

A Slow Burn: Paradata for a Model of Charcoal Production in the Eastern United States.

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I have been studying the archaeological evidence of the charcoal making industry that fueled iron production in the eastern United States from its colonial period until the mid-nineteenth century, when it was gradually replaced by bituminous coal. In areas where iron was produced, such as Western Maryland, Pennsylvania, Northern New Jersey, Connecticut, Vermont and Eastern New York State, forested areas contain numerous relict charcoal hearths (RCH) distributed across the landscape.

This project attempts to simulate the work of colliers and loggers who produced charcoal to better understand the pattern of distribution of charcoal hearths and relate that to the archaeological record. A greater understanding of the pattern of construction of charcoal hearths leads to better estimates of historical charcoal production, especially in areas that are now developed where the evidence of RCH has been built or plowed over. This simulation will also explore how work was accomplished in an industry vital to the economic development of the United States and to better understand the history of its workers.

I use Agent Based Modelling (ABM) for this simulation.¹ To perform ABM I considered three options: [NetLogo](#), ABM written in Java with its own modelling language with the same name; [Hash.ai](#), an on-line ABM platform and Mesa, an ABM framework for Python.² I wanted ABM software that was extensible, open and portable, so I ruled out Hash.ai since it required users to store models on its platform. I chose Mesa because its Python code seemed more readily extensible than Netlogo's Java application. I prefer using Python, which has an established and large user base with historians, rather than using NetLogo, which, while being a well-established language for ABM, appears to have a smaller community of users overall.

I hoped to program and use models on Google Collaboratory since it has Python already installed. However, early in my work with Mesa, I saw Mesa's web visualization would not work on Google Colab. Instead, I made the model work on a personal computer. I programmed it on a PC and tested it on both a PC and a Chromebook. I first made a simple model of a lumber mill to test concepts and develop my knowledge before modelling an iron furnace's charcoal consumption.

Using Mesa, two dimensional models are stored in grids of (x,y) coordinates. Grids can be visualized as squares or hexagons. I chose hexagons because they seem to visually represent a pattern of logging where cut wood would be brought to centralized points, better than squares.

Each hexagon represents an area. Early in the development of the model, I considered specifying the dimensions of the hexagon where, for example, each would be 100 feet wide to

¹ Shawn Graham, *An Enchantment of Digital Archaeology: Raising the Dead with Agent-Based Models, Archaeogaming and Artificial Intelligence* (New York: Berghahn Books, 2020). The idea to use ABM came from this book.

² Jackie Kazil, David Masad and Andrew Crooks. Mesa: Agent-Based Modeling in Python 3+. Python. 2014. Reprint, Project Mesa, 2021.

<https://github.com/projectmesa/mesa/blob/ab3cec5b788104d2dad6f27434f1fadfb8a7452f/CITATION.bib>.

easily reflect the distances colliers would walk from their huts to maintain a group of charcoal hearths.

Based on reading Victor Rolando's article "19th-Century Charcoal Production in Vermont" and sections of Robert Gordon's, *American Iron, 1607-1900*, this model equates the amount of wood cut on an acre of forest being equal to the amount of wood required to build a single charcoal hearth meiler, or pile. In the model each hexagon has an area of 1 acre.³ An acre of trees produced 30 cords of charcoal wood on average and 30 cords were required to build a typical meiler.⁴ This simplifies the visualization of a model. If a furnace held 12,000 acres of forest, it would be represented by an equal number of hexagons. A cutting cycle of 20 years would consume 600 acres of woodland annually.⁵

Since equating an acre of wood production to the amount required to construct a meiler is the basis of the model, I searched for more evidence to ensure this equation was correct. Gordon cites an example of a woodland producing 20 cords an acre in Connecticut.⁶ David Marquis, in his article "Clearcutting in Northern Hardwood: Results after 30 Years", notes an acre of old growth forest in New Jersey produced 60 cords of split wood per acre when cut in the 1930's.⁷ My calculation using Marquis' table of tree regrowth 25 years after clearcutting multiplied by the amount of firewood produced per tree according to Marshall Patmos' document "Estimating Firewood from Standing Trees" was only 7.3 cords of wood after 25 years.⁸ As a result of this, I questioned whether the basis of my model is wrong. However, my calculation of 7.3 cords of wood per acre is based on a table to calculate the amount of firewood, not charcoal wood, a tree produces. Checking Patmos' source of S. R. Gevorkiantz and L. P. Olsen's "Composite Volume Tables for Timber and Their Application in the Lake States" showed the authors considered only wood above

³ Victor R. Rolando, "19th-Century Charcoal Production in Vermont," *IA. The Journal of the Society for Industrial Archeology* 17, no. 2 (1991): 15–16.

Robert B. Gordon, *American Iron, 1607-1900* (Baltimore: Johns Hopkins University Press, 2019), 40, <https://muse.jhu.edu/book/72153/pdf>.

⁴ Rolando, "19th-Century Charcoal Production in Vermont," 18. "A mound of these dimensions used 30 cords of wood, the equivalent of a one-acre woodlot."

⁵ Gordon, *American Iron*, 40.

⁶ Gordon, *American Iron*, 40.

⁷ David A Marquis and Northeastern Forest Experiment Station, *Clearcutting in Northern Hardwood: Results after 30 Years* (Upper Darby, Pa: Northeastern Forest Experiment Station, 1967), 2, https://www.fs.fed.us/ne/newtown_square/publications/research_papers/pdfs/scanned/rp85.pdf.

⁸ Marquis, *Clearcutting in Northern Hardwood*, 7.

Marshall Patmos, "Estimating Firewood from Standing Trees," Educational, University of New Hampshire Cooperative Extension, January 2005, Accessed December 5, 2021, https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource001044_Rep1200.pdf.

My calculation is here:

https://github.com/jeffblackadar/hist5706_digital_history/blob/main/charcoalhearth_paradata_workbook.ipynb.

4 inches in diameter in their volume calculations.⁹ Lapwood, the smaller pieces of wood used to fill spaces in a meiler, was as thin as 3.8 cm (1.5 inches) in diameter¹⁰. I was calculating a volume of wood for each tree that was too low. It is also possible that the more intensive methods to clear-cut forests in the mid-twentieth century inhibited the regeneration of trees more so than clearing with an axe in earlier centuries, as damaging to forests as that also was. It is likely loggers using axes left trees to grow that were smaller than 3.8 cm (1.5 inches) in diameter. Also, coppicing of hardwood trees would have been practiced rather than a full clear cut. On the other hand, an argument in favour of a lower volume is Marquis' graph is for tree regeneration after 25 years, not just 20 years as practiced by some furnaces. What is clear is that there is great variation in the amount of wood produced by an acre. While 30 cords per acre is a usable figure for a model, this number is likely high for less productive forests or forests degraded after repeated cycles of cutting. To reflect this uncertainty and variability, the model has a parameter for number of cells cut per charcoal hearth. This can be set to a higher value to reflect relatively unproductive forests and large meilers or set as small as one cell of wood required per meiler. Finally, the idea that each cell is an acre can be rethought to consider this uncertainty. A cell may be thought of as half an acre or a certain width, such as 30 meters, for example. The number of cells required to construct a charcoal hearth can be adjusted to a model with hexagons of different sized areas.

Each step for the model is a year and charcoal making happened over a season of each year. Gordon writes that colliers preferred to work during the summer with dry weather and a lack of wind.¹¹ Rolando states that colliers worked from then end of the winter to the start of the next, which in Vermont's Green Mountains at that time may be a shorter period than at first thought.¹²

If the construction of a meiler took one week, burning one to two more with a further week to rake out charcoal, let it cool and load it in a wagon, the cycle of production using a single meiler was roughly four weeks. Since four weeks is much shorter than the whole charcoal producing season, it is probable that the same site was used more than once in a year, if sufficient wood was nearby to build another meiler.¹³ This probability is based on efficiency and evidence charcoal hearths were reused. Building a site for a charcoal hearth requires leveling the site which is labour

⁹ S. R. Gevorkiantz and L. P. Olsen, *Composite Volume Tables for Timber and Their Application in the Lake States* (Washington, DC: U.S. Government Printing Office, 1955), 7, <https://naldc.nal.usda.gov/download/CAT86201093/PDF>.

Gevorkiantz and Olsen's Table 4 measures cord volume to a variable "top diameter inside bark of not less than 4.0 inches."

¹⁰ Jackson Kemper, *American Charcoal Making in the Era of the Cold-Blast Furnace* (Washington, D.C.: U.S. Department of the Interior; National Park Service, 1941), 10, https://www.nps.gov/parkhistory/online_books/popular/14/index.htm.

¹¹ Gordon, *American Iron*, 34.

¹² Rolando, "19th-Century Charcoal Production in Vermont," 18.

¹³ Rolando, "19th-Century Charcoal Production in Vermont," 18. Gordon, *American Iron*, 35.

Kemper, *American Charcoal Making*, 22.

Charcoal burning took between 1-2 weeks. Raking our charcoal was a tedious task due to the risk of fire.

intensive in a hilly area with tree stumps. This work would be done only if necessary and with consideration that the transporting wood to a charcoal hearth is also labour intensive or may require teamsters to haul the wood, increasing the cost of production. New charcoal hearths would have been built near available wood rather than hauling logs a long distance to an existing charcoal hearth. Colliers needed to pay close attention when making charcoal so they would need to be nearby to check a hearth frequently. They often tended more than one hearth at a time in order to maximize the productivity of their labour.¹⁴ The model's parameter "Radius from charcoal hearth of cut area" is used to simulate how far wood would be hauled to construct a meiler.

The questions the model examines are: How far away were charcoal hearths from one another considering the factors of construction effort, transportation and travel distance of the collier between hearths? How did these factors determine the pattern of construction of charcoal hearths? How does the model's patterns compare to the archaeological record? The model is now in a state that allows simulation using parameters to explore these questions further. The model's [documentation](#) provides more detail about its function.

¹⁴ Gordon, *American Iron*, 36.

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