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Energy Flow on a Nineteeth Century Farm

Karl S. Finison
University of Massachusetts - Amherst

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Karl S. Finison

University of Massachusetts
Amherst, Massachusetts 01003

Abstract

An energy flow study of a mid-19th century farm in the Connecticut River Valley is developed in order to understand agricultural patterns at the individual farm level. Utilizing journals and account books from the Charles Porter Phelps farm in Hadley, Massachusetts, covering the years 1815-1876, an analysis of labor inputs and productive outputs is made. Energetic relationships can be compared through time and with other farms for which historical journals are available in order to determine diversity and changes in agricultural practices. Results can be used to compare energetic efficiencies on 19th century farms with other agricultural systems and to test at the individual farm level general trends suggested by agricultural historians.

General ecological theory provides a comprehensive paradigm for studying the systemic relationships between human groups and their environments. One approach to describing ecological systems is to analyze their energetic relationships between component parts. In human systems these relationships, or "energy flows," can be divided into three key variables: energy acquisition (E_a), energy consumption (E_c), and energy expenditure (E_e). Energetic analysis contributes to rigorous comparisons of different systems and, thus,to processual explanation. The following is an energetic analysis of a nineteenth century farm in Western Massachusetts.

This study of nineteenth century agricultural energetics contributes to our understanding of general ecological processes and the particulars of rural life. The farm is a well defined spatial unit with information on the historic environment (e.g., soil type, topography, resource availability, etc.) and human behavioral systems (from census records, farm account books, farm journals, and diaries). With this information, we can analyze family household consumption, model agricultural systems, and understand the interactions between demographic, environmental, and techno-economic variables. As such records are available throughout the century, it is possible to conduct a diachronic analysis, an essential dimension for understanding processual change. Furthermore, the resulting model complements the extensive historical literature on northern agriculture (e.g. Bidwell and Falconer 1941; Rogin 1931; Wilson 1936; Pabst 1941; Danhof 1969; and Russell 1976) and adds a case to the general study of cultural adaptation.

Attaining all these goals is beyond the scope of one paper. My analysis does move in this direction by detailing the synchronic "energy flows" of a mid-nineteenth century Hadley farm. I cannot emphasize enough that it is <u>not</u> intended to be the "typical" nineteenth century farm. It <u>does</u> supply a useful framework and some benchmark values for comparison <u>with</u> other farms. The differences between the Phelps farm and other farms will be as important as the similarities for understanding human adaptation. These points can be better appreciated with a brief consideration of the use of models in systems analysis.

Systems Models

Ecologists use modelling as a method of simplifying complex ecological relationships, thereby guiding research. A model is an analytical tool. It provides a description of the structure, pattern, and functional relationship of a community and its environment. This tool is constructed through a process of abstraction by which "distracting" elements of complex systems are removed.

These models can be used to achieve a number of goals. Shantiz and Behrens (1973:289) list four of these:

1. The theory of complex feedback loop systems can aid in understanding and organizing the important causal relationships in the observed system.

2. Analysis of the model's sensitivity to changes in its parameters can indicate where precise observations or measurements are important and where large observational errors are relatively unimportant in understanding overall societal functions.

3. The model provides a framework within which one can raise new questions and perceive missing information to design further studies more efficiently.

4. Analysis of the model can provide information on the behavioral relationship outside the range of parameter values historically observed. Thus it is useful for testing the probable effects on the society of new technologies or social policies.

In this paper, I will be using an energy flow systems analysis to understand causal relationships (goal 1) and to generate new questions for future study (goal 2).

There are a number of characteristics of energy that make it particularly useful for a systems model of nineteenth century agriculture. Energy is basic to all processes in the universe. Thus, energy flow systems analysis is a convenient procedure for relating component parts of an ecosystem. It is the ability to do work (measured in heat units or kilocalories); and, energy flow is energy per unit of time. The first law of thermodynamics states that energy must be transformed from one type to another, but is never created or destroyed. By this principle we should be able to account for or predict all the energy flowing through a system at a given time.

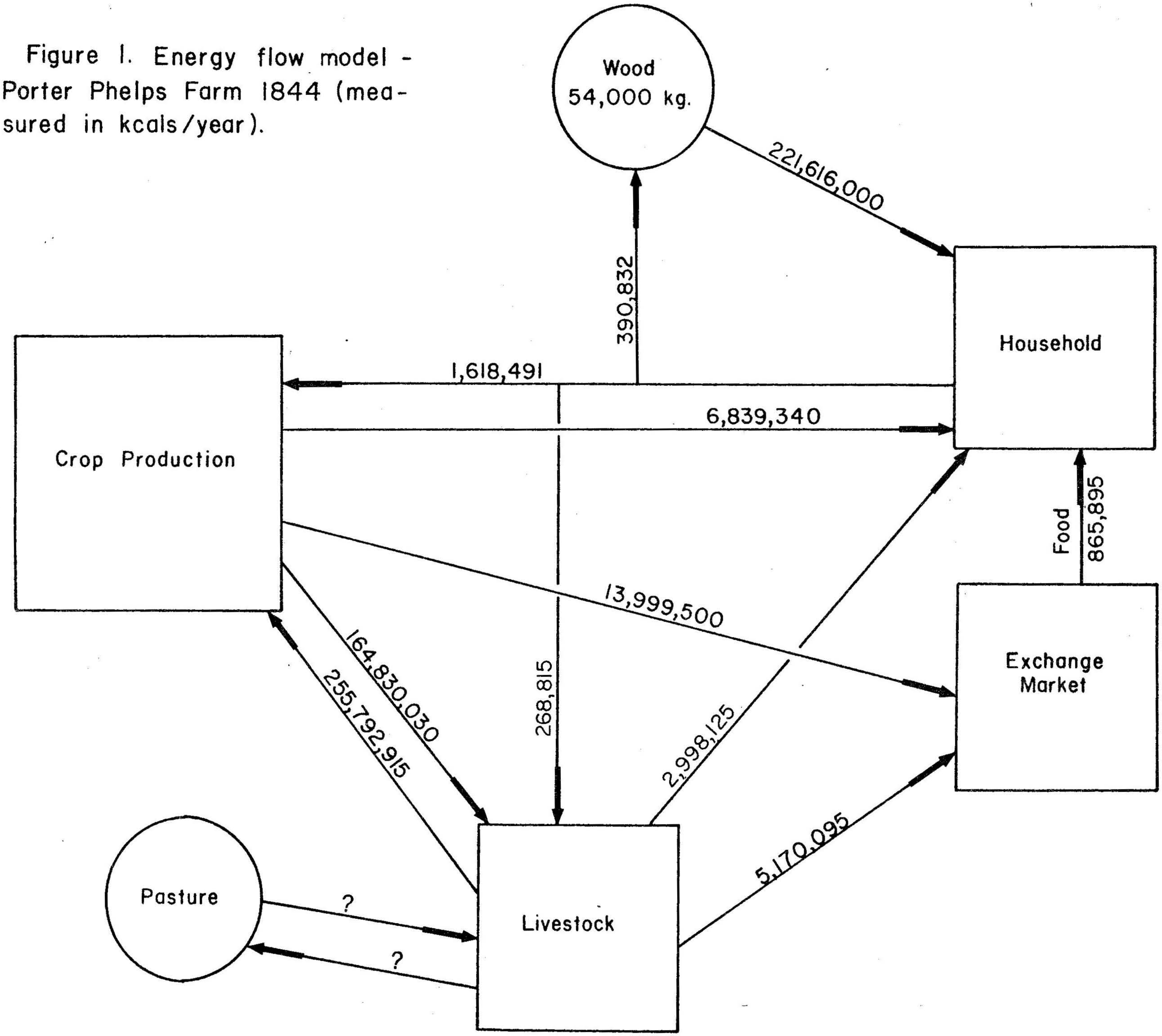
To summarize, an energy flow model provides an abstract representation of the structure and dynamic functioning of a real system. It is an analytical tool which can be used to guide research. Use of energy as a unit of measure allows for precise analysis of relationships between component parts of a systems model and allows quantitative comparisons with other systems.

The Charles Porter Phelps Farm

The energy flow model was developed from farm journals, account books, and diaries for the Charles Porter Phelps farm in Hadley, Massachusetts.[1] The farm is located in the fertile floodplain of the Connecticut River and is still being operated as a dairy farm. A considerable number of historical documents during the nineteenth century are associated with the farm. The study year for this initial model was 1844, thus giving a perspective on the farm during the pre-railroad era. The following documents were utilized.

1. A farm journal recording daily work events and production outputs is available for the years 1833 to 1876. The 1844 journal data was incorporated in the model.

Figure 1. Energy flow model - Porter Phelps Farm 1844 (measured in kcals/year).



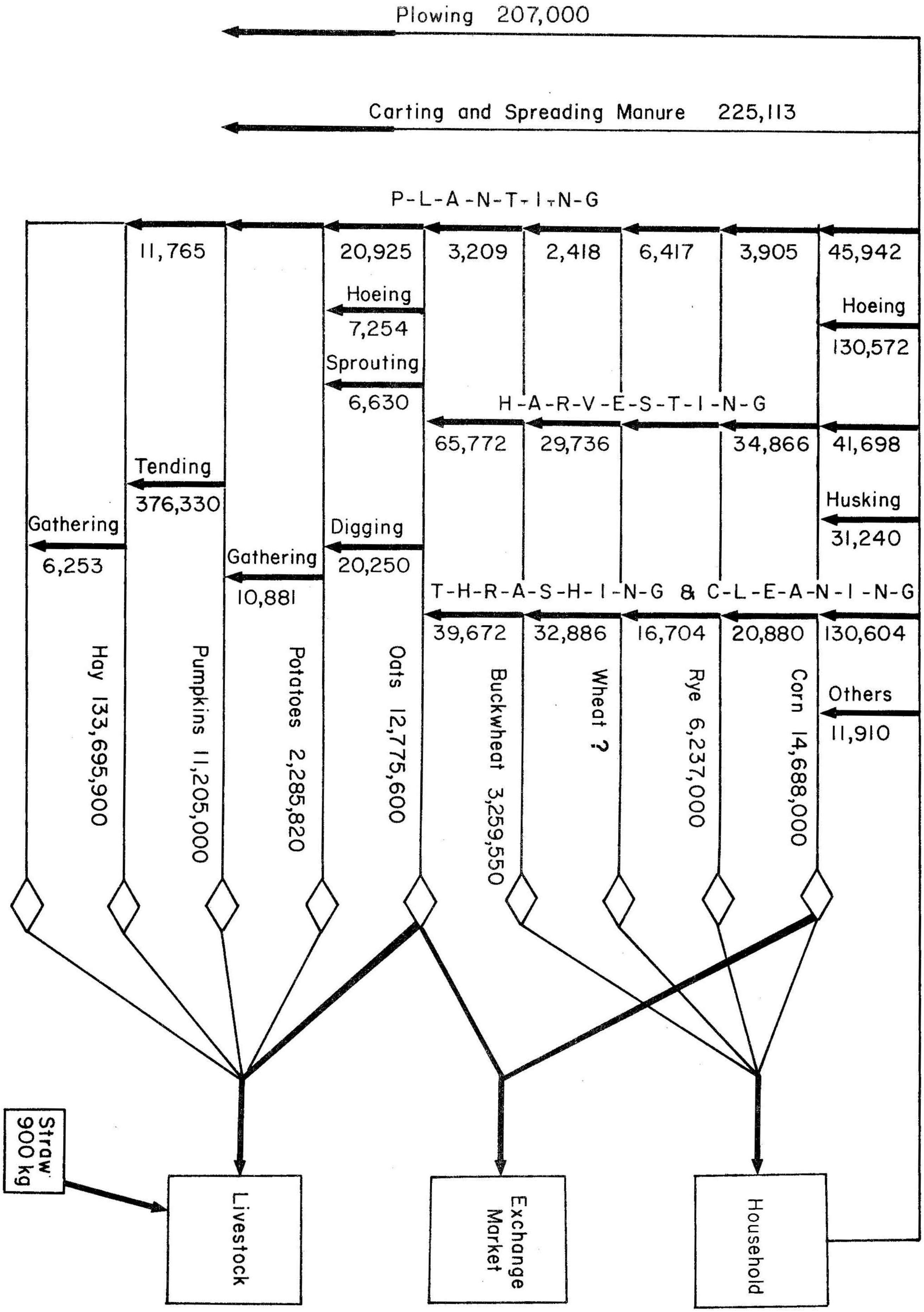


Figure 2. Crop production - Porter Phelps Farm 1844 (measured in kcals/year).

2. Farm account books from 1815 to 1876 document the economic stability of the farm and its interaction with local markets.

3. Several mid-nineteenth century agricultural publications (e.g., The New England Farmer, The Connecticut Valley Farmer and Mechanic, and the Colman Reports) were consulted to check labor expenditures and production data as well as to provide estimates of livestock production and food consumption rates.

4. Federal census material for 1840 and 1850 assisted in reconstructing family composition.

Labor expenditures were converted from man-hours to kilocalories using the work grading system developed by Durnin and Passmore (1967). Production and food consumption estimates were converted to kilocalories using Watt and Merrill's Composition of Foods (1963). Family food consumption was recorded directly from the farmer's own estimates recorded in his account books.

Energy Flow on the Charles Porter Phelps Farm - 1844

The model is presented in Figures 1-4. Figure 1 gives an overview of energetic relations of the whole system. Figures 2-4 break the system into smaller components: crop production, livestock production, and family consumption. Figure 4 also gives the demographic structure of the household in 1844.

Some of the major features of the system are:

1. Major labor expenditures go into wood-fuel acquisition, livestock care, manure carting and spreading, ploughing, and hay and corn production tasks. Of the household family of 5 males and 5 females ranging in age from 17 to 71, only two adult males are fully involved in agricultural tasks. Off-farm hired labor accounts for 26% of the total crop labor input and is concentrated during the summer harvest months.

2. Major energy productions are wood and hay (hay accounting for 72% of the total crop production). Of the total crop production, 89% is fed to livestock. A large portion of the energy flow through livestock is returned to the crop production system as manure. Major products exported to market are beef, pork, and corn. Dairy products are consumed almost entirely by the family.

3. Family consumption comes almost entirely from on-farm production with food imports accounting for only 6% of all food consumed.

4. A major problem facing this farm may have been lack of pastureland. Farm size was small, 58 acres, of which 16-20 acres was

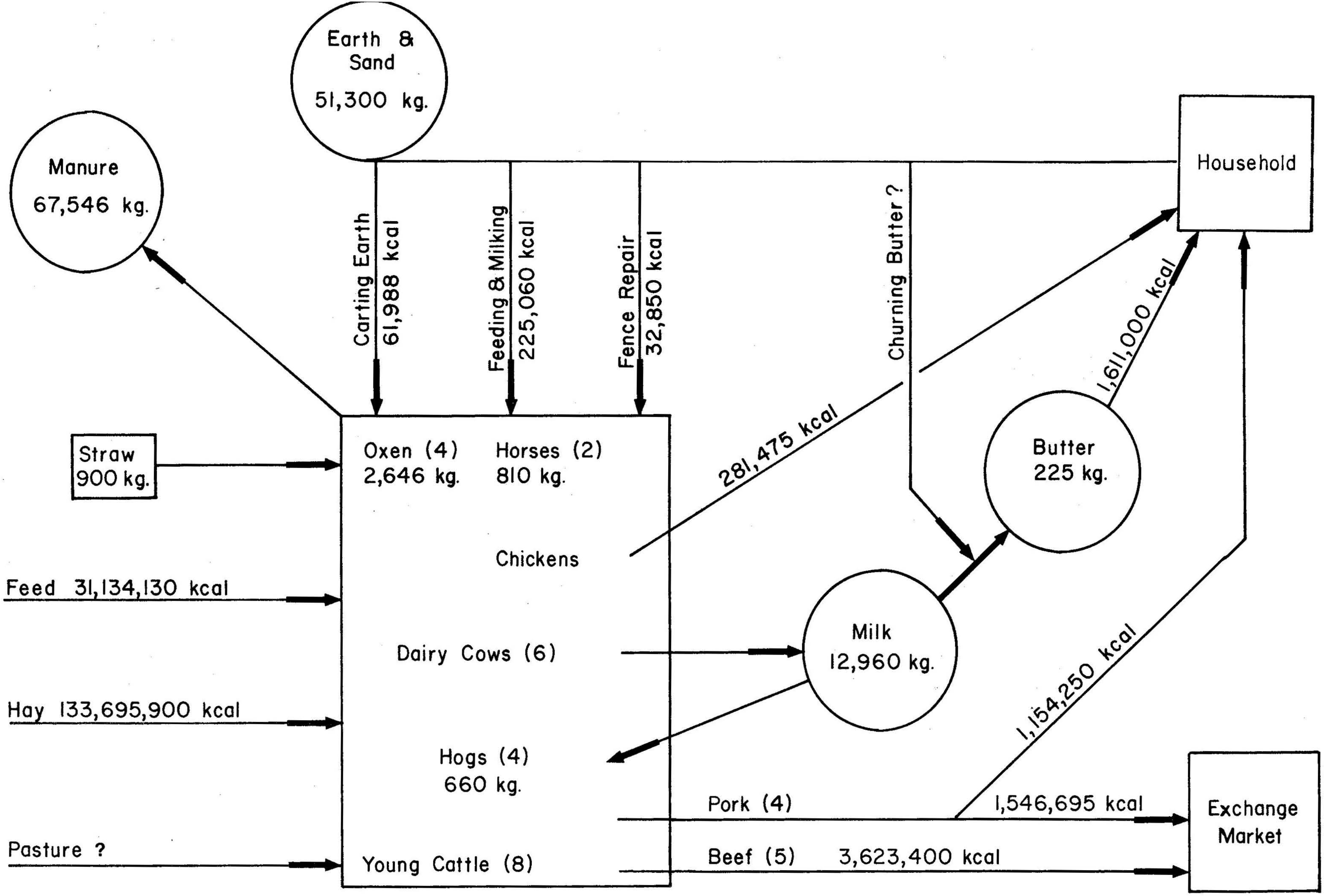


Figure 3. Livestock production - Porter Phelps Farm 1844 (numbers of animals in parentheses).

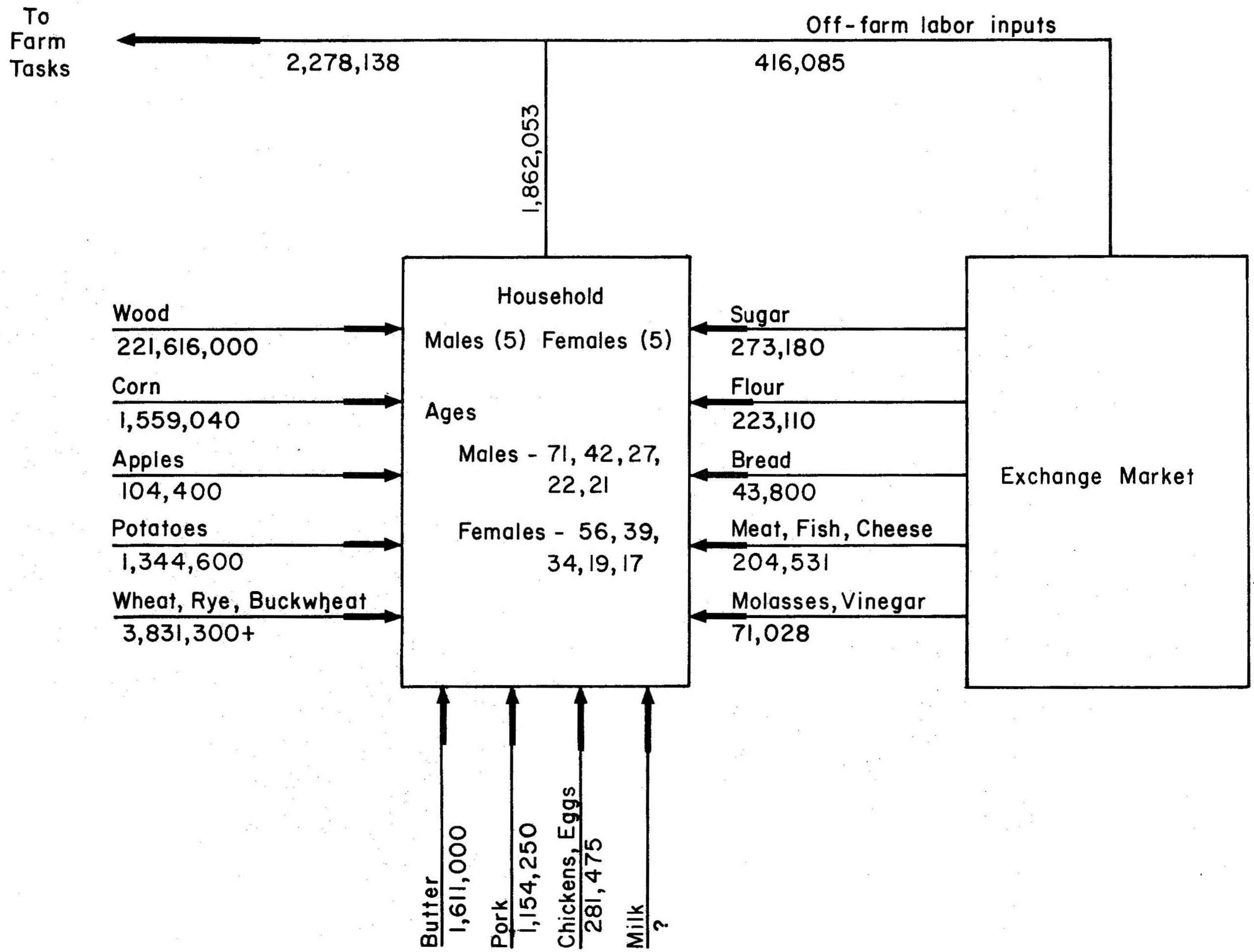


Figure 4. Household consumption - Porter Phelps Farm 1844 (measured in kcals/year).

cultivated, 20-25 mowing grass, and the rest orchard and pasture. Each year a portion of the livestock are sent to pasture in the hilltowns to the west. (It will be interesting to see if other lowland farms followed this practice of utilizing upland pastures for summer grazing.)

5. An energy acquisition efficiency ratio was computed. This ratio compares energy acquired by the household (E_a) to energy expended in acquisition (E_e). In other words, how many kilocalories are produced for each kilocalorie expended. In this model E_a was estimated as production consumed, P_c, plus production exported, P_e. E_e was estimated as energy expended in crop production, E_{ec}, plus energy expended in livestock care, E_{el}. The energy acquisition efficiency ratio (E_a/E_e) was found as follows:

$$E_a/E_e = \frac{P_c + P_e}{E_{ec} + E_{el}}$$

Substituting values from the energy model yields:

$$E_a/E_e = \frac{9,837,465 + 19,169,595}{1,618,491 + 265,815}$$

or, an energy acquisition effiency

$$= 15.39.$$

The energy efficiency figure computed here, 15.39, falls within the range for non-mechanized agricultural systems. Little and Moren (1976) have compiled efficiency ratios from several studies of slash-and-burn agriculturalists in New Guinea - specifically the Miyanmin, 3.8, the Raiapu Enga, 5.3, and the Tsembaga Maring, 10.2. Peruvian Indians practicing a mixed cultivation-herding system have an efficiency of 7.5. The highest ratios, some as high as 30.0, were found for Central and South American systems.

A word of caution is required concerning the ratio, 15.39, computed here. This is likely to be too high as it was not possible to estimate some of the major labor inputs such as churning butter, butchering animals, preparing food, or other work, especially that of women. If these values had been included the ratio would decrease.

Prospects

There are four important areas for future research. First, additional work values, particularly for women and children, need to be estimated. Second, the conversion values taken from Durrin & Passamore (1967) and Watt and Merrill (1963), could be refined. Third, diachronic analysis for this farm could be pursued to study human adaptation to changes in demographic, environmental, and techo-economic conditions. Finally, the Phelps farm can be compared with other farms to see how energy production, labor acquisition and allocation, and the energy acquisition efficiency ratio varied in the Connecticut River Valley.

Results of these expanded studies will have important implications for our understanding of the evolution of human societies. To encourage such work, I offer the following tentative scenario based on my study of the Phelps farm.

It is generally recognized that as societies grow and become more complex they must capture more energy from their environments. During the nineteenth century population growth in cities, such as Boston and later Greenfield, Northampton, and Springfield, made new demands for energy on the agricultural "producers" of the Connecticut Valley. After 1800 a transition took place from farming strategies which were generalized, diversified, and primarily subsistence with production for local consumption to farming strategies which were specialized, simplified, and commercial, with production for export to urban centers.

On the Phelps farm in 1844 we can see elements of both types of farming strategies. The farm is largely self-sufficient, supplying its own wood for fuel and most of its own food. Labor inputs come largely from the family itself. Oxen are still the primary power sources and hand tools are being utilized for agricultural tasks. These are characteristic of "subsistence" agriculture. Other elements of the farm strategy indicate growing involvement in commercial networks. Corn for fattening livestock and pork and beef are being produced for the growing market in Boston. In this pre-railroad era, while little energy input is being received from off the farm, the farm is exporting considerable amounts of energy to Boston. If the Phelps farm proves to be typical of other farms in the valley at this time, we can view the Connecticut Valley as a "producer" subsystem for a growing and increasingly complex system in Boston.

While the Phelps farm can be viewed as an energy "producer" in 1844, I expect that analysis of later years following introduction of railroad ties to the area will show that the farm has become an energy "consumer" as well. As the farm devotes more of its energy to production of a few special items for sale in commercial markets, it must begin to rely more and more on other specialists for items it no longer has the time or energy to produce. Thus, increased specialization which is characteristic of commercial agriculture forces energy "producers" to increasingly become energy "consumers".

This scenario is sure to be refined with work along the lines suggested above. The refinements will come about through studying how other farms differ from the benchmark values found for the Phelps' energy flow system, and by studying how the Phelps' values changed through time. Clearly, working with a systems model approach to energy flows holds great promise as a way to understand the human responses to the changing conditions of rural life in the nineteenth century Connecticut River Valley.

Footnotes

1 I would like to thank Mrs. Doheny H. Sessions and Mr. Robert J Pierce of the Phelps farm in Hadley for their assistance in this study. Mrs. Sessions granted me access to the material used to prepare the study and answered many questions about the family history. Mr. Pierce helped make the labor expenditure estimates and answered questions about farming technology used in the journals.

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