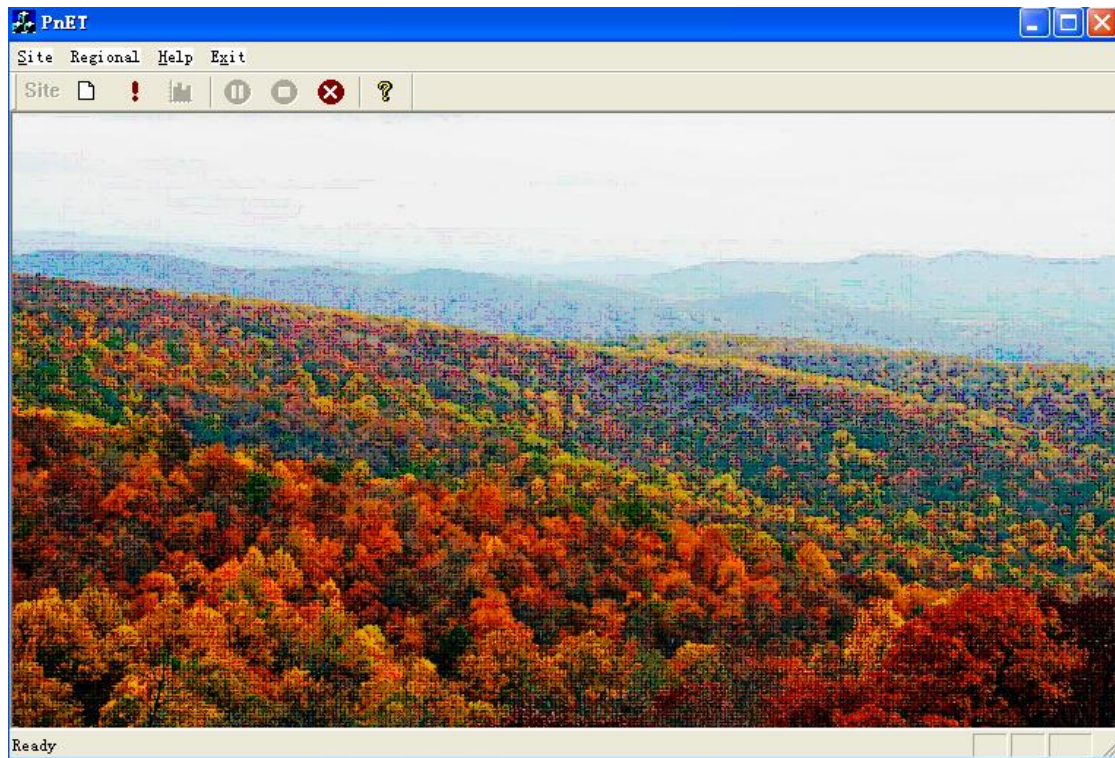


A BRIEF USER'S GUIDE FOR PnET MODELS



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DISCLAIMER

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The researchers involved in the models' development are John D. Aber, Anthony Federer, Scott V. Ollinger, Peter B. Reich, Michael L. Goulden, Charles T. Driscoll, Alexandra M. Thorn, Jennifer C. Jenkins, Andrew P. Ouimette, Jingfeng Xiao, Weifeng Wang, Zaixing Zhou, Christina Tonitto, Christine L. Goodale, Serita D. Frey, et al.

PnET models are still under development. If you have any comments or suggestions, please send them to Dr. Zaixing Zhou via email: zaixing.zhou@unh.edu. We will keep updating the models and this manual.



Information above is subject to change without notice.

1 Introduction

PnET is a suite of nested computer models which provide a modular approach to simulating the carbon, water and nitrogen dynamics of forest ecosystems. Though primarily a temperate forest canopy model, work is currently underway to generalize PnET and produce a simple, alternative model applicable to all terrestrial ecosystem types.

PnET-Day is the instantaneous canopy flux module, PnET-II adds nutrient allocation, a water balance and soil respiration to produce a monthly time-step carbon and water model which is driven by nitrogen availability. PnET-CN further extends the soil dynamics component and closes the N cycle by tracking nitrogen, along with carbon, throughout all compartments and fluxes. PnET-Daily extends the monthly prediction of PnET-CN into daily dynamics. PnET-SOM replaces the single SOM pool of the PnET-CN model with representation of organic matter dynamics by soil horizon (O, A, B) and organic matter form.

The best source of information about PnET are the journal publications available for online viewing on the Publications page. The model itself is released as open source and users are encouraged to extend and enhance it for their own purposes.

PnET is available as MATLAB, Visual Basic, C++, R sources. The distribution package contains example files which will allow the user to run each version of the model using data acquired at the Harvard Forest and Hubbard Brook experimental forests and a subset of the VEMAP continental U.S. data.

PnET was developed at the Earth Systems Research Center (formerly Complex Systems Research Center, a division of the Institute for the Study of Earth, Oceans and Space at the University of New Hampshire). Read more about the history of PnET at the ESRC. PnET development and application is supported through grants from the following agencies:

the University of New Hampshire (UNH), Department of Agriculture (USDA), US Environmental Protection Agency (EPA), National Aeronautics, Space Administration (NASA), National Science Foundation (NSF), and The Long Term Ecological Research Network (LTER).

It is recommended to review the publications listed in the references for obtaining an adequate understanding of the scientific concepts underlining the model functions.

2 Model Description

The PnET Family - Nested Models of Forest Biogeochemistry

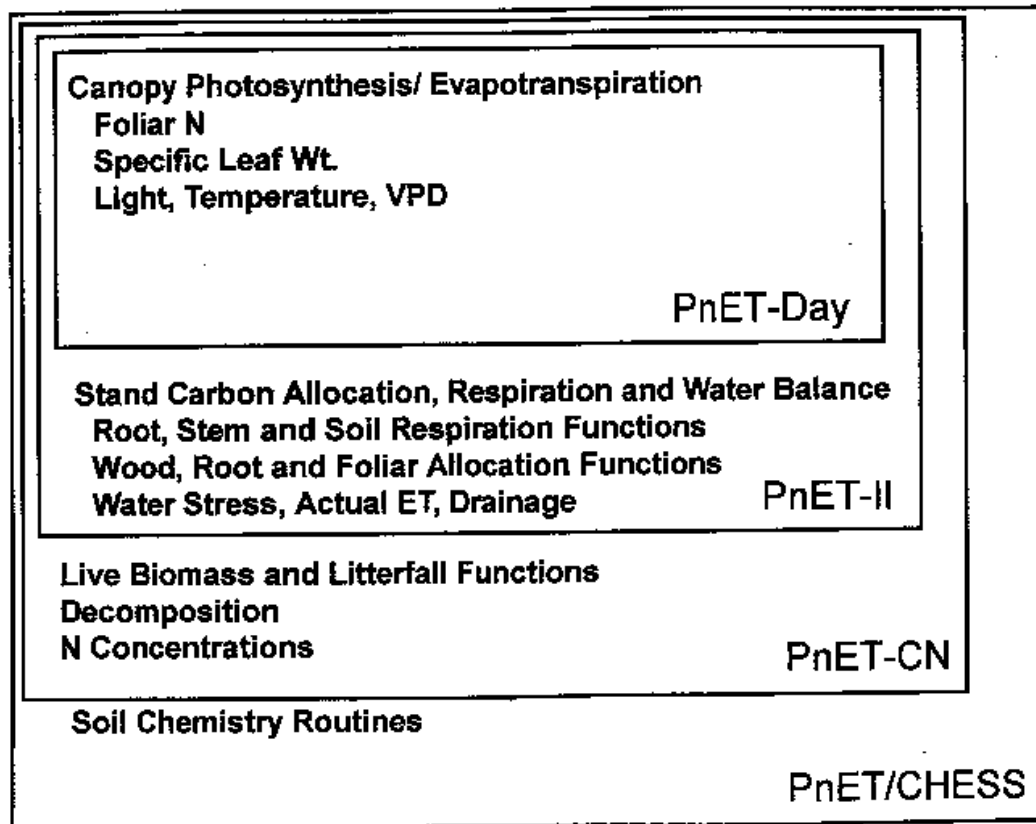


Fig. 1 The concept structure of the PnET model

3 Versions of PnET

3.1. C++ on Windows

3.1.1. Software and Hardware Requirements

3.1.2. Installation

PnET package is available from EOS, UNH, NH, USA. Model package can be copied into any directory in your local hard drive. The model package has a .exe executable and several pre-created directories, such as '*Input*', '*Library*', and '*Result*'.

3.1.3. Input for Site-Scale Simulation

3.1.4. Getting started

After the installation procedure, by double clicking the executable (normally, PnET.exe) in the model directory, the windows interface of the model will be popped up on the screen as shown in Fig.2. By clicking the button you will be able to send your input data to the model or run the mode in the site or regional mode.

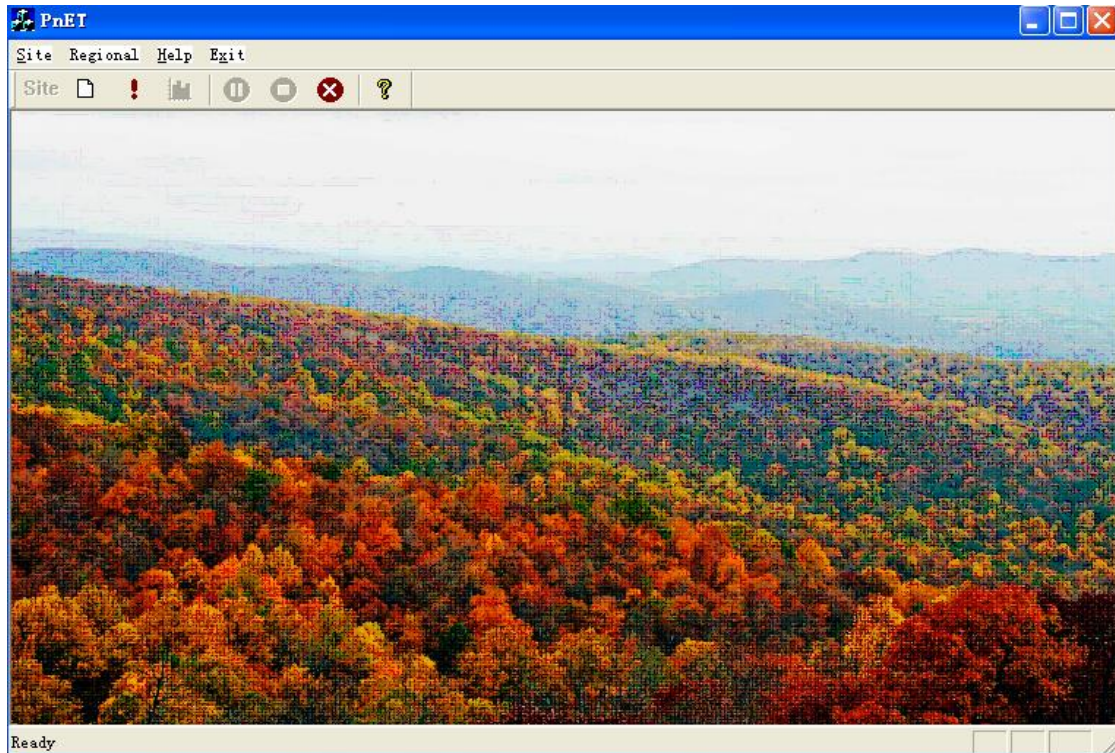



Fig. 2 PnET model interface

3.1.5. Site Mode

In the site mode, most of the input parameters will be typed in manually through the input pages. Clicking the '*Setup Site...*' button by the sign '*Site*' on the main menu will initiate the input procedure in site mode. There are five pages for inputting (1) Model options, (2) Site parameters, (3) Vegetation parameters, (4) Disturbance and management parameters, and (5) Result visualization, respectively. During the input process, you can come back to any specific page to make modifications. Generally, a project case run has to be completely excuted and then output all results, thus, the result visualization can be correctly presented. When all the inputs have been typed in for all the pages except **Result**, you are ready to start the site simulation by clicking button '**Run**' on **Model Options** or on the toolbar after clicking the OK button at the bottom of the climate page to end the input procedure.

3.1.6. Model Options

PnET can be operated on IBM-PC computers with 486 or better capabilities or on workstations. Computers with a RAM of 64 MB or more and a speed of 350MHz or higher are recommended.

Click the  button by “Site” in the toolbar. A new property sheet is opened. The “Model Options” page is shown as the active page. (Figure 3).

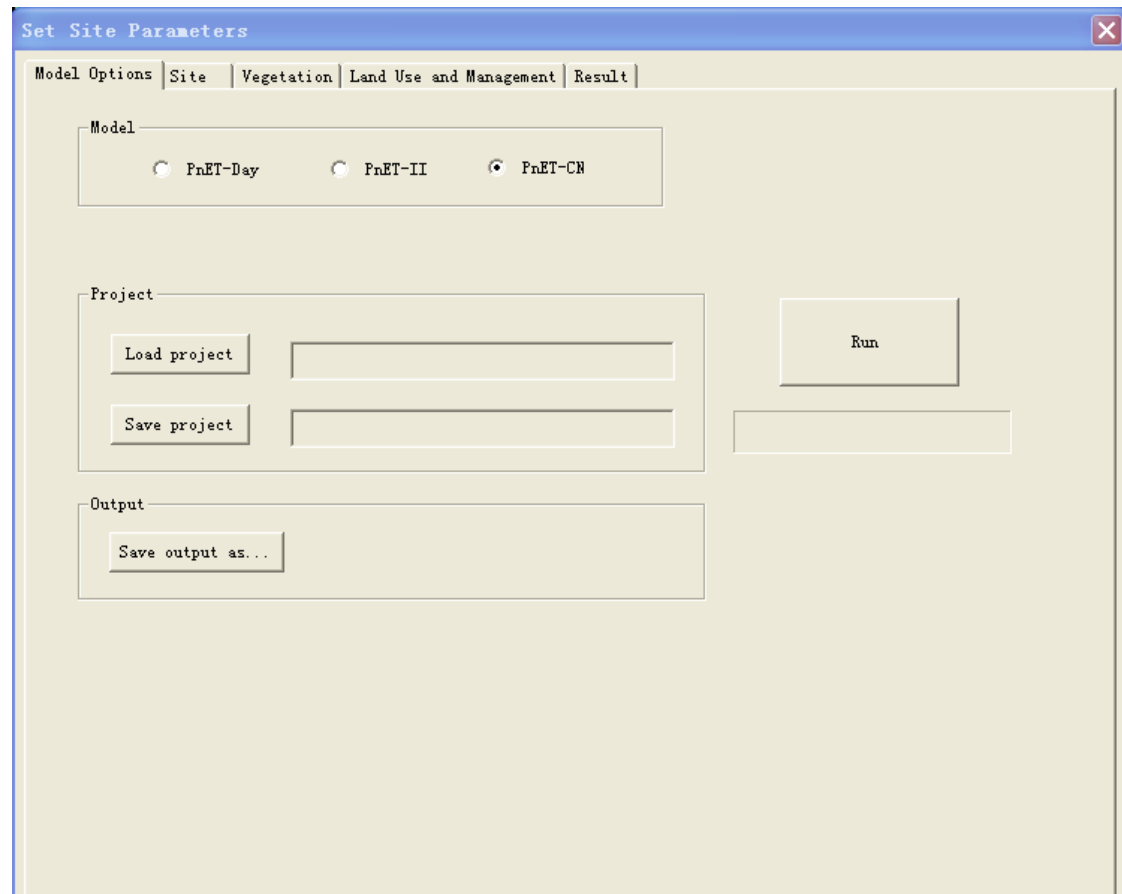


Fig. 3 Page for Model Options

[**Model**]: Three types of PnET model for selection;
PnET-Day, PnET-II, and PnET-CN

3.1.7. Site

Set Site Parameters

Model Options | **Site** | Vegetation | Land Use and Management | Result

Latitude (degree)

Climate options

☒ Ozone effect

☒ CO2 effect on stomatal conductance

☐ Use absolute N content (mg/l)

Simulated years from to

Soil

Water hold capacity (cm)	<input type="text" value="12"/>	Humus mass (g/m ²)	<input type="text" value="13500"/>	Humus decomposition constant	<input type="text" value="0.075"/>
Snow pack (cm)	<input type="text" value="13"/>	Humus N mass (g/m ²)	<input type="text" value="390"/>	Soil respiration factor A	<input type="text" value="27.46"/>
Soil water (cm)	<input type="text" value="12"/>	Soil NH ₄ content (g/m ²)	<input type="text" value="0.01"/>	Soil respiration factor B	<input type="text" value="0.068"/>
Soil moisture factor	<input type="text" value="0"/>			N immobilization factor A	<input type="text" value="151"/>
Fast flow fraction	<input type="text" value="0.1"/>			N immobilization factor B	<input type="text" value="-35"/>
Water release factor f	<input type="text" value="0.04"/>				
DWater	<input type="text" value="0.9"/>				

Fig. 4 Page for Site information

Click the “Site” tab. A new page is opened. This is the “Site” page (Figure 4).

3.1.8. Vegetation

Set Site Parameters

Model Options | Site | **Vegetation** | Land Use and Management | Result

Type: 1 RORM Red_Oak_Red_Maple Age: 40

Leaf: 0 Live wood: 20000 Dead wood: 0 Root: 8 MaxL: 300 MinL: 0

BudC: 130 WoodC: 300 PlantC: 900 PlantN: 1 NRatio: 1.4

Tree parameters

AmaxA, n mole CO ₂ /g/s	-46	DVPD1	0.05	Wood turnover rate	0.025
AmaxB	71.9	DVPD2	2	Root turnover factor A	0.789
Amax fraction	0.75	Water use efficiency	10.9	Root turnover factor B	0.191
Base leaf respiration fraction	0.1	Precipitation intercepted	0.11	Root turnover factor C	0.021
Respiration Q10	2			Wood litter loss rate	0.1
Light half satur constant	200			Wood litter C loss	0.8
Minimum Psn temperature	4				
Optimum Psn temperature	24	C fraction of dry matter	0.45	Min %N in foliage litter	0.009
Leaf retention, yrs	1	Growth respiration fraction	0.25	Min %N in wood litter	0.002
		Wood start TDD	100	Min %N in root litter	0.012
Initial %N in foliage	2.2	Wood end TDD	900	Leaf %N range	0.6
Specific leaf weight, g/m ²	100	Wood maintain resp. frac	0.07	Leaf N retranslocation	0.5
SLWdel	0.2	Root maintain resp. fraction	1		
Canopy light attenuation k	0.58	Root allocation factor A	0	Max N storage, kg N/ha	20
Leaf start TDD	100	Root allocation factor B	2		
Leaf end TDD	900	PlantC reserve fraction	0.75		
Senesc start day	270	Min wood/leaf	1.5		
Max leaf growth rate %/yr	0.95				

Default

Fig. 5 Page for Vegetation

Click the “Vegetation” tab. A new page is opened for entering the vegetation information (Figure 5).

3.1.9. Disturbance and Management

Set Site Parameters

Model Options | Site | Vegetation | **Disturbance and Management** | Result

Land Use/Disturbance (harvest/fire)

Total disturbance #

Disturbance #

Year Biomass mortality Fraction removed Soil loss fraction Foliar regeneration

NO	Year	Mortality	Remove	Soil loss	Foliar regeneration
1	1750	0.200	0.010	0.000	100.0
2	1930	0.500	0.800	0.000	100.0
3	1950	0.010	0.010	1.000	100.0

Agriculture

Removed: From year To Fraction

Fertilization

Application: Year DOY

From

To

Type and rate (g/m2)

NH4+ NO3- Urea

Fig. 6 Page for Disturbance and Management

Click the “Disturbance and Management” tab. A new page is opened for entering the vegetation information (Figure 5).

3.1.10. Save and Load Input Files

After you input all data needed for the model and return to the *Model Options* page, you can save all input data into a user-named file by clicking the *Save project* button.

Meanwhile, you can manually edit the save project file with Notepad or other word processor and read the file into the model by clicking the *Load project* button. In this way, you do not need to enter all parameters one page by one page any more.

3.1.11. Execution of Simulation

By clicking the *Run* button on the *Model Options* page, you will command the model to read in all of the input parameters, and execute the relevant calculations. After successful completion of the model run, the progress bar under the *Run* button will show 100% to inform of the ending of calculation (Figure 6).

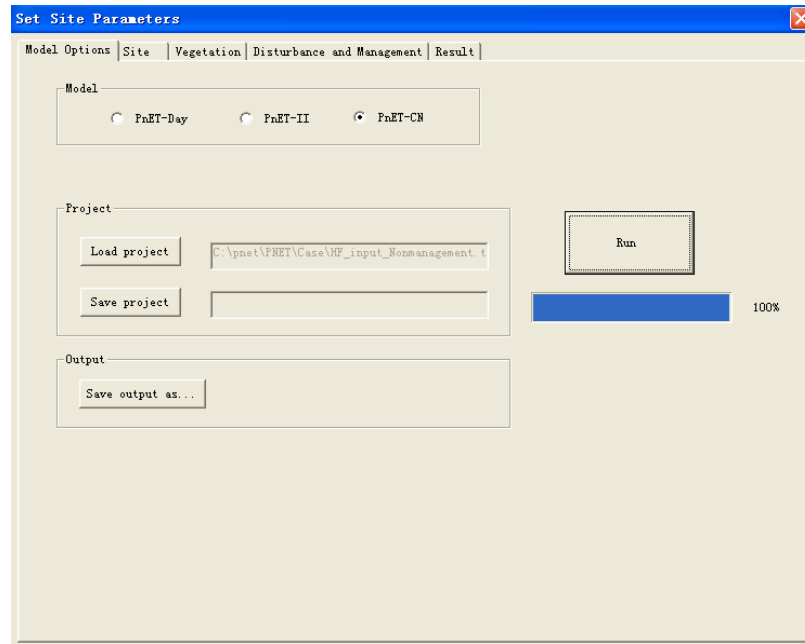


Fig. 7 Completion of the model run

3.1.12. Visualization and Save of Results

Model results are recorded in files located at **Result** directory. They can be opened with any text editors.

Click the “Result” tab. A new page is opened for viewing the results (Figure 8). Figures shown on this page are not based on the same scale. They are displayed only to show patterns of variation for diagnosis.

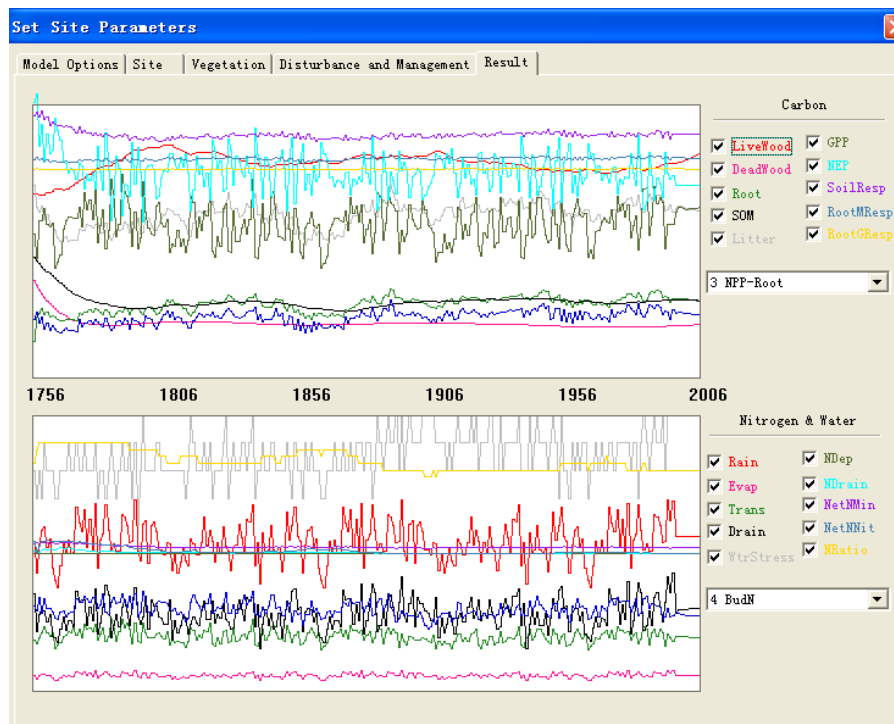


Fig. 8 Visualization of model results

3.1.13. Help

By clicking the *Help* button given in the top toolbar, you will have this user guide to display on the screen for reference.

3.2. C++ on Linux system

3.2.1. Installing and running

A PnET version in C++ is provided for using with text files as input and output interface. Its codes can be compiled by GNU Compiler GCC or using a free development environment on Windows, e.g., Eclipse. A make file companies with the original codes to facilitate the compilation.

3.2.1.1. Linux system

If you use a Linux system, run a terminal and locate to the PnET code folder (pnet\pnet_linux). Type **make** to compile and build the codes. You can run PnET model by entering **./pnet**.

3.2.1.2. Windows system

If you use a Windows system, in order to compile the codes, MingGW, a freely distributable compiler system using GCC to produce Windows programs, is recommended to install (<http://www.mingw.org/>) in the root directory (i.e., C:\MinGW). When running the installer, check all boxes on the step specifying different programming languages. After successful installation, you must add **C:\MinGW\bin** and **C:\MinGW\msys\1.0\bin** to the PATH environment variables as follows:

- 1, Right-click **My Computer**, and then click **Properties**.
- 2, Click the **Advanced** tab.
- 3, Click **Environment Variables**.
- 4, Double click **Path** in **System Variable**.
- 5, Add **C:\MinGW\bin**, and **C:\MinGW\msys\1.0\bin** to the end of the value after a semicomma separator.

To use MinGW Shell to compile and execute PnET, run MinGW Shell (C:\MinGW\msys\1.0\msys.bat) and locate to the PnET code folder (pnet\pnet_linux). Typing **Make** command into the shell terminal starts the compilation of the model. A

pnet.exe executable is generated and you can run PnET model by typing **./pnet** in the shell or click pnet.exe in the code folder.

3.2.1.3. Eclipse IDE

If you prefer a better development environment, Eclipse is recommended as well as MingGW.

If you use Windows, first install MingGW by following the above section. To install Eclipse (probably you also need to install JDK 7 or above, besides the latest JRE):

- 1, Download Eclipse IDE for C/C++ Developers from <http://www.eclipse.org/downloads/>.

- 2, Unzip it into your designated directory.

- 3, Click **eclipse.exe** to run it.

To set up PnET Project in Eclipse IDE:

- 1, Run Eclipse by clicking the executable.

- 2, Click **File** and Click **New** to create a C++ Project.

- 3, Uncheck **Use default location** and use **Browse** to locate to the PnET code folder (pnet\pnet_linux), type a project name in **Project name**, e.g., PnET.

- 4, In the **Project type** box, choose **Makefile project**, build an **Empty project**.

- 5, In the Toolchains box, choose MinGW GCC. Click **Finish** to complete the setting up.

To compile and execute PnET with Eclipse, Click **Project** and then click **Build project**. Click **Run** command to run PnET.

As PnET codes have to be compiled with a make file, if you add a new code file into the project, you have to update the make file in the code folder, namely **makefile**, using the existing text as an example.

3.3. Matlab version

PnET has a Matlab version for PnET-Day, PnET-II, and PnET-CN. To run this version, users have to have a license to access Matlab application.

- 1, Run your Matlab.

- 2, Set the model folder. Click **Browse for folder** in the tool bar to select the PnET code directory as the current active directory. In the **Explorer** panel you can see all matlab routines.

3, Load the input climate, site, and vegetation structures. Use the "load" command to load these input files separately from the sample directory, e.g.

```
>>load ('C:\pnet\PnET_R2\samplefiles\nhwd.mat') for veg structure
```

```
>>load ('C:\pnet\PnET_R2\samplefiles\hfsite.mat') for site structure
```

```
>>load ('C:\pnet\PnET_R2\samplefiles\hf_1000y_avg.mat') for climate structure.
```

Alternatively, you can just drag those files and release into the command window. You also can use the **Import Data** command in the tool bar to load those files.

After loaded, those structures can be viewed and edited in the **Workspace** panel.

4, Run PnET. Simply type "out=pnetcn(climIn,siteIn,vegIn)" in the command window to run PnET-CN, where you have to use your own climIn, siteIn, vegIn, and out structures instead. out is a structure that consists of all the output variables (e.g., gpp, nep, plantc, et), including monthly and annual output variables.

5, Plot your results. You can use Matlab Plotting commands or tools to visualize model results.

3.4. VB version

The original version of the model is programmed in Visual Basic. It has a graphical user interface and makes an excellent teaching tool. This version of the model runs natively on Windows platforms. Unfortunately, as Windows system keep updating as well as Visual Basic, we have not made the VB version updated along with the latest versions of VB.

4 References

A bibliography of peer review journal publications and book chapters related to the PnET model. The four primary reference papers for PnET are listed separately and are available for online reading.

Original PnET paper

From *Oecologia* (1992) 92:463-474. This first PnET related publication is included for historical background only as the early version of the model described is superseded by PnET-II.

PnET-Day

From *Oecologia* (1996) 106:257-265. Description of the instantaneous, daily time-step version of PnET.

PnET-II

From Climate Research (1995) 5:207-222. Introduction to the monthly time-step foliar nitrogen driven version of PnET.

PnET-CN

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-----2007-----

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