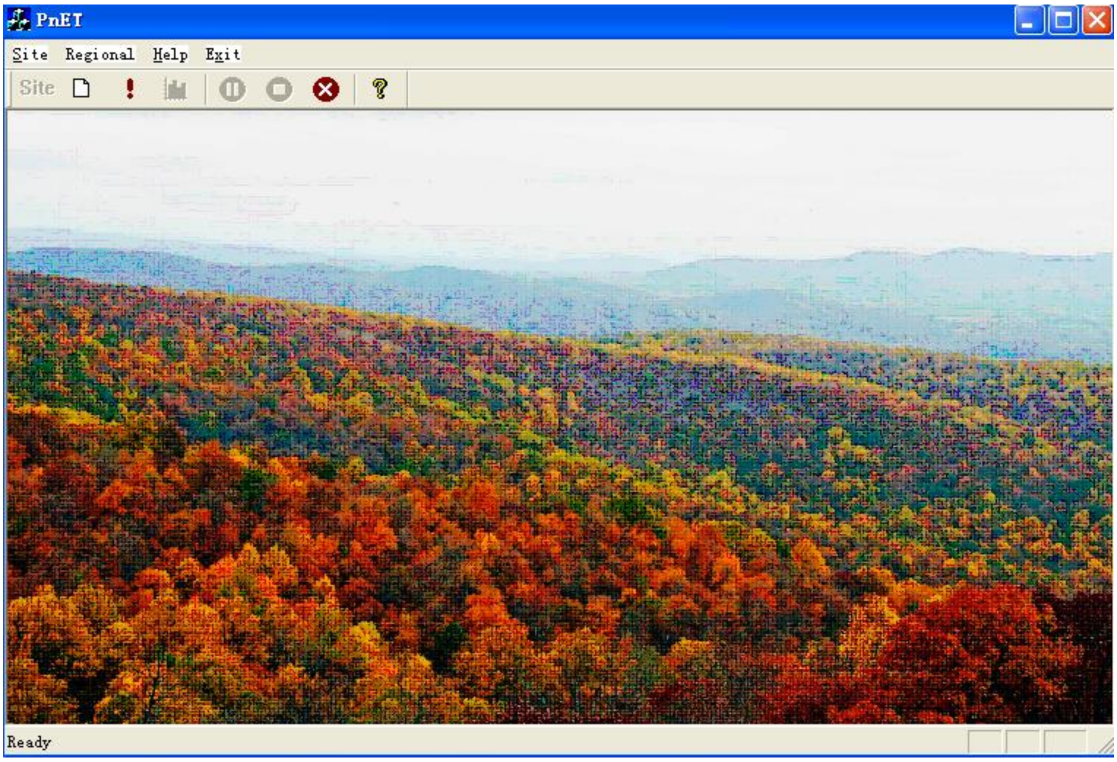
# A BRIEF USER'S GUIDE
# FOR PnET MODEL




Institute for the Study of Earth, Ocean and Space,
University of New Hampshire, Durham, NH, USA

# Contents

**Contents** ........ 1
**DISCLAIMER** ........ 2
**ACKNOWLEDGMENTS** ........ 3
1 Introduction ........ 4
2 Model Description ........ 5
3 Versions of PnET ........ 5
**3.1. C++ on Windows** ........ 5
3.1.1. Software and Hardware Requirements ........ 5
3.1.2. Installation ........ 5
3.1.3. Input for Site-Scale Simulation ........ 6
3.1.4. Getting started ........ 6
3.1.5. Site Mode ........ 6
3.1.6. Model Options ........ 7
3.1.7. Site ........ 8
3.1.8. Vegetation ........ 9
3.1.9. Disturbance and Management ........ 9
3.1.10. Save and Load Input Files ........ 10
3.1.11. Execution of Simulation ........ 10
3.1.12. Visualization and Save of Results ........ 11
3.1.13. Help ........ 12
**3.2. C++ on Linux system** ........ 12
3.2.1. Installating and running ........ 12
3.2.1.1. Linux system ........ 12
3.2.1.2. Windows system ........ 12
3.2.1.3. Eclipse IDE ........ 13
3.2.1.4. Visual Studio Code IDE ........ 14
3.2.2. Adding a new code file ........ 14
**3.3. Matlab version** ........ 14
**3.4. VB version** ........ 15
**3.5. R version** ........ 15
**3.6. Python version** ........ 15
4 References ........ 15

# DISCLAIMER

# ACKNOWLEDGMENTS

PnET models were developed with financial support from 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).

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

PnET-Day is the instantaneous canopy flux (carbon) module. PnET-II adds carbon allocation, a water balance, and soil respiration to produce a monthly time-step carbon and water model, which is driven by nitrogen availability (e.g., foliar N) along with weather forcing. PnET-CN further extends the soil dynamics component and closes the N cycle by tracking nitrogen throughout all compartments and fluxes. i.e., instead of prescribing a foliar N in PnET-II, PnET-CN dynamically predicts foliar N through N cycling. 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 representations of organic matter dynamics by soil horizons (O, A, B) and organic matter forms.

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

PnET is available in MATLAB, Visual Basic, C++, R sources (PnET-CN), Python (PnET-II). The distribution package contains example files that will allow the user to run each model version 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 was 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 to obtain an adequate understanding of the scientific concepts underlining the model functions.

# 2 Model Description

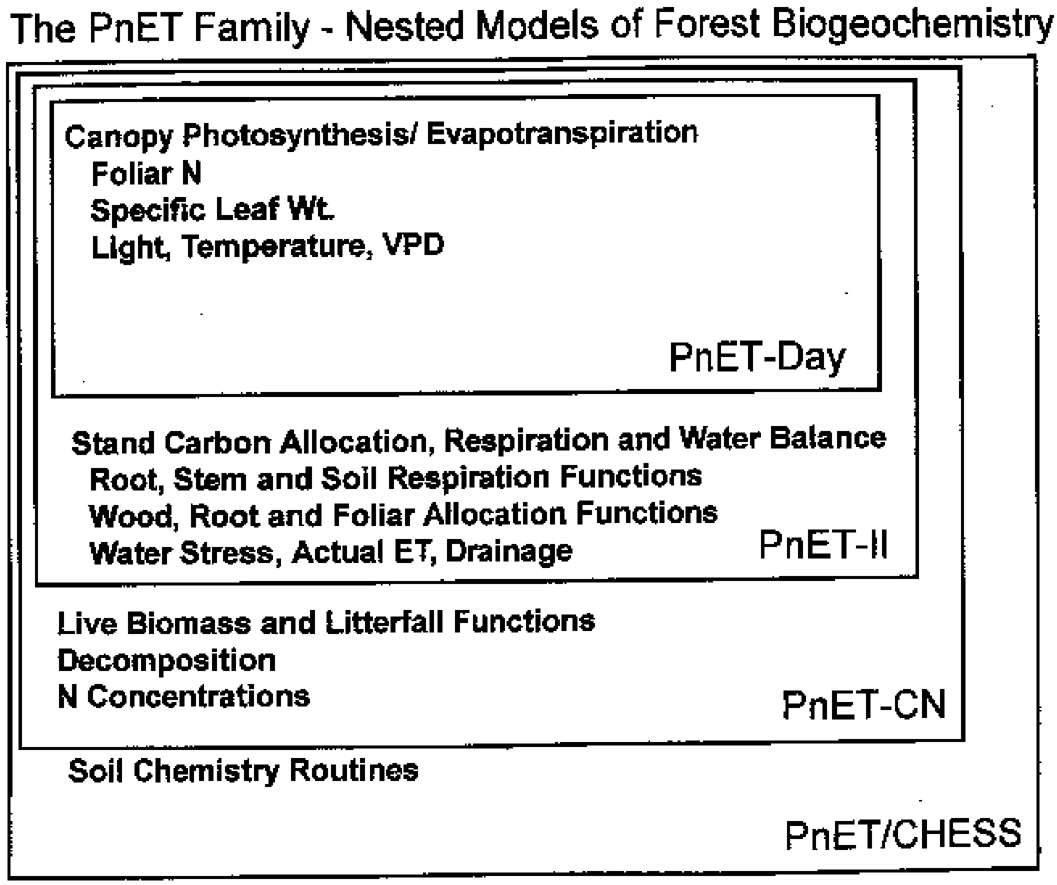



**Fig. 1** The concept structure of the PnET model

# 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.

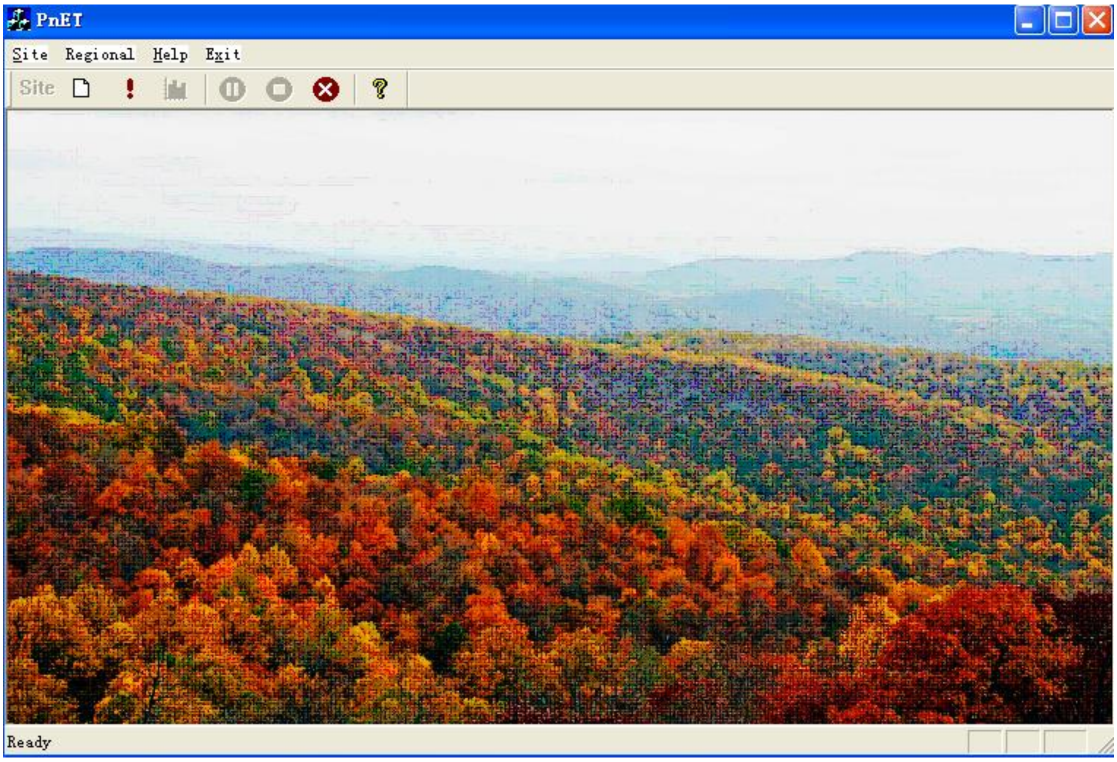



**Fig. 2** PnET model interface

### 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).

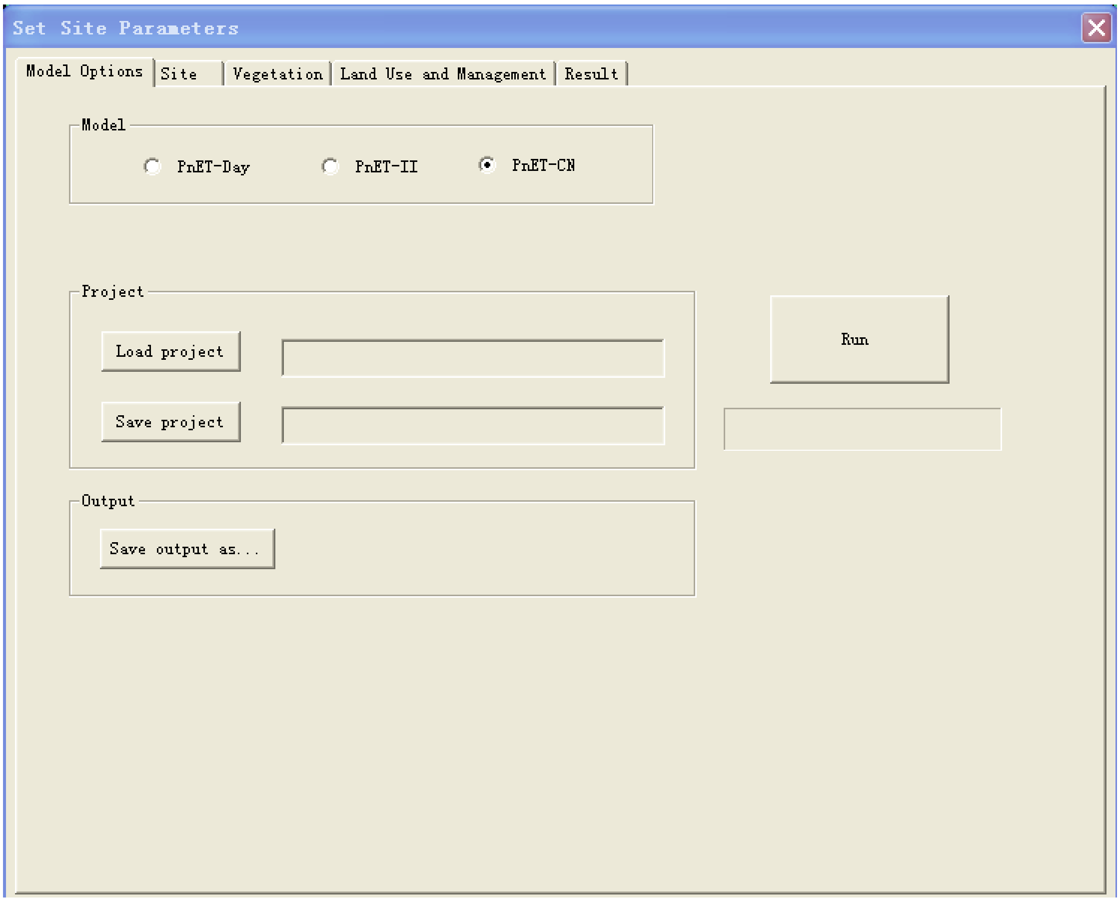



**Fig. 3** Page for Model Options

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

## 3.1.7. Site

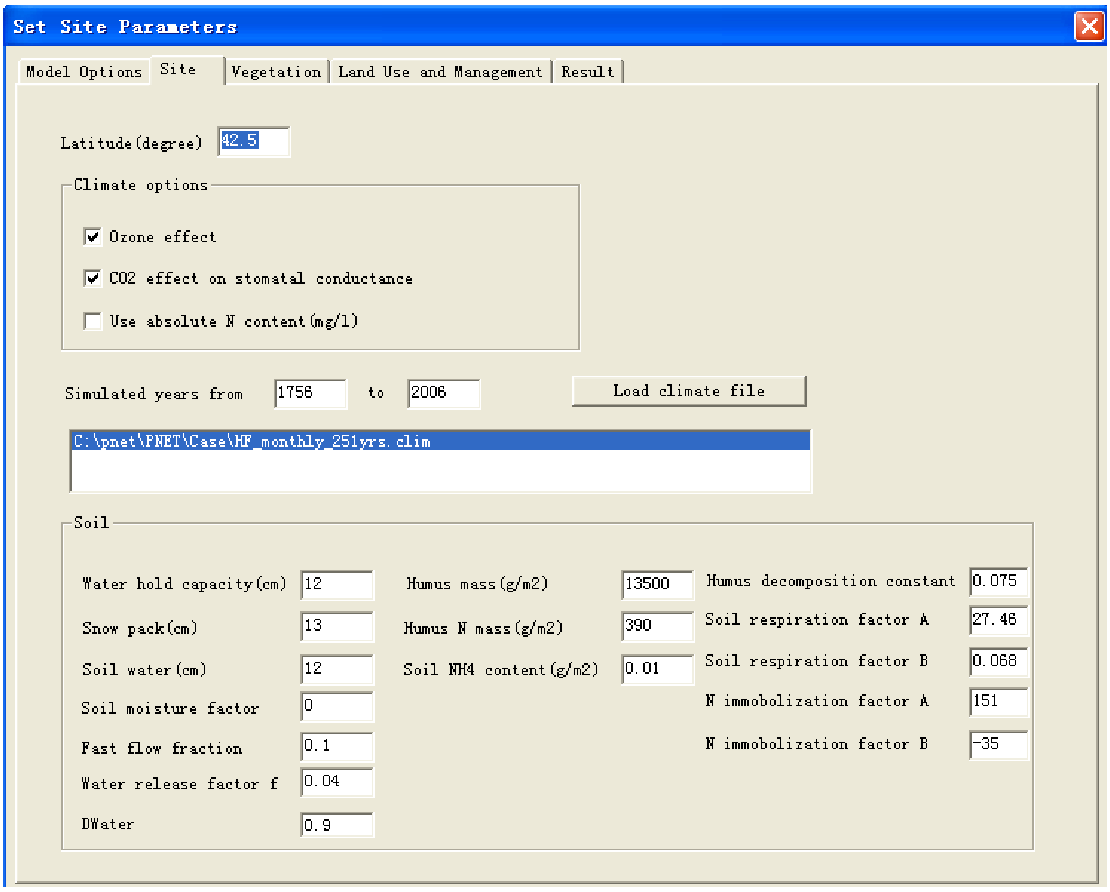



**Fig. 4** Page for Site information

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

## 3.1.8. **Vegetation**

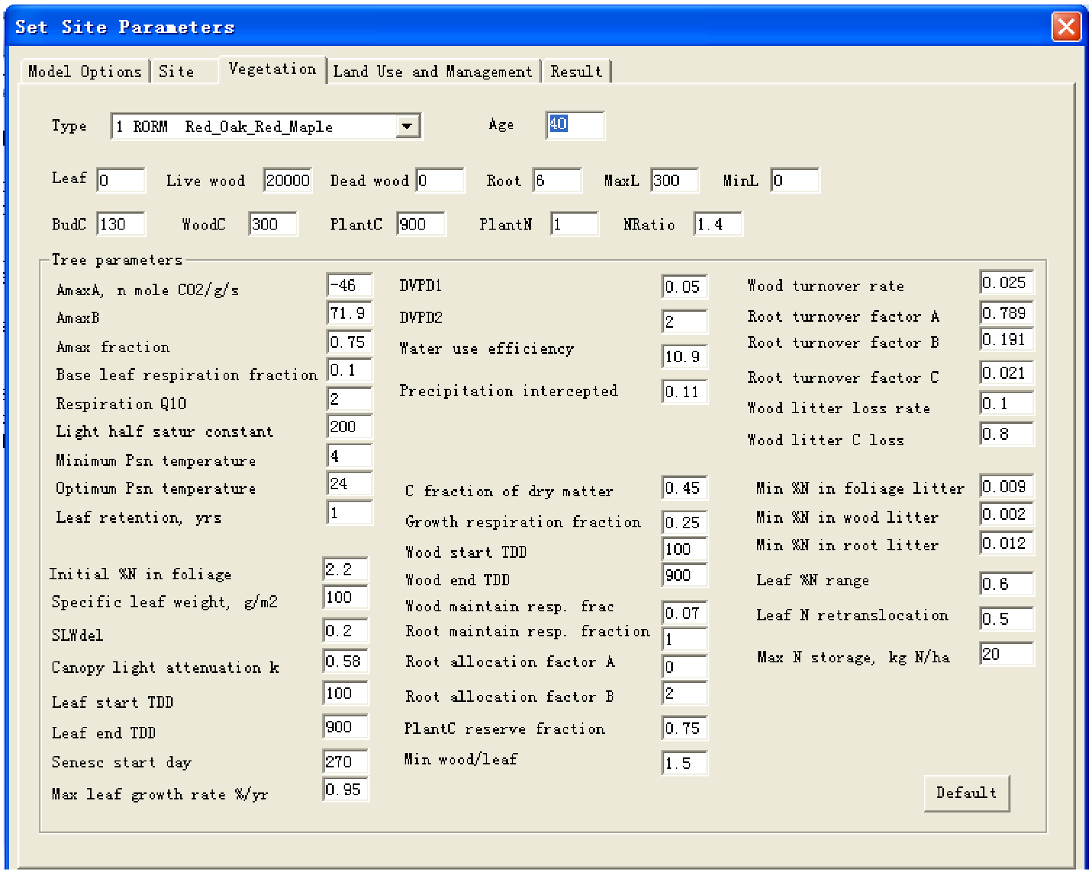



**Fig. 5** Page for Vegetation

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

## 3.1.9. **Disturbance** and Management

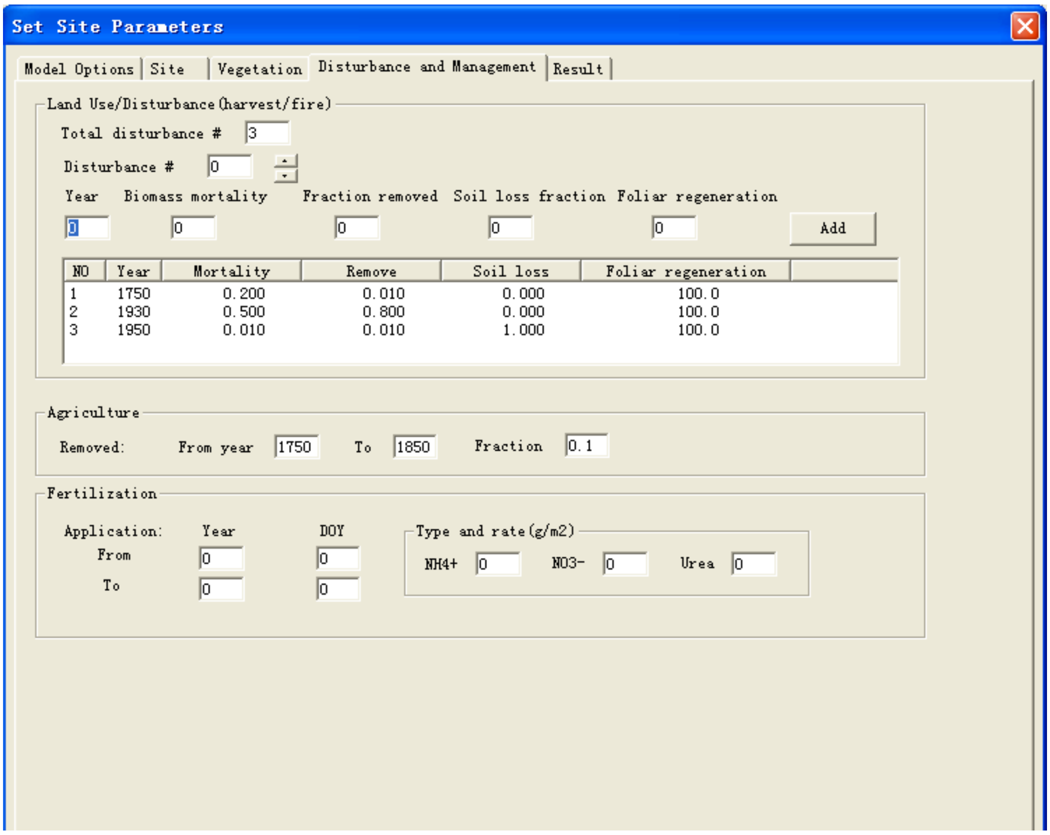



**Fig. 6** Page for Disturbance and Management

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).

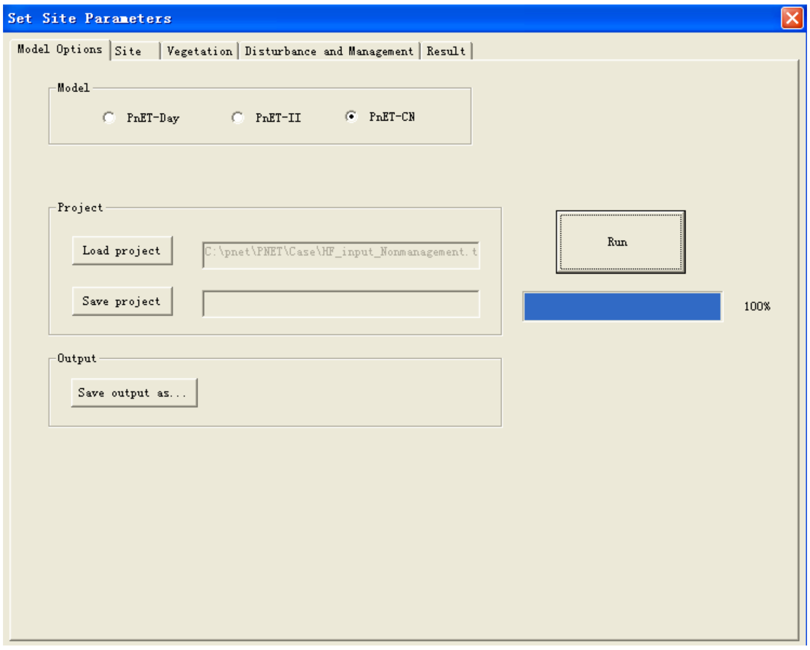



**Fig. 7** Completion of the model run

### 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.

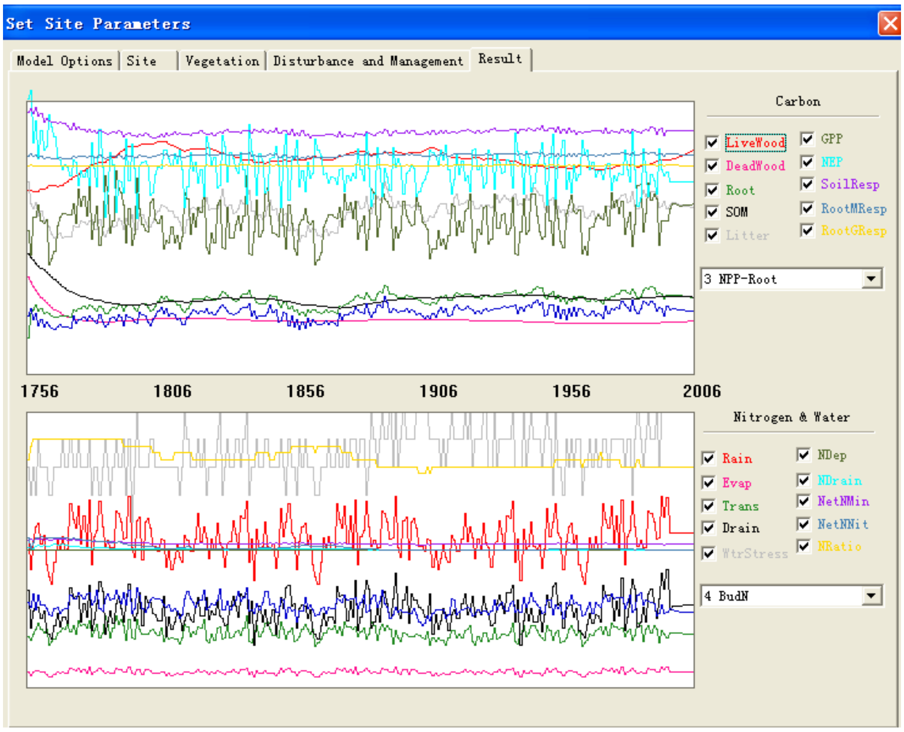


**Fig. 8** Visualization of model results

### 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. Installating 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 or Visual Studio Code. A make file companies with the orginal codes to facilitate the compilation.

#### 3.2.1.1. Linux system

Run a terminal and locate the PnET code folder (pnet\pnet_linux) if you use a Linux system. Type **make** (**or make cleanall** to clean all built files in advance) to compile and build the codes. You can run the PnET model by entering **./pnet.**

#### 3.2.1.2. Windows system

If you use a Windows system 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 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 (for old **Windows**, add a semicomma separator after each field.

To use MinGW Shell to compile and excute 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 clicking pnet.exe in the code folder.

To use Windows Command Prompt (cmd) to compile and excute PnET, run cmd from the Run by typing cmd and locate to the PnET code folder (pnet\pnet_linux), or first locate the folder and then type cmd in the address bar to run cmd. Typing **Make** command **(or make cleanall** to clean all built files in advance**)** into the 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 clicking pnet.exe in the code folder.

### 3.2.1.3. Eclipse IDE

If you prefer a better development environment, Eclipse is recommended along with MingGW.

If you use Windows, first install MingGW by following the above section. To install Eclipse (you probably also need to update your Java by installing the latest JDK or JSE, add Java path into the PATH environment variables as with **MinGW**):

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

2, Install Eclipse for C/C++.

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

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

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

6, To compile and execute PnET with Eclipse, Click **Project** in the menu and then click **Build project (or Build All)**. Click **Run** command to run PnET.

7, If the Build menu does not make any response, the builder property should be updated as follows:

Right-click the project name, go to the **Property**, click the **C/C++ Build.** In the

**Enviroment** tab seen by unfolding the **C/C++ Build,** the MinGW and MSYS should appear in the table; otherwise, add manually. In the **Tool Chain Editor**, The **Current Toolchain** should be MinGW GCC, and the **Current builder** is Gnu Make Builder. Then go back to **C/C++ Build** home page to uncheck **Makefile generation.** The **Builder type** should be **External builder**, **Build command** is make, The Build location is active, instead of gray out.

Apple MacOS needs to install Xcode before installing Eclipse.

#### 3.2.1.4. Visual Studio Code IDE

PnET codes can also be compiled and run in Visual Studio Code. After installation of Visual Studio Code (VSCode), you can add the **Makefile Tools** extension in VSC to support makefile by clicking **Extensions** and installing **Makefile Tools**. See the https://devblogs.microsoft.com/cppblog/now-announcing-makefile-support-in-visual-studio-code/ for more details to install, activate, and use Makefile Tools in VSCode.

### 3.2.2. Adding a new code file

For all versions, 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 must have a license to access the 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 rountines.

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 drag and release those files 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. Type “out=pnetcn(climIn,siteIn,vegIn)” in the command window to run PnET-CN, where you have to use your 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 Ploting 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 keeps updating as well as Visual Basic, we have not updated the VB version along with the other latest versions.

## 3.5. R version

PnET has an R version of PnET-CN.

## 3.6. Python version

Python versions of PnET are under development. A Python PnET-II is available on GitHub. https://github.com/zaixingzhou/PnET_python_master.

# 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 superceeded by PnET-II.

**PnET-Day**

From Oecologia (1996) 106:257-265. Description of the intantaneous, 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

From Ecological Modelling (1997) 101:61-78. Description of the monthly time-step version of PnET which includes a complete nitrogen cycle.

## Journal Articles


---------------------------------------------2007----------------------------

Richardson, A. D., D. Y. Hollinger, J. D. Aber, S. V. Ollinger, and B. H. Braswell. 2007. Environmental variation is directly responsible for short-but not long-term variation in forest-atmosphere carbon exchange. Global Change Biology, 13:788-803.

Werner, C., R. Kiese, and K. Butterbach-Bahl. 2007. Soil-atmosphere exchange of N2O, CH4, and CO2 and controlling environmental factors for tropical rain forest sites in western Kenya. Journal of Geophysical Research-Atmospheres 112:15.

---------------------------------------------2006----------------------------

Kesik, M., N. Bruggemann, R. Forkel, R. Kiese, R. Knoche, C. S. Li, G. Seufert, D. Simpson, and K. Butterbach-Bahl. 2006. Future scenarios of N2O and NO emissions from European forest soils. Journal of Geophysical Research-Biogeosciences 111:14.

McNeil, B. E., R. E. Martell, and J. M. Read. 2006. GIS and biogeochemical models for examining the legacy of forest disturbance in the Adirondack Park, NY, USA. Ecological Modelling 195:281-295.

Miehle, P., S. J. Livesley, P. M. Feikema, C. Li, and S. K. Arndt. 2006. Assessing productivity and carbon sequestration capacity of Eucalyptus globulus plantations using the process model forest-DNDC: Calibration and validation. Ecological Modelling 192:83-94.

Pan, Y., R. Birdsey, J. Hom, K. McCullough, and K. Clark. 2006. Improved estimates of net primary productivity from MODIS satellite data at regional and local scales. Ecological Applications 16:125-132.

Radtke, P. J. and A. P. Robinson. 2006. A Bayesian strategy for combining predictions from empirical and process-based models. Ecological Modelling 190:287-298.

Sacks, W. J., D. S. Schimel, R. K. Monson, and B. H. Braswell. 2006. Model-data synthesis of diurnal and seasonal CO2 fluxes at Niwot Ridge, Colorado. Global Change Biology 12:240-259.

Werner, C., X. H. Zheng, J. W. Tang, B. H. Xie, C. Y. Liu, R. Kiese, and K. Butterbach-Bahl. 2006. N2O, CH4 and CO2 emissions from seasonal tropical rainforests and a rubber plantation in Southwest China. Plant and Soil 289:335-353.

---------------------------------------------2005----------------------------

Chen, L. M. and C. T. Driscoll. 2005. A two-layer model to simulate variations in surface water chemistry draining a northern forest watershed. Water Resources Research 41.

Chen, L. M. and C. T. Driscoll. 2005. Regional application of an integrated biogeochemical model to northern New England and Maine. Ecological Applications 15:1783-1797.

Chen, L. M. and C. T. Driscoll. 2005. Regional assessment of the response of the acid-base status of lake watersheds in the adirondack region of New York to changes in atmospheric deposition using PnET-BGC. Environmental Science & Technology 39:787-794.

Chen, L. M. and C. T. Driscoll. 2005. Strategies for emission controls to mitigate snowmelt acidification. Geophysical Research Letters 32.

Fahey, T. J., T. G. Siccama, C. T. Driscoll, G. E. Likens, J. Campbell, C. E. Johnson, J. J. Battles, J. D. Aber, J. J. Cole, M. C. Fisk, P. M. Groffman, S. P. Hamburg, R. T. Holmes, P. A. Schwarz, and R. D. Yanai. 2005. The biogeochemistry of carbon at Hubbard Brook. Biogeochemistry 75:109-176.

Falge, E., S. Reth, N. Bruggemann, K. Butterbach-Bahl, V. Goldberg, A. Oltchev, S. Schaaf, G. Spindler, B. Stiller, R. Queck, B. Kostner, and C. Bernhofer. 2005. Comparison of surface energy exchange models with eddy flux data in forest and grassland ecosystems of Germany. Ecological Modelling 188:174-216.

Johnston, M. and T. Williamson. 2005. Climate change implications for stand yields and soil expectation values: A northern Saskatchewan case study. Forestry Chronicle 81:683-690.

Kesik, M., P. Ambus, R. Baritz, N. B. Bruggemann, K. Butterbach-Bahl, M. Damm, J. Duyzer, L. Horvath, R. Kiese, B. Kitzler, A. Leip, C. Li, M. Pihlatie, K. Pilegaard, G. Seufert, D. Simpson, U. Skiba, G. Smiatek, T. Vesala, and S. Zechmeister-Boltenstern. 2005. Inventories of N2O and NO emissions from European forest soils. Biogeosciences 2:353-375.

Kiese, R., C. S. Li, D. W. Hilbert, H. Papen, and K. Butterbach-Bahl. 2005. Regional application of PnET-N-DNDC for estimating the N2O source strength of tropical rainforests in the Wet Tropics of Australia. Global Change Biology 11:128-144.

Ollinger, S.V. and M.L. Smith. 2005. Net Primary Production and Canopy Nitrogen in a temperate forest landscape: an analysis using imaging spectrometry, modeling and field data. Ecosystems, 8(7):760-778.

Wythers, K. R., P. B. Reich, M. G. Tjoelker, and P. B. Bolstad. 2005. Foliar respiration acclimation to temperature and temperature variable Q(10) alter ecosystem carbon balance. Global Change Biology 11:435-449.

------------------------------------------2004---------------------------

Bauer, G. A., F. A. Bazzaz, R. Minocha, S. Long, A. Magill, J. Aber, and G. M. Berntson. 2004. Effects of chronic N additions on tissue chemistry, photosynthetic capacity, and carbon sequestration potential of a red pine (Pinus resinosa Ait.) stand in the NE United States. Forest Ecology and Management 196:173-186.

Butterbach-Bahl, K., M. Kesik, P. Miehle, H. Papen, and C. Li. 2004. Quantifying the regional source strength of N-trace gases across agricultural and forest ecosystems with process based models. Plant and Soil 260:311-329.

Chen, L. M. and C. T. Driscoll. 2004. An evaluation of processes regulating spatial and temporal patterns in lake sulfate in the Adirondack region of New York. Global Biogeochemical Cycles 18.

Chen, L. M. and C. T. Driscoll. 2004. Modeling the response of soil and surface waters in the Adirondack and Catskill regions of New York to changes in atmospheric deposition and historical land disturbance. Atmospheric Environment 38:4099-4109.

Chen, L. M., C. T. Driscoll, S. Gbondo-Tugbawa, M. J. Mitchell, and P. S. Murdoch. 2004. The application of an integrated biogeochemical model (PnET-BGC) to five forested watersheds in the Adirondack and Catskill regions of New York. Hydrological Processes 18:2631-2650.

Turner, D.P, S.V. Ollinger and J.S. Kimball. 2004. Integrating Remote Sensing and Ecosystem Process Models for Landscape to Regional Scale Analysis of the Carbon Cycle. BioScience. 54(6):573-584.

Pan, Y. D., J. Horn, J. Jenkins, and R. Birdsey. 2004. Importance of foliar nitrogen concentration to predict forest productivity in the Mid-Atlantic region. Forest Science 50:279-289.

Scheller, R. M. and D. J. Mladenoff. 2004. A forest growth and biomass module for a landscape simulation model, LANDIS: design, validation, and application. Ecological Modelling 180:211-229.

------------------------------------------2003---------------------------

Gbondo-Tugbawa, S. S. and C. T. Driscoll. 2003. Factors controlling long-term changes in soil pools of exchangeable basic cations and stream acid neutralizing capacity in a northern hardwood forest ecosystem. Biogeochemistry 63:161-185.

Robinson, A. P. and A. R. Ek. 2003. Description and validation of a hybrid model of forest growth and stand dynamics for the Great Lakes region. Ecological Modelling 170:73-104.

Wythers, K. R., P. B. Reich, and D. P. Turner. 2003. Predicting leaf area index from scaling principles: corroboration and consequences. Tree Physiology 23:1171-1179.

------------------------------------------2002----------------------------

Aber, J. D., S. V. Ollinger, C. T. Driscoll, G. E. Likens, R. T. Holmes, R. J. Freuder, and C. L. Goodale. 2002. Inorganic nitrogen losses from a forested ecosystem in response to physical, chemical, biotic, and climatic perturbations. Ecosystems 5:648-658.

Andersson, P., D. Berggren, and I. Nilsson. 2002. Indices for nitrogen status and nitrate leaching from Norway spruce (Picea abies (L.) Karst.) stands in Sweden. Forest Ecology and Management 157:39-53.

Gbondo-Tugbawa, S. S., C. T. Driscoll, M. J. Mitchell, J. D. Aber, and G. E. Likens. 2002. A model to simulate the response of a northern hardwood forest ecosystem to changes in S deposition. Ecological Applications 12:8-23.

Gbondo-Tugbawa, S. S. and C. T. Driscoll. 2002. Evaluation of the effects of future controls on sulfur dioxide and nitrogen oxide emissions on the acid-base status of a northern forest ecosystem. Atmospheric Environment 36:1631-1643.

Gbondo-Tugbawa, S. S. and C. T. Driscoll. 2002. Retrospective analysis of the response of soil and stream chemistry of a northern forest ecosystem to atmospheric emission controls from the 1970 and 1990 amendments of the Clean Air Act. Environmental Science & Technology 36:4714-4720.

Goodale, C.L., K. Lajtha, K.J. Nadelhoffer, E.W. Boyer, and N.A. Jaworski. 2002. Forest nitrogen sinks in large eastern U.S. watersheds: Estimates from forest inventory and an ecosystem model. Biogeochemistry 57/58:239-266.

Liang, Y. G., S. R. Durrans, and T. Lightsey. 2002. A revised version of pnET-II to simulate the hydrologic cycle in southeastern forested areas. Journal of the American Water Resources Association 38:79-89.

Mickler, R. A., T. S. Earnhardt, and J. A. Moore. 2002. Regional estimation of current and future forest biomass. Environmental Pollution 116:S7-S16.

Mickler, R. A., T. S. Earnhardt, and J. A. Moore. 2002. Modeling and spatially distributing forest net primary production at the regional scale. Journal of the Air & Waste Management Association 52:407-415.

Ollinger, S.V., J.D. Aber, P.B. Reich and R. Freuder. 2002. Interactive effects of tropospheric ozone, nitrogen deposition, elevated CO2 and land use history on the carbon dynamics of northern hardwood forests. Global Change Biology. 8 (6): 545-562

Ollinger, S.V., M.L. Smith, M.E. Martin, R.A. Hallett, C.L. Goodale and J.D. Aber. 2002. Regional variation in foliar chemistry and soil nitrogen status among forests of diverse history and composition. Ecology. 83 (2): 339-355.

Radtke, P. J., T. E. Burk, and P. V. Bolstad. 2002. Bayesian melding of a forest ecosystem model with correlated inputs. Forest Science 48:701-711.

Smith, M.L., S.V. Ollinger, M.E. Martin, J.D. Aber, R.A Hallett and C.L. Goodale. 2002. Direct prediction of aboveground forest productivity by hyperspectral remote sensing of canopy nitrogen. Ecological Applications.12 (5): 1286-1302.

Zhang, Y., C. S. Li, C. C. Trettin, H. Li, and G. Sun. 2002. An integrated model of soil, hydrology, and vegetation for carbon dynamics in wetland ecosystems. Global Biogeochemical Cycles 16.

---------------------------------------------2001----------------------------

Aber, J.D., R. Nielson and S.G. McNulty. 2001. Forest Processes and global environmental change: predicting the effects of individual and multiple stressors. BioScience. 51 (9): 735-751.

Gbondo-Tugbawa, S.S., C.T. Driscoll , J.D. Aber and G.E. Likens. 2001. The evaluation of an integrated biogeochemical model (PnET-BGC) at a northern hardwood forest ecosystem. Water Resources Research. 37 (4): 1057-1070.

McNulty, S.G. and J.D. Aber. 2001. United States national climate change assessment on forest ecosystems: An introduction. BioScience 51 (9): 720-722.

---------------------------------------------2000----------------------------

Aber, J.D. and R. Freuder. 2000. Sensitivity of a forest production model to variation in solar radiation data sets for the Eastern U.S. Climate Research 15:33-43

Berntson, G.M. and J.D. Aber. 2000. The importance of fast nitrate immobilization in N-saturated temperate forest soils. Soil Biology and Biochemistry 32:151-156

Goodale, C.L., J.D. Aber and W.H. McDowell. 2000. The long-term effects of disturbance on organic and inorganic nitrogen export in the White Mountains, New Hampshire. Ecosystems 3:433-450.

Goodale, C.L., J.D. Aber and W.H. McDowell. 2000. The long-term effects of disturbance on organic and inorganic nitrogen export in the White Mountains, New

Hampshire. Ecosystems 3:433-450.

Hendricks, J.J., J.D. Aber, K.J. Nadelhoffer and R.D. Hallett. 2000. Nitrogen controls on fine root substrate quality in temperate forest ecosystems. Ecosystems 3:57-69

Law, B.E., R.H. Waring, J.D. Aber, and P.M. Anthoni. 2000. Measurements of gross and net ecosystem productivity and water vapor exchange of a Pinus poderosa ecosystem, and an evaluation of two generalized models. Global Change Biology 6:155-168

Li, C., J.D. Aber, F. Stange, K. Butterbach-Bahl, H. Papen. 2000. A process-oriented model of nitrous oxide emissions from forest soils: 1. Model development. Journal of Geophysical Research 105:4369-4384

Magill, A.H. and J.D. Aber. 2000. Dissolved organic carbon and nitrogen relationships in forest litter as affected by nitrogen deposition. Soil Biology and Biochemistry 32:603-613

Magill, A.H., J.D. Aber, G.M Berntson, W.H. McDowell, K.J. Nadelhoffer, J.M. Melillo and P.A. Steudler. 2000. Long-term nitrogen additions and nitrogen saturation in two temperate forests. Ecosystems 3:238-253

McNulty, S.G., J.A. Moore, L. Iverson, A. Prasad, R. Abt, B. Smith, G. Sun, M. Gavazzi, J. Bartlett, B. Murray, R. Mickler and J.D. Aber. 2000. Application of linked regional scale growth, biogeography and economic models for southeastern United States pine forests. World Resource Review 12:298-320

Minocha, R., S. Long, A.H. Magill, J.Aber and W.H. Mcdowell. 2000. Foliar free polyamine and inorganic ion content in relation to soil and soil solution chemistry in two fertilized stands at the Harvard Forest. Plant and Soil 222:119-137

Stange, F., K. Butterbach-Bahl, H. Papen, C. Li and J.D. Aber. 2000. A process-oriented model of nitrous oxide emissions from forest soils: 2. Model applications. Journal of Geophysical Research 105:4385

Yano, Y., W.H. McDowell and J.D. Aber. 2000. Biodegradable dissolved organic carbon in forest soil solution and effects of chronic nitrogen deposition. Soil Biology and Biochemistry 32:1743-1751

---------------------------------------------1999-----------------------------

Currie, W.S., J.D. Aber and C.T. Driscoll. 1999. Leaching of nutrient cations from the forests floor: effects of nitrogen saturation in two long-term manipulations. Canadian Journal of Forest Research 29:609-620

Currie, W.S., K.J. Nadelhoffer and J.D. Aber. 1999. Soil detrital processes controlling the movement of 15N tracers to forest vegetation. Ecological Applications 9:87-102

Jenkins, J.C., D.W. Kicklighter, S.V. Ollinger, J.D. Aber and J.M. 1999. Melillo. Sources of variability in NPP predictions at a regional scale: A comparison using PnET-II and TEM 4.0 in northeastern forests. Ecosystems 2:555-570

Jenkins, J.C., J.D. Aber and C.D. Canham. 1999. Hemlock wooly adelgid impacts on community structure and N cycling rates in eastern hemlock forests. Canadian Journal of Forest Research 29:630-645

Kram, P., R.C. Santore, C.T. Driscoll, J.D. Aber and J. Hruska. 1999. Application of the forest-soil-water model (PnET-BGC/CHESS) to the Lysina catchment, Czech Republic. Ecological Modelling 120:9-30

Law, B.E. R.H.Waring, P.M. Anthon and J.D. Aber. 1999. Measurementsof gross and net ecosystem productivity and water vapour exchange of a Pinus ponderosa ecosystem, and an evaluation of two generalized models. Global Change Biology 5:1-15

Nadelhoffer, K.J., M.R. Downs, B. Fry, A. Magill and J.D. Aber. 1999. Controls on N retention and exports in a fertilized forested watershed. Environmental Monitoring and Assessment 55:187-210

------------------------------------------1998---------------------------

Aber, J.D., W.H. McDowell, K.J. Nadelhoffer, A. Magill, G. Berntson, M. Kamakea, S.G. McNulty, W. Currie, L. Rustad and I. Fernandez. 1998. Nitrogen saturation in temperate forest ecosystems: hypotheses revisited. BioScience 48:921-934

Aber, J.D. 1998. Mostly a misunderstanding, I believe. Bulletin of the Ecological Society of America 79:256-257

Bishop, G.D., M.R. Church, J.D. Aber, R.P. Neilson, S.V. Ollinger and C. Daley. 1998. A comparison of mapped estimates of long-term runoff in the northeastern United States. Journal of Hydrology 206:176-190

Goodale, C.L., J.D. Aber and E.P. Farrell. 1998. Predicting the relative sensitivity of forest production in Ireland to site quality and climate change. Climate Research 10:51-67

Goodale, C.L., J.D. Aber and S.V. Ollinger. 1998. Mapping monthly precipitation, temperature and solar radiation for Ireland with polynomial regression and a digitial elevation model. Climate Research 10:35-49

Magill, A.H. and J.D. Aber. 1998. Long-term effects of chronic nitrogen additions on foliar litter decay and humus formation in forest ecosystems. Plant and Soil 203:301-

Martin, M.E., S.D. Newman, J.D. Aber and R.G. Congalton. 1998. Determining Forest Species Composition Using High Spectral Resolution Remote Sensing Data, Remote Sensing of the Environment, 65:249-254

McDowell, W.H., W.S. Currie, J.D. Aber and Y. Yano. 1998. Effects of chronic nitrogen amendment on production of dissolved organic carbon and nitrogen in forest soils. Water, Air and Soil Pollution 105:175-182

Nadelhoffer, K.J., J.W. Raich and J.D. Aber. 1998. Ecosystem stoichiometry: Carbon budgets and fine root production in forests. Ecology 79:1822-1825

Ollinger, S.V., J. A. Aber and C. A. Federer. 1998. Estimating regional forest productivity and water yield using an ecosystem model linked to a GIS. Landscape Ecology 13:323-334

Ryan, D.F. and R. Stottlemeyer. 1998. Nitrogen excess in North American ecosystems: A review of predisposing factors, geographic extent, ecosystem responses and management stratgies. Ecological Applications 8:706-733

--------------------------------------------1997----------------------------

Aber, J.D., S.V. Ollinger, C.A. Federer and C. Driscoll. 1997. Modeling nitrogen saturation in forest ecosystems in response to land use and atmospheric deposition. Ecological Modelling 101:61-78

Aber, J.D. and C.T. Driscoll. 1997. Effects of land use, climate variation and N deposition on N cycling and C storage in northern hardwood forests. Global Biogeochemical Cycles 11:639-648

Aber, J.D. 1997. Why don't we believe the models? Bulletin of the Ecological Society of America 78:232-233

Currie, W. S. and J. D. Aber. 1997. Modeling leaching as a decomposition process in humid, montane forests. Ecology 78:1844-1860

Foster, D.F., J.D. Aber, J.M. Melillo, R. Bowden and F. Bazzaz. 1997. Forest response to distrubance and anthropogenic stress. BioScience 47:437-445

Hendricks, J.J., K.J. Nadelhoffer and J.D. Aber. 1997. A 15N tracer technique for assessing fine root production and turnover. Oecologia 112:300-304

Magill, A..H., J.D. Aber, J. J. Hendricks, R.D. Bowden, J.M. Melillo and P.A. Steudler. 1997. Biogeochemical response of forest ecosystems to simulated chronic nitrogen deposition. Ecological Applications 7:402-415

Magill, A.H. and J.D. Aber. 2000. Variation in soil net mineralization rates with dissolved organic carbon additions. Soil Biology and Biochemistry 32:597-601

Martin, M.E. and J.D. Aber. 1997. Estimation of forest canopy lignin and nitrogen concentration and ecosystem processes by high spectral resolution remote sensing. Ecological Applications 7:431-443

Ollinger, S.V., J.D. Aber and P.B. Reich. 1997. Simulating ozone effects on forest productivity: interactions between leaf-, canopy- and stand-level processes. Ecological Applications 7:1237-1251

Reich, P.B., D.F. Grigal, J.D. Aber and S.T. Gower. 1997. Nitrogen mineralization and aboveground net primary production in 50 stands in a cold-temperate forest biome. Ecology 78:335-347

Vitousek, P.M., J.D. Aber, R. W. Howarth, G.E. Likens, P.A. Matson, D.W. Schindler, W. H. Schlesinger and D. Tilman. 1997. Human alteration of the global nitrogen cycle. Ecological Applications 7:737-750

Whytemare, A.B., R.L. Edmonds, J.D. Aber and K. Lajtha. 1997. Influence of excess nitrogen deposition on a northern coniferous ecosystem. Biogeochemistry 38:173-187

---------------------------------------------1996----------------------------

Aber, J.D., P.B. Reich and M.l. Goulden. 1996. Extrapolating leaf CO2 exchange to the canopy: a generalized model of forest photosynthesis validated by eddy correlation. Oecologia 106:257-265

Martin, M.E. and J.D. Aber. 1996. Estimating canopy characteristics as inputs for models of forest carbon exchange by high spectral resolution remote sensing. IN: Gholz, H.G., K. Nakane and H. Shimoda (eds.) The use of remote sensing in the modeling of forest productivity. Kluwer Academic, Dordrecht, The Netherlands,(Springer: 1 edition) pp 61-72

---------------------------------------------1995----------------------------

Aber, J.D., S.V. Ollinger, C.A. Federer, P.B. Reich, M.L. Goulden,D.W. Kicklighter, J.M. Melillo and R.G. Lathrop, Jr. 1995. Predicting the effects of climate change on water yield and forest production in the Northeastern U.S. Climate Research 5:207-222

Lathrop, R.G., J.D. Aber and J.A. Bognar. 1995. Spatial variability of digital soil maps and its impact on regional ecosystem modeling. Ecological Modeling 82:1-10

Ollinger, S.V., J.D. Aber, G.M. Lovett, S.E. Millham, R.G. Lathrop and J.M. Ellis.

1993. A spatial model of atmospheric deposition for the northeastern U.S. Ecological Applications 3:459-4

Postek, K.M., C.T. Driscoll, J.D. Aber and R.C. Santore. 1995. Application of PnET-CN/CHESS to a spruce stand in Solling, Germany. Ecological Modeling 83:163-1

--------------------------------------------1993----------------------------

Aber, J.D., C.T. Driscoll, C.A. Federer, R. Lathrop, G. Lovett, J.M. Melillo, P. Steudler and J. Vogelmann. 1993. A strategy for the regional analysis of the effects of physical and chemical climate change on biogeochemical cycles in northeastern (U.S.) forests. Ecological Modeling 67:37-47

--------------------------------------------1992----------------------------

Aber, J.D. and C.A. Federer. 1992. A generalized, lumped-parameter model of photosynthesis, evapotranspiration and net primary production in temperate and boreal forest ecosystems. Oecologia 92:463-474

### Books and Chapters

Aber, J.D. 1999. Can we close the water/carbon/nitrogen budget for complex landscapes? Chapter 16 IN: J.D. Tenhunen and P. Kabat. Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. Dahlem Workshop Report. Chichester: John Wiley and Sons Ltd. pp. 313-334

Aber, J.D., I.C. Burke, B. Acock, H.K.M. Bugmann, P.Kabat, J.-C. Menaut, I.R. Noble, J.F. Reynolds, W.L. Stefen and J. Wu. 1998. Group Report: Hydrological and biogeochemical processes in complex landscapes - What is the role of temporal and spatial ecosystem dynamics? Chapter 17 IN: J.D. Tenhunen and P. Kabat. Integrating Hydrology, Ecosystem Dynamics and Biogeochemistry in Complex Landscapes. Dahlem Workshop Report. Chichester: John Wiley and Sons Ltd. pp. 335-355

Aber, J.D. and J.M. Melillo. 2001. Terrestrial Ecosystems (2nd Ed.) Academic Press

Foster, D.F. and J.D. Aber. Forest Landscape Dynamics in New England: Ecosystem Structure and Function as a Consequence of 1000 Years of Change. (in review)

Jenkins, J.C., Kicklighter, D.W. and Aber, J.D. 2000. Regional impacts of increased CO2 and climate change on forest productivity. pp. 383-423 in: Mickler, R.H., Birdsey, R.A., and Hom, J., (eds). Responses of Northern U.S. Forests to Environmental Change. Springer-Verlag, New York.

### Symposia Proceedings and Technical Reports

Aber, J.D. 1997. Paradox lost: nitrogen retention in carbon limited soils. Journal of Conference Abstracts 2:121

Aber, J., N. Christensen, I. Fernandez, J. Franklin, L. Hidinger, M. Hunter, J. MacMahon, D. Mladenoff, J. Pastor, D. Perry, R. Slangen, H. van Miegroet. 2000. Applying ecological principles to management of the U.S. National Forests. Issues in Ecology, No.6, 20pp

Martin, M.E., M.L. Smith, S.V. Ollinger, R.A. Hallett, C.L. Goodale and J.D. Aber. 1999. Applying AVIRIS at the sub-rgional scale: forest productivity and nitrogen and cation cycling. IN: Proceedings of the AVIRIS Earth Science and Applications Workshop, Jet Propopulsion Laboratory, Pasadena, CA February 1999, pp 275-280

Ollinger, S.V., J.D. Aber, C.A. Federer, G.M. Lovett and J.M. Ellis. 1995. Modeling physical and chemical climatic variables across the northeastern U.S. for a geographic information system. U.S.D.A. U.S. Forest Service General Technical Report NE-191. 30pp

Vitousek, P.M., J.D. Aber, S.E. Bayley, R.W. Howarth, G.E. Likens, P.A. Matson, D.W. Schindler, W.H. Schlessinger and G.D. Tilman. 1997. Human alteration of the global nitrogen cycle: causes and consequences. Issues in Ecology, No. 1, 15pp