Computer Modeling in the Classroom

Background:
How can agent based models of Neolithic farming communities help us understand sustainability today? By learning to use the Swidden Agricultural Model, students will better understand the human induced effects on the environment brought about by the Neolithic Revolution and how this relates to current issues of sustainability. Students and teachers should be familiar with background information provided in the Medland introduction booklet about the effects of the Neolithic Revolution on the environment and current land-use problems as they relate to sustainability.

Objective(s):
1- Using the modeling software on the internet, the student will be able to use technology to simulate how scientists are using computers to understand problems.
2- The student will be able to identify trends presented on line graphs.
3- The student will be able to use data collected about the Neolithic to explain how people sustained their populations in the past and how it can be applied to current populations.

Advanced Preparation:
*   Reserve computer room.
*   Go to the website and make sure access is not restricted by the server and your computers have the necessary software (Java and Windows XP or Mac OS 10 or greater). If you have difficulty opening the program, you can download Netlogo and swidden farming.nlogo and run it locally. This version is located at: http://www.public.asu.edu/~cmbarton/files/netlogo/ Netlogo can be downloaded from: http://ccl.northwestern.edu/netlogo/
*   Print out worksheets.
*   Become familiar with using the model.

Materials:
*   Computers with internet connection
*   Handouts: "Swidden Model Background and Glossary," "Swidden Model Worksheet" and "Checklist"

Procedure:
(If possible, load the website on all computers before class or as soon as students enter the room)
*   Give a brief overview of the project and its goals as provided by the introduction booklet.
*   Split students into groups of 1-3.
*   Read the introduction and explanation of variables together.
*   View the model to locate buttons as you explain each.
*   Each group sets up the model based on the story and runs it.
*   Teacher facilitates students using the model.
*   Students complete worksheet.

Questions for discussion:
> Poor farming decisions have already caused erosion and desertification of 7.5 million square miles of land. This has directly affected the food supply of 250 million people. (Mann, Sept 2008 National Geographic).
> Are we still facing the same problems as people living 10,000 years ago?
> Can you brainstorm other examples of negative impacts people have had on the environment? Can you think of ways people can help lessen these negative impacts?

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Evaluation:
Draw a conceptual model or write a short paragraph explaining how the decisions people make today affect the sustainability of our society. Students can choose from topics like recycling and ways to reduce your carbon footprint.

Extensions:
Students can change the values for each variable to see how they affect the model and draw conclusions about sustainability.

Resources
http://en.wikipedia.org/wiki/Agent_based_model for explanation of agent based models.
http://www.public.asu.edu/~cmbarton/files/netlogo/swidden_farming_ODD.pdf for further explanation of the Swidden Farming Model.
http://ngm.nationalgeographic.com/2008/09/soil/mann-text/1 article about depletion of soils.

Note
Two versions of the Swidden Model Worksheet have been provided. The second was adapted for an enclosed special education classroom. Teachers can decide which version of the worksheet best suits the needs and abilities of the students in their class.

Arizona Standards

Science
Inquiry Process
C1-PO4
C2-PO5
C3-PO1
History and Nature of Science
C2-PO2
Science in Personal and Social Perspective
C1-PO1
C1-PO2
C1-PO3
C1-PO4
C1-PO5
C2-PO5
C3-PO2
C3-PO3
Earth and Space Sciences
C1-PO2

Technology
Standard 1
Standard 5
Standard 6

Social Studies
Geography
C2-PO6
C2-PO7
C4-PO1
C5-PO3
C5-PO4
C5-PO5
C5-PO6
C5-PO7
C6-PO1
World History
C1-PO7
C2-PO4
C9-PO4
C9-PO5

Swidden Model Background and Glossary

The Neolithic Revolution took place 10,000 years ago when people switched from hunting and gathering their food to farming. It is called a revolution because it forever changed how people lived and what the landscape looked like. In order for these new farmers to grow their own food, they had to make decisions about how to farm. Certain decisions had negative effects on the landscape, for example a decision that decreased the soil fertility might lead to less food and starvation.

The Swidden Farming Model is an "agent based" computer model that graphically shows how different decisions affected people and landscapes during the Neolithic. It is based on the amount of energy people need to get from food in order to stay alive and continue to farm. Scientists are using the results from this model and other more complicated models to make farming decisions that will help sustain the fertility of our land and our population.

The model works by adjusting 13 variables that are based on the decisions people make and the environment they live in. The model starts as forested land on which a small farming village is established. This village grows or dies depending on what decisions people make. The model can't account for all the decisions people make, but it can simulate how agriculture would have affected the land and population.

13 Variables:
1- Initial Households
>The number of families that start the village

2- Fission Energy
>Amount of food energy needed by each family to split and make a new household.

3- Swidden Radius
>Amount of land each family can farm on. Only one family can use a patch of land at a time.

4- Harvest
>Amount of food that is grown and can be eaten. If more food can be grown, more people can live in the village.

5- Farm Cost
>Amount of food energy it takes the farmer to plant and harvest the crops.

6- Tree Clearing Cost
>Amount of food energy needed to clear the forest before crops can be planted on the land.

7- Initial Move Threshold
>If the amount of food energy drops below this number because of bad harvests, people need to move or their population with decrease.

8- Move Cost
>If a patch becomes infertile, people need to move to a new one within the village. This is the amount of food energy that the move will cost including the energy needed to build a new home.

9- Fertility Loss
>Amount of nutrients taken out of the soil by the farming method they have chosen to use.

10- Restore
>Amount the nutrients in the soil are restored by leaving fields fallow.

11- Bad Years
>Percentage of years that harvest is lower than it should be due to environmental conditions, like drought.

12- Limit Tenure
>Off- Only one person can own that piece of land
>On- If the land hasn't been farmed in a number of years (determined by Max Fallow), someone else can use it.

13- Max Fallow
>Amount of time land is left fallow before it can be re-claimed by someone else for farming.

Colors in the Model:
Red houses: households
Violet: Households that are abandoned
Magenta: Households that have died
White: Land cleared of trees for farming
Dark Green: Forest
Light Green: Farmed
Brown: Bare or Fallow

Farming Returns Graph:
Magenta: amount of food energy gained by people through harvest
Green: Amount of food harvested

Vegetation Graph:
Dark Green: Forest
Light Green: Shrub
Yellow: Herb
Brown: Bare
Magenta: Average Fertility of the Soil
Grey: Farmed
Blue: Fallow

The following is a story about Neolithic people. We are going to use a computer model to visualize how decisions made in farming can affect the sustainability of the people. It is called the Swidden Farming Model because it simulates the effects of this farming technique in which forested land is cleared by fire and cutting down trees, and then crops are planted.   The model has inputs and outputs. The inputs or variables are set by us and are based on the decisions farmers would have made. The outputs are the effects of these decisions on the landscape and the people that we can see as the model runs.

Now go to
http://www.public.asu.edu/~cmbarton/files/netlogo/swidden_farming.html,
read the story below and enter the information into the model by adjusting the sliders on the website. You can keep track of which variables were entered by using the checklist. Answer the questions and finish the story using what you know about the Neolithic and sustainability.

The Decision to Move
          Ten Neolithic families decide to leave their village in Jordan because the once thick deposit of rich soil on their farmland is starting to become dusty and erode and the environment looks different than it did when these people first lived there (set Initial Households to 10). The stalks of wheat and barley can't take root in this soil, so they are blown over on windy days and wash away on rainy days. These families are hungry!

          They have found some land that is not too far from where they live now so it will not cost them a lot of energy to move (set Move Cost to 10%). This land has some big trees on it, but it is not densely forested. It will cost this group some energy to clear the land, but not that much (set Tree Clearing Cost to 10%). The land is mostly flat but there are some hilly sections that will make it a little harder to farm (set Farm Cost to 10%).

How to Farm the Land
          After a discussion with the members of the new village, it is decided that a new method of farming is going to be used that will produce a lot of food at first (set Harvest to 40%). This new type of farming is called Swidden agriculture. But, there are tradeoffs. Harvesting more means they are removing nutrients from the soil even faster (set Fertility Loss to .30). This leaves less to grow more crops in future years (set Restore to 0).

Rules of the Village
          During the village discussion, new rules for living are made. It is decided that new households can be created once there is enough food produced (set Fission Energy to 5%), and each household can occupy 5 patches of land (set Swidden Radius to 5 patches). It is also decided that if a piece of land has not been farmed for 20 years by the original owner, anyone can use it as their farmland (set Tenure On and Max Fallow to 20 years).

Environmental Factors
          The weather where this new village is being established is relatively stable so there shouldn't be too many droughts or big storms that could affect the crops being grown (set Bad Years to 5%). But, if there is a small drop in the amount of food energy people will need to sustain themselves, they will have to move (set Initial Move Threshold to 10%)

Press Setup: houses will appear on the model
Press Run: let the model run until it stops on its own.

Finish the story…

Using the graphs and the pictures that the model made, answer the questions and finish the story about this group of Neolithic farmers.

1. Did the number of households change over time? What eventually happened to the people in the village?

_____

_____

2. Using the Farming Returns Graph, determine what happened to the amount of food they produced over time.

_____

3. Using the Vegetation Graph, determine what happened to the environment:

    A. What happened to the forest? What is this called?

    _____

    B. What types of native plants began to grow when they stopped farming the land? Did trees grow back first?

    _____

    C. What happened to the soil fertility? Did the amount of bare ground increase or decrease?

    _____

4. Was this a sustainable way to farm? Where did they go wrong with the rate at which they went through their soil resources?

_____

_____

5. What are some of the independent variables in this model?

_____

_____

6. What are the dependent variables?

_____

_____

7. Look at the computer screens around you. Did everyone get exactly the same results you did after running this same scenario? Why or why not?

_____

_____

8. Let's change some of the decisions the farmers made. Keep all the other variables the same, but change Fertility Loss to 0 and Restore to .50. By doing this, we are creating a story in which the farmers made more sustainable decisions and put nutrients back into the soil. Press Setup and Run. To stop it, press Run again. What changes do you see occurring?

_____

9. How can the decisions illustrated by the group of Neolithic farmers in both stories help us sustain our populations today?

_____

The following is a story about Neolithic people. We are going to use a computer model to visualize how decisions made in farming can affect the sustainability of the people. It shows the effects of the Swidden Farming technique (clear-clearing and burning trees, and then planting crops). The model has inputs and outputs. We will input decisions farmers made, and the model will show us what could have happened to the farmers (outputs). Archaeologists can see the outputs/effects when they dig so they use this model to predict what decisions the farmers made.

Step #1
Now go to:
http://www.public.asu.edu/~cmbarton/files/netlogo/swidden_farming.html

Read the story below and enter the information into the model.

The Decision to Move
Step #2
Ten Neolithic families decide to leave their village in Jordan because the once thick deposit of rich soil on their farmland is starting to become dusty and erode. The stalks of wheat and barley can't take root in this soil, so they are blown over on windy days and washed away on rainy days. These families are hungry!

Set Households to 10 (Click and drag the red bar to change the numbers.)

init_households

Step #3
They have found some land that is not too far from where they live now so it will not cost them a lot of energy to move.

Set Move Cost to 10%

move_cost

Step #4
This land has some big trees on it, but it is not densely forested. It will cost this group some energy to clear the land, but not that much.

Set Tree Clearing Cost to 10%

tree_clearing_cost

Step #5
The land is mostly flat but there are some hilly sections that will make it a little harder to farm.

Set Farm Cost to 10%

farm_cost

How to Farm the Land

Step #6
After a discussion with the members of the new village, it is decided that a new method of farming is going to be used that will produce a lot of food at first. This new type of farming is called Swidden agriculture.

Set Harvest to 40%

harvest

Step #7
But, there are tradeoffs. Harvesting more means they are removing nutrients from the soil even faster.

Set Fertility Loss to .30

fertility_loss

Step #8
This leaves less to grow more crops in future years.

Set Restore to 0

restore

Rules of the Village

Step #9
During the village discussion, new rules for living are made. It is decided that new households can be created once there is enough food produced.

Set Fission Energy to 5%

fission_energy

Step #10
Each household can occupy 5 patches of land.

Set Swidden Radius to 5 Patches

Step #11
It is also decided that if a piece of land has not been farmed for 20 years by the original owner, anyone can use it as their farmland.

Set Tenure On and Max Fallow to 20 years

Environmental Factors
Step #12
This area has very nice weather so there shouldn't be too many droughts or big storms that could affect the crops being grown.

Set Bad Years to 5%

Step #13
But, if there is a small drop in the amount of food produced, they will have to move.

Set Initial Move Threshold to 10%

Press Setup and Run. Let the model run until it stops on its own.

Finish the story:

1. Did the number of households change over time? What eventually happened to the people in the village?

_____

_____

3. Look at the Farming Returns Graph. What happened to the amount of food they could grow over time?

_____

_____

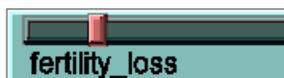2. List three things that might be causing the dips in the farming returns graph?

_____

4. Was this a sustainable way to farm?

_____

5. Let's change some of the decisions the farmers made. They wanted to be more sustainable so they decided to compost and make sure their soil did not erode away.

Keep everything else the same, but change:

Fertility Loss to 0 and Restore to .50

Press Setup and Run. Let the model run for a few minutes and press Run again to stop it. What changes do you see?

_____

_____

6. What do we do today to conserve resources?

_____

Story 1 Checklist

Variable	Setting	Check
Initial Households	10	
Fission Energy	5%	
Swidden Radius	5	
Harvest	40%	
Farm Cost	10%	
Tree Clearing Cost	10%	
Initial Move Threshold	10%	
Move Cost	10%	
Fertility Loss	0.30	
Restore	0	
Bad Years	5%	
Limit Tenure	ON	
Max Fallow	20	

Story 2 Checklist

Variable	Setting	Check
Initial Households	10	
Fission Energy	5%	
Swidden Radius	5	
Harvest	40%	
Farm Cost	10%	
Tree Clearing Cost	10%	
Initial Move Threshold	10%	
Move Cost	10%	
Fertility Loss	0.00	
Restore	0.50	
Bad Years	5%	
Limit Tenure	ON	
Max Fallow	20	

Detailed instructions and description copied from the Swidden model:

This models some of the dynamics of swidden agriculture (also called shifting cultivation or slash-and-burn agriculture)

MODEL FUNCTION

INITIALIZATION: A number of households selected by the user are placed randomly on a landscape. All households begin with 100 eu (energy units). Initially, all patches are covered with forest (vegetation = 50) and have a maximum fertility value (= 1.0). All households use a minimum amount of energy to continue to live, even if they don't farm (currently set to 1% of the initial energy).

ESTABLISHING A FARM: Households establish a farmstead and claim ownership of all patches within the user-specified <swidden_radius>. Other households cannot farm this land while it is owned. The household then begins to farm patches in area owned. Farming is not permitted on the farmstead patch itself. Farm-steads are identified by their red color. When a household moves or dies, it relinquishes ownership of its patches. An abandoned farmstead turns violet in color; a farmstead where the household dies turns magenta.

SELECTING A PATCH TO CULTIVATE: Each household selects a patch to cultivate each cycle from among owned patches that 1) have the maximum fertility and 2) produce the maximum potential net return (harvest minus costs to farm, clear land, and travel to the farmed land).

CULTIVATING A PATCH: When a patch is cultivated, it is cleared of vegetation (vegetation set to 0) and the color is set to white. The cost of clearing vegetation is scaled according to the cost of clearing forest (set by the user), with forest (vegetation = 50) costing the most to clear and nearly bare grass (vegetation = 1) the least. There is a small energy cost for travel to and from fields (currently set to 20% of the distance to the field in eu's -- i.e., cultivating a patch that is 5 units away will incur a cost of 1 eu per cycle).

The fertility value of the patch declines by the <fertility_loss> factor set by the user. The patch produces a net return to the household = <harvest> * fertility - <farm_cost>. The <harvest> (in eu's) return for each patch is set by the user, as is the <farm_cost> (i.e., the energy cost to cultivate the patch, also in eu's). The harvest is weighted by the patch fertility, which declines with each time it is farmed. The household's total energy is in-creased (or decreased) by the net return.

MOVING: If the energy of a household drops below a percentage of the initial energy (<init_move_threshold>, set by the user), the household will search for a new location to farm. It will look for a patch with fertility at least 80% of the maximum value within a radius that is 2 X <swidden_radius> X [a random number between 1 and 5]. When it finds such a location, the household will move to that patch, establish a new farmstead, and begin swidden farming around the new farmstead. There is a fixed cost to moving <move_cost> (in eu's) set by the user plus a cost scaled to distance (currently set to 20% of the distance in eu's).

LAND TENURE: If the "tenure" switch is on, households have limited land tenure. If land has lain fallow for more than the number of years set by the user in the <fallow> slider, it reverts to unclaimed and any agent (including the original owner) can claim it in the next cycle.

REVEGETATION AND FERTILITY RECOVERY: Each patch that has been cultivated but that is not currently being farmed nor is a current or former farmstead begins to re-grow vegetation. Vegetation increments by a value of 1 each cycle until it reaches 50 (forest). The user can also set a soil fertility recovery value <restore>. A patch that is not a farmstead will regain this much of its fertility each cycle until it reaches a maximum of 1.00.

STOCHASTIC EVENTS: A temporally variable environment can be simulated. A <bad_years> value can be

set by the user. This represents the approximate percentage of total cycles that there are poor harvests. Currently, a poor harvest is half its normal value. A random function selects cycles as a 'bad year'. All households are affected equally by bad years, although this could easily be changed to randomly select an individual household to have a poor harvest in any particular cycle.

OUTPUT DISPLAYS: The displays are self-explanatory. For each cycle, they track the number of households actively farming, the sum of fertility values in all patches, the mean of net harvest returns and energy per household, and cumulative number of farmsteads established.

STARTING THE SIMULATION

Set options (see above). Most options are expressed in percent of initial household energy.

Click setup

Optionally set the maximum cycles. When this number of ticks is reached, the simulation stops. If cycles is set to 0, the simulation continues indefinitely or until all households die.

Optionally set the switch to display the energy value for each household during the simulation

Click run (or step to step through the simulation one cycle at a time)

THINGS TO NOTICE

With only very small soil recovery values, farming can be maintained for thousands of cycles. Over time, initial boom bust cycles seem to level out to a dynamic equilibrium.

Varying the soil fertility loss and recovery values will cause households to shift between short and long fallow farming.

Shrubs are an uncommon vegetation community except during boom-bust cycles. Swidden farming creates a mosaic of forest and open land, but does not encourage the spread of shrubs.