Modeling Whole Farm Systems to Enhance Beginning Small Farmer Success in Southwest Virginia

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ACADEMIC ABSTRACT

The number of very small farms (<10 acres) is increasing and beginning farmers (in practice for <10 years) are more likely to run them. Very small farms are typically complex systems in which the farmer manages both production of a diverse array of crops and marketing of crops directly to consumers and their failure rate in early years is high. This work seeks to increase the likelihood of success for beginning farmers by understanding these complex systems better. We collected qualitative and quantitative data from interviews with three successful beginning farm operations in Southwest Virginia covering practical and philosophical aspects of farm production, sales and management. We mapped social, environmental and economic aspects of farming systems and studied how farmers use resources (Community Capitals) and management to enhance their system's success, developing a broader definition of success that encompasses what farmers gain from farming beyond profitability. Using these maps, we created a system dynamics model of a small farm system in STELLA including unique components such as customer attraction and retention. Through model development, we learned that these successful farmers began their operations with experience and financial resources, and employed their skills, resourcefulness and cultural and social capital to charge prices for their products that could sustain their operations financially. Using our model, current and aspiring farmers, service providers, and small farm advocates will be able to simulate real or hypothetical farm systems to better understand what establishing a successful small farm might require and how to confront potential challenges.

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GENERAL AUDIENCE ABSTRACT

Changes in the US farming system over the 20th century have led to both an increased need for new farmers to enter the profession as well as increased barriers to entry for aspiring farmers. The number of very small farms (<10 acres) is increasing and beginning farmers who have been in practice for less than 10 years are more likely to run them. Very small farms are typically complex systems in which the farmer manages both the production of a diverse array of crops and the marketing of those crops directly to consumers, and the failure rate in the beginning years of these enterprises is high. This work seeks to better understand these complex systems in order to increase the likelihood of success for beginning farmers. We began by developing a definition of success based on what farmers seek to gain by farming beyond establishing profitable farms and by studying how farmers can use resources (Community Capitals) and management to achieve that success. Financial viability is necessary for the success of commercial farms, but success often also encompasses environmental stewardship, establishing ties to the community and achieving a healthy work-life balance. We based our analysis on three case study farm operations—farmers in their first 10 years of practice who have established successful farms in Southwest Virginia. We conducted interviews during site visits to each farm that addressed practical and philosophical aspects of farm production, sales and management. The qualitative and quantitative data collected from interviews were then used to map out social, environmental and economic dimensions of a small farm system. We developed our farm system map into a system dynamics model in STELLA to define the relationships between farm system components and to simulate and observe system behavior. Through developing the model, we learned that these successful farmers began their operations with experience and financial resources, and employed their skills, resourcefulness and cultural and social capital to charge prices for their products that could sustain their operations financially. Model users will be able to use the model to test scenarios based on real or hypothetical farming systems and to observe the potential impacts of changes. Through the use of this tool, current and aspiring farmers, service providers, and small farm advocates can better understand what may be required to establish a successful small farm and the potential challenges they may face.

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I have prefaced my thesis with a Wendell Berry quotation as a tribute to the second farmer who participated in this work. Across both interviews, he mentioned Wendell Berry nine times, citing the inspiration he found in Berry's writing. I regret that for my readers he, and all of the farmers, must remain only an anonymous source of data in an academic work. I'm deeply grateful to the three farms for their warmth and openness and for taking time out of their very full lives to participate in this project.

Further, I'm grateful for my opportunity to work with a project team that embraces the human dimensions of a farming system alongside the biophysical and economic. Although it is impossible for me to do full justice presenting the culture and values of these farmers, I appreciate that the Mapping Sustainable Farm Systems project team agrees that the concept of "success" must emphasize that farmers pursue this lifestyle seeking so much beyond their income. Thanks to Dr. Kim Niewolny and Lorien MacAuley on the Virginia Tech team for leading the way with the interviews and for Lorien's help with transcription. Thanks also to Dr. Niewlony as well as Drs. Evanylo and O'Rourke for their willingness to entertain and challenge my ideas as members of my committee.

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Agriculture must mediate between nature and the human community, with ties and obligations in both directions. To farm well requires an elaborate courtesy toward all creatures, animate and inanimate. It is sympathy that most appropriately enlarges the context of human work. Contexts become wrong by being too small - too small, that is, to contain the scientist or the farmer or the farm family or the local ecosystem or the local community - and this is crucial.

— *Wendell Berry, Bringing it to the Table: On Farming and Food*

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Chapter 1: Introduction

Shifts in the Farming System

Industrialization and Farmer Exit

The agricultural sector in the United States has undergone great structural changes during the 20th century. There have been sharp declines in the percentage of the US population employed in agriculture as well as the absolute number of people employed. Between 1900 and 1999, the portion of the labor force employed on farms went from 38% (approximately 9.1 million people) to less than 3% (approximately 4.2 million) despite the more than threefold increase in population during the period (Fisk, 2001). Simultaneously, the number of farms declined by 63% and average acreage of farms increased 67% (Dimitri et al., 2005). These changes have been made possible by technological advances that have increased yields, such as improvements in breeding, pesticide and fertilizer use, as well as increased mechanization that allowed individuals to manage greater and greater tracts of land (Ilg, 1995). As farms have increased in size and use of technology, the share of the food dollar returned to farmers has been shrinking, greatly increasing the expense and risk of establishing a commercially viable farm (Heller and Keoleian, 2003). Although median farm household income in 2010 was $54,162, slightly higher than the national median of $49,445, the median net worth of farm households was $576,745, compared to the national median of $77,300 (Park et al., 2011; Noss, 2012). This high asset-to-income ratio makes entry to farming prohibitively expensive for an aspiring farmer who has not inherited assets from a previous generation.

Although these trends have been continuing for over a century, there is evidence that these changes may not be sustainable. The average age of farmers has been increasing for decades and continues to rise, from 50.3 in 1978, 54 in 1997, to 58.3 in 2012 (National

Agriculture Statistics Service, 2009, 2014). A new generation of farmers is needed to ensure the stability of our food system as many farmers prepare for retirement. Despite the barriers to entry of "average" or "conventional" farms, very recent shifts in the US farming system are providing an easier pathway to entry for aspiring farmers.

Rise of the "Local Foods Movement" and Opportunities for Farmers

The notion of a "farmers market" long predates industrial agriculture, although with the popularization of supermarkets in the mid-20th century they all but disappeared. Farmers markets slowly regained popularity in the second half of the 20th century and have expanded greatly in the last 20 years. For example, New York State had only six markets in 1965, growing to 174 by 1994, then quadrupling to nearly 700 by 2015 ("USDA - AMS - Local Food Directories,"; Lyson et al., 1995). Nationally, the number of markets has more than doubled each decade since 1994, from 1,755 to 3,706 in 2004 to 8,284 in 2014 (Economic Research Service, 2014).

This proliferation in farmers markets has come about due to recent changes in consumer preferences, often broadly referred to as the "local foods movement." Many report that the purchase and consumption of fresh produce directly from farmers who grew it in the region has an array of benefits: promoting healthier diets for the consumers, keeping money in the local economy, maximizing the share of the food dollar retained by the farmer, reducing fossil fuel emissions through the short distance food travels from field to plate and promoting sustainable and organic agricultural practices, to name a few (Guptill and Wilkins, 2002; DeLind, 2010). The geographic boundary of what food can be considered "local" is generally expressed as a radius, in miles, around a community in which the food must be grown. There is no universally defined limit to the distance that can be considered "local" since the population density and production capacity of a region need to be considered (Martinez et al., 2010; Duram and Oberholtzer, 2010).

In 2012, direct-to-consumer food sales outlets such as farmers markets generated $1.31 billion in sales (Economic Research Service, 2015). Direct-to-consumer outlets also include farm stands and farm shares/“community supported agriculture” (CSAs) in which customers pay the farmer upfront in exchange for installments of products over the growing season. Under the farm share or CSA system, delivery of products is not guaranteed; customers share the risks inherent in farming with the farmer. There are many other sales outlets considered a part of the “local foods movement” that are not direct-to-consumer. These include sales to restaurants or schools and institutions, or to aggregators or “food hubs” who distribute and market the products of multiple farms (Barham et al., 2012). Altogether, 7.8 percent of U.S. farms use local food sales pathways, with all avenues of local food sales representing about 1.5 percent of the total value of U.S. agricultural production (Economic Research Service, 2015).

This change in demand and consumption is tied to changes in production as well. Due to the aforementioned shifts in conventional farms, the midpoint acreage (a measure of median that considers only cropland) across all farms in the U.S. was 1,105 acres as of 2007 (MacDonald et al., 2013). However, the number of very small farms (less than 10 acres) is currently increasing. Through intensive production of high value crops and access to sales outlets willing to pay a premium price, among them farmers markets, these very small farms can be commercially viable and able to financially support a family from farm income (Martinez et al., 2010). Further, these small scale farms, with small land and equipment requirements, have much lower barriers to entry than their conventional counterparts a hundred times their size. As such, these very small farms seem to be a practical means of entry for aspiring farmers, and, indeed, they are statistically more likely to be operated by farmers who have been in practice for less than 10 years (Ahearn and Newton, 2009). However, the establishment of very small farms to serve the new “local foods” consumer should not be viewed as simply a calculated economics move to fill a market niche (Lyson, 2012). Interviews conducted by Alsos et al., 2003, indicated that farmers who had been motivated to start farming for social reasons (the farm lifestyle, sense of community) were more likely to operate small farms with low capital requirements than farmers who were more motivated to farm as a business opportunity. Recently, there seems to be increased interest in farming as a way of joining the “local foods movement” from the supply side, with people from non-traditional backgrounds aspiring to become farmers in order to produce food for others in ways that align with their ethical beliefs (Hamilton, 2010). Lyson, 2012, describes the rise in small farms as the growth of a “civic agriculture” movement, a departure from “commodity agriculture.” The “small farm” as presented in this work aligns with his concept of civic agriculture (Table 1.1).

TABLE 1.1—CHARACTERISTICS OF CIVIC AGRICULTURE (LYSON, 2012)

Farming is oriented toward local markets that serve local consumers rather than national or international mass markets.
Agriculture is seen as an integral part of rural communities, not merely as production of commodities.
Farmers are concerned more with high quality and value-added products and less with quantity (yield) and least-cost production practices.
Production at the farm level is often more labor-intensive and land-intensive and less capital-intensive and land-extensive. Farm enterprises tend to be considerably smaller in scale and scope than industrial producers.
Producers more often rely on local, site-specific knowledge and less on a uniform set of “best management practices”.
Producers forge direct market links to consumers rather than indirect links through middlemen (wholesalers, brokers, processors, etc.).

The term “farmer” evokes an enduring mental image of someone working their land to produce food. However, it’s an imprecise term that may mask the complex relationships of who owns the land being cultivated, who is managing the operation, and who is laboring on the land. The term “farmer” connotes a sense of authority, beyond what a “farm laborer” or “farmworker” might have, but, as we use the term here, it does not necessarily imply ownership of the land being farmed. Depending on how management of the farm is structured, there may be more than one farmer per farm, and management may be a collective effort of a “farm household” or “farm family,” the individuals supported by the farm.

Although sustainability on farms is conventionally thought of in terms of the prevention of degradation of natural capital in order to support production in perpetuity, we take a more complex and comprehensive perspective in our analysis of small farm systems. “If agriculture is to meet the needs of society – providing food and other products while protecting natural resources – it must first meet the needs of the farmers who implement and manage it” (Hansen and Jones, 1996). Preservation of natural capital is an integral part of a sustainable farming operation, but if the farm cannot also meet the financial needs and fulfil the personal goals of a farm family is not truly sustainable.

PROJECT ORIGINS

The work presented here is a part of a larger research project designed to better understand beginning farm operations in the Upper Southeast. As defined by the USDA, beginning farmers are anyone who has been in operation for 10 years or less (Ahearn and Newton, 2009). The project is entitled “Mapping Sustainable Farm Systems: An Integrated Focus on Upper South New Producers as Catalyst of ‘Good Stewardship’” and is funded by a Southern Sustainable Agriculture Research and Education grant from the USDA. The project is a collaboration of three universities: the University of Kentucky, the University of Tennessee and Virginia Tech and is composed of a diverse team of researchers who bring together a social science perspective (rural sociology, adult and extension education) with a biophysical perspective (agroecology, crop and soil sciences) as well as agricultural economics. The project is framed around "maps" as a multi-faceted approach to comprehensively assess the forms of capital available to and used by beginning farmers. The three principle foci of these maps are farms (biophysical), farmers (socioeconomic) and perspectives on sustainability (cultural). The project seeks to explore how aspiring and beginning farmers make use of the information and resources available to them and how they incorporate those concepts into their operations, with special emphasis on their perception and adoption of sustainable practices. Through a better understanding of the farmer learning and decision making process, this work aspires to assist extension, outreach and education efforts to more effectively serve the population of beginning farmers.

In the first stages of this project, an advisory board of producers and stakeholders was formed in each state. Each board was composed of farmers and service providers in the study region who met regularly with one or more members of each state's research team to guide and advise further project steps. Researchers at the University of Kentucky developed and piloted a protocol for a series of listening sessions as a means of exploring how beginning farmers make use of the resources available to them. Farmer resources were defined in terms of the Community Capitals Framework (CCF), which was originally developed for use in community development work (Emery et al., 2006). The CCF defines seven types of capital to address cultural-socioeconomic-environmental interaction (Table 1.2). Analyzing a farmer's resources in terms of the CCF helps broaden the scope of our research beyond wealth, with the hopes of learning how farmers can make full use of the array of resources available to them while managing their resources sustainably.

TABLE 1.2—THE SEVEN COMMUNITY CAPITALS (EMERY ET AL., 2006)

natural	*the ecosystem services available to farmers*
human	*the skills and abilities of people, e.g. on-farm labor*
social	*the connections between farmers and other individuals and organizations*
cultural	*benefits from sharing an ethos or values with others, e.g. customer loyalty*
political	*access to power and power brokers*
financial	*money or wealth*
built	*supporting infrastructure*

The listening sessions guided groups of participants consisting of beginning and aspiring farmers through a collaborative activity to brainstorm the resources a farmer must have access to in order to succeed, to identify categories for grouping these resources, and to select which resources are the most critical for success and which are the most challenging to access. Farmers were then asked why they selected those resources and what kinds of research and outreach they would find helpful. The advisory board assisted the research team in finding opportunities to conduct listening sessions, such as conferences or classes where beginning farmers would be present. The Virginia team conducted a total of seven listening sessions, each with an average of seven participants, in six different communities throughout the study region.

The next stage of the project was to conduct case study interviews to collect in-depth information about the farming operations of a few select beginning farmers whom advisory board members identified as having established commercially successful farms. The listening sessions gave the research team better awareness of which resources are critical to beginning farmers and helped them to write a case study protocol designed to learn from successful farmers how their resource use has contributed to their success. Researchers at University of Kentucky drafted an interview protocol and worksheet which received contributions from the other members of the research team. Protocol questions were arranged into themes representing the diverse disciplines and interests of research team members. The protocol was used to conduct the three case study interviews in each state. The questions were generally not asked verbatim but used to shape conversation with the farmers while ensuring each topic was covered. Each farm was interviewed in two on-site visits, conducted a few weeks apart. The protocol for the first interview was designed to introduce the farmer to the research team and orient them to their farming operation. This initial interview covered the farmers' history and experience, how this farm was started and financed, how the farm is managed and who makes management decisions, the ownership of the land being farmed and land use history, how records are kept, and which markets the farm relies on. At the end of the first interview, farmers were asked to complete a worksheet detailing their crops, farm equipment, labor, sales outlets and budgets to be returned during the second interview. The protocol for the second interview covered specifics of biophysical management, the farmers' motivations, aspirations and worries, their connectedness to their community, reflections on their financial situation, and their perception of vulnerability and risk. The research team presented preliminary concept maps at the second interview to communicate with farmers about how their systems would be mapped and modeled by the research team. A portion of each interview was spent walking around the farm, inviting the farmers to explain their operations visually and giving researchers a spatial understanding of the farm.

Study Site

Of the three states that conducted these case study interviews, this study draws exclusively from the three interviews with farmers in Southwest Virginia. Virginia is a socio-economically, demographically and geologically diverse state, spanning from the Atlantic Ocean in the east to the Appalachian Mountains in the west. Areas with high population density are concentrated in the east of the state, with affluent suburbs of Washington, D.C. in the northeast of the state and lower-income urban areas like Richmond in the southeast. The Appalachia communities in the southwest of the state tend to be rural and lower-income.

Virginia's congressional districts generally align with the socioeconomic diversity across the state. All farms and the farmers markets they participate in are located in Virginia's 9th congressional district which contains all counties west of Roanoke. According to 2011 Census data, the 9th congressional district has the second lowest population density in the state, the lowest median household income ($36,634), lowest percent high school graduates (80.9%), and the second highest percentage of households receiving SNAP benefits (16.3%) (Table 1.3). The table below also illustrates that although Virginia has a higher median household income, higher educational attainment and lower percent of households receiving SNAP assistance than the US as a whole, the data for the 9th district show the opposite (US Census Bureau, 2011).

TABLE 1.3—SOCIOECONOMIC DATA OF STUDY SITE (US CENSUS BUREAU, 2011)

	MEDIAN HOUSEHOLD INCOME (2011 USD)	UNEMPLOYMENT (% LABOR FORCE)	HIGH SCHOOL EDUCATION OR HIGHER (%)	BACHELOR'S DEGREE OR HIGHER (%)	HOUSEHOLDS RECEIVING SNAP (%)
9th District	$36,634	9.2	80.9	18.5	16.2
Virginia	$66,744	7.7	87.8	34.9	9.5
United States	$50,502	10.3	85.9	28.5	13.0

As of 2012, the 9th district ranks third in the state in value of sales of vegetables produced, and is in the 40th percentile among all congressional districts (National Agriculture Statistics Service, 2012). The top three land use classifications for farms in the 9th district are pasture (42.8%) and woodland (29.5%) with cropland (24.0%). Less than 5% of farms are in the district across all use classifications are under 10 acres in size.

These statistics may have a wide variety of implications for a small vegetable operation trying to sell locally. The data suggest that small farms are relatively uncommon in the region. However since these farms fit a small niche within the large and diverse agricultural sector as a whole, it is impossible to conclude from this data whether or not that niche has been filled. Farming in a rural area may prohibit access to large markets, but may offer shorter distances to smaller markets and lower prices for land. A higher unemployment rate could make it easier for the farmer to hire labor, but may make it more difficult to supplement the farm income by seeking employment off the farm.

The data in Table 1.3 seem to suggest that a farmer trying to sell produce within lower income communities is at a business disadvantage, but the reasons are not clear cut. Low-income areas, both rural and urban, often meet the definition of "food deserts" where fresh produce from supermarkets and farmers markets is inaccessible to most residents, and farmers markets are often market themselves to middle class consumers (Hinrichs, 2000; Ver Ploeg, 2010). However, when physical access is addressed, financial barriers may still exist. This may be, in part, a matter of perception since locally grown produce is often perceived to be more expensive than the same products in grocery stores although this is not always true (Pirog and McCann, 2009). Regardless, since fresh produce is more expensive on a per-calorie basis and more difficult to prepare than the palatable prepared or packaged food most widely available in food deserts, the consumption of fresh produce is disincentivized for low income families (Drewnowski and Darmon, 2005). Further, low income families must put more work into planning meals than middle class families given their tighter budgets (Thomas, 2014). Thus the unpredictable selection and prices coupled with the limited hours and locations of a farmers market may provide more barriers to low income families who have less flexibility in their food purchases, even when desire and price are held equal. SNAP programs that increase the value of SNAP benefits at farmers markets are becoming increasingly available and hope to reincentivize local produce consumption for low income families. Also, it should be noted that income distribution even in a low-income region is often highly heterogeneous. There are small farms in the region, including in our case study, who have access to a solid market base of traditional, middle class farmers market customers and are relatively unaffected by the regional socioeconomic trends.

RESEARCH QUESTIONS

1. *How can qualitative and quantitative case study data be used to develop a model of a farm system?*

In this work we have developed a system dynamics model in STELLA to capture the farm operation of a small scale beginning farmer as a means of better understanding these systems. The model is generic in the sense that it is constructed using components and process common to many small farm operations. Through modifying inputs, the user can simulate a real or hypothetical farm system—but the model structure and how those components interact are drawn primarily from the three farms that participated in the case study interviews. The wide variety of data collected in these interviews shaped the creation of the model on many levels, making for an innovative model building process.

2. *How do small scale, beginning farmers in Southwest Virginia define success?*

For commercially oriented farms, profitability is a necessary, not sufficient, factor of success. Excessive focus on this single dimension of success can overshadow farmers' other motivations that inspired them to enter the profession and make their work fulfilling. A study to enhance farmer success must look beyond the bottom line and acknowledge that farmers likely seek to gain much more by farming.

3. *What role do the many resources of a farming system play in the success of that farm? Which are necessary for success? Which have the strongest influence on success? What are the tradeoffs?*

In order to enhance the success of beginning farmers, both in terms of the farmer's perspective and economic viability, we can use the model and the model creation process to learn how resources (studied in this work using the Community Capitals Framework) contribute to the success of the farm. Further, we can determine the extent to which each type of capital contributes to success and identify which have the greatest impact.

4. *Which of these factors were in place when the farmer began the operation (exogenous) and which factors can be acquired or strengthened over time when the farm is in business (endogenous)?*

It is important to distinguish between exogenous and endogenous success factors because they are relevant to different model users. Aspiring farmers can better equip themselves before they begin farming by considering exogenous success factors. Endogenous factors can help current farmers make changes to their current operations in hopes of achieving greater success and can assist aspiring farmers in planning their farming practice.

5. *How can a successful farm also become a resilient farm? What does resiliency look like in a farming operation?*

Ideally, a farm operation will not only be able to attain success by metrics they define but can also maintain a successful operation over time, despite varying and unpredictable conditions. A resilient operation can handle periodic "shocks" in weather or markets as simulated in the model and still be successful. The greater the shock the system can recover from, the more resilient the system is.

MODELS AS A RESEARCH TOOL

Why Models Are Useful: Systems Thinking and System Dynamics Modeling

In its broadest sense, a model is a simplified version of another thing, be it an architectural model, a mental model, or a computer model. This simplification process is essential to modeling—the object is stripped down to only the components that are needed for a given purpose. For example, an architectural model may be built to show a client what the exterior of a finished building will look like. The model ignores details, like the floor plan, that are vital to a real building but that don't impact the exterior appearance. A mental model of how to bike to the supermarket will contain which streets to take, how long to take them for, and which direction to turn at the intersections, but since the species of flowers and number of squirrels in the neighborhood yards aren't helpful to get there, they're likely left out. As George Box's quotation "all models are wrong, but some are useful" illustrates, this simplification process makes models inherently "wrong" compared to what they seek to model. However, by ignoring the zinnias and the squirrels' affinity for the oak tree, we can devise an efficient way to navigate the world by thinking only of sections of streets, intersections, and turns.

In this work, our unit to be simplified and studied through modeling is a "system." Within systems thinking and system dynamics, a system is a collection of interconnected fixed causal relationships that operate within a defined boundary. When using a systems approach to study a concept, a researcher must decide the bounds within which to explore causal relationships, the granularity at which to study the relationships and which components of the system to study at that level of detail. For example, when taking the ocean as a system, causal relationships exist between individual fish, schools of fish, species of fish, or one may view the ocean system only as an interacting network of ocean currents, abstracting from fish entirely. Within a system, there are causal relationships that emerge at each scale of resolution. The nature of the relationships that exist between schools of fish, for example, shape the causal relationships that exist between different species. Systems research gives us a means of approaching broad questions of cause and effect, like the effects on the ocean ecosystem caused by the fishing industry, in a way that can be likened to a mathematical proof. If a researcher carefully selects the components of a system at the proper highest resolution and defines the relationships between them, the researcher can produce a well-justified assertion about the nature of causal relationships across the system at the broadest level. By using a systems approach to make explicit the many fine-scale causal relationships, a researcher can provide good evidence to link a cause, such as the overfishing of one species of fish, to an effect, like the extinction of another species within the food web.

Although mental models form the basis of the way we understand the world around us, our ability to understand complex interactions in systems is quite limited. The human mind is not adept at thinking causally and considering feedback when predicting system response (Vennix, 1999). According to systems thinking advocate Barry Richmond, people tend to overlook any feedback that an effect may have on its cause, and they tend to view multiple causes with a common effect as independent from one another (Richmond, 1993). Our mental models tend to do a poor job understanding "dynamic complexity," the sometimes unintuitive results of interactions within a system over time (Sterman, 2001). Beyond individual feedback loops, dynamic complexity also arises from shifts in the relative strength of multiple feedback loops and nonlinear or time-delayed relationships causal relationships. Through the use of systems thinking tools like mind maps, causal loop and stock and flow diagrams and the development of system dynamics models, we are better able to visualize and understand how complex systems work.

The Modeling Process

The quality of a model depends largely on adherence to appropriate and rigorous methods for development (Homer, 1996). In this work we follow the model development process outlined by Sterman, 2000, as shown in Table 1.4. The process begins by identifying the system to be modeled and the stakeholders who will contribute to and use the model. The next step is to develop a clear statement of the problematic behavior, and define the boundaries of the model.

This entails selecting which variables the modeler wishes to study the change of over time (endogenous), which variables will be set initially and will impact the system (exogenous), and which variables he or she chooses to ignore. The scope should be limited in order to allow the model to be only as complex as is necessary to address the problem of interest. Since models are inherently simplifications of the system that they address, it is the job of the modeler to determine which aspects of the full system contribute to the model's purpose and need to be included, and which can be safely eliminated or held constant.

The resulting model is quite sensitive to this process—if two modelers address the same system but select different components to model, the resulting models will likely bear little resemblance to one another. Further, who makes these decisions as the modeler or modelers is important as well. Models may be constructed by an expert or experts in the field being modeled who rely on their own knowledge of the problem (the traditional approach), or by an expert in modeling who guides clients or stakeholders with knowledge of the problem through the modeling process (participatory modeling, e.g. Mendoza and Prabhu, 2006). In the work presented here, stakeholders do not play an active participatory role, but we solicit their ideas about the problem we address, and use those ideas as qualitative data incorporated into our model development process.

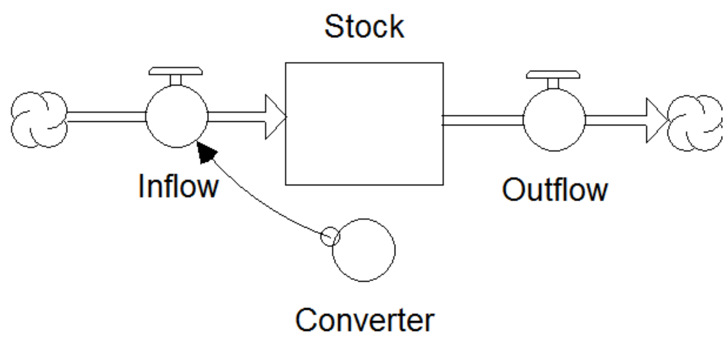
TABLE 1.4—THE MODELING PROCESS (STERMAN, 2000)

Problem Articulation	*Identifying the problem, defining the boundary around that problem, defining the time horizon*
Dynamic Hypothesis	*Developing a theory of what is causing the problem*
Model Creation	*Developing a model, using the boundaries you defined, to simulate the problematic system*
Testing	*Ensuring the model replicates expected problem behavior, testing for robustness, sensitivity, and limits of use, validating and verifying inputs and equations*
Policy Design and Evaluation	*Application of scenarios to the model to observe outcomes*

The modeler must make a hypothesis about why the system behaves as it does, and can then proceed through the iterative steps of concept testing to formal model construction in order to explore that hypothesis. Although each step cannot proceed until the prior one has been fulfilled, model building is not a straightforward progression through the list of steps. As new insights emerge, earlier work and assumptions must be revisited and refined. It is through the use of this rigorous, systematic and iterative modeling process that we are able to produce reliable and useful models (Homer, 1996).

Depending on where the modeler terminates the process, different types of models may be produced. A traditional quantitative model requires parameterizing each component in the model with numeric values and explicitly defining the relationships between components. This produces a model that can take numeric input, run a simulation, and produce numeric output that may be useful in the study of the systems behavior. By contrast, the modeler of a soft systems model does not pursue creation of a “running” model, but creates a qualitative model through use of the same basic process (Mendoza and Prabhu, 2006). Soft systems models and quantitative models alike require identifying the boundaries of a system, thinking through system behavior, breaking the system down into its relevant components and mapping the relationships of those components in causal maps. These methods are valuable in themselves in the study of better understanding the nature of a system.

If a researcher proceeds beyond an abstract soft systems model to system dynamics (SD) model construction, she must develop her maps and causal loop diagrams of system behavior into distinct entities such as dollars, pounds of product, number of customers or customer satisfaction, and must explicitly define the processes through which they change over time and affect one another. Commonly used SD development platforms include STELLA and iThink (isee systems), Vensim (Ventana Systems, Inc,) and Simile (Simulistics, Ltd.). Using these platforms, the model is mapped out in a visual, icon-based graphical user interface in which variables are assigned numbers and relationships as represented through equations (Figure 1.1). This symbolic modeling schema emphasizes the components and relationships over discrete values and equations, making it easier for a wider audience to read, navigate and engage with the model.



- Stocks – stores units of a given entity being modeled in the system
- Flows – control the rate of flow of units of this entity into and out of a stock
- Clouds – units enter or exit the model’s boundaries
- Converters – hold variables or equations that alter the rate of flow

FIGURE 1.1—STOCKS AND FLOWS IN STELLA

In the work presented here, we used a traditional quantitative SD modeling tool, STELLA, to construct a soft systems model. Although some soft systems models address systems too abstract for qualitative modeling, our model has the potential for further development as a qualitative model in STELLA. In constructing a quantitative SD model, the modeler must ensure that the model replicates system behavior when running simulations, and incorporating reliable data sources when available. The model must then be rigorously tested, ensuring the model behaves as expected and verifying the input data used and the appropriateness of the structure, relationships and equations and the assumptions that underlie them (Barlas, 1996; Sterman, 2000; Peić-Bach and Čerić, 2007). The limits of the model should be tested and defined through sensitivity analysis and use of extreme inputs (Forrester and Senge, 1979). After the model has been verified and tested, it may then be put to use for its intended purpose to test policies, draw conclusions, etc.

System Dynamics Modeling Limitations and Applications

System dynamics models allow us to understand the processes, functions, interactions and relationships within a system, but cannot, however, be used as predictive models. Predictive models are designed to maximize the accuracy of the model's output, and generally rely on large data sets and use of empirical relationships. From SD models we can gain a sense of directionality (e.g. as price increases customers decrease, as customers decrease sales decrease) and magnitude (e.g. price has a ten times greater impact on sales than marketing) of relationships within the system, and thus of overall system behavior, but SD models are not designed to produce reliable numerical predictions (e.g. a $250 investment in marketing will have $500 return in sales). These limitations in use are a result of system dynamics' ability to model systems with uncertainty in ways predictive models cannot. However, it is the responsibility of the modeler to minimize assumptions and uncertainties when possible and to make all unavoidable assumptions and uncertainties known to the user.

The list of applications for SD models is long and varied since development of a system dynamics model may be useful in any case where there is a complex system to be studied. Uses span from Forrester's development of the field for use in business management and later into public policy with *Urban Dynamics* (Forrester, 1970, 1993), to applications in mechanical engineering (Schiehlen, 1997) civil and environmental engineering and architecture (Thompson and Bank, 2010), environmental systems (Ford, 2009), population and sustainable development (Randers, 2000), community development in marginalized urban communities (Hovmand, 2014) and public health (Koelling and Schwandt, 2005), to name a few. In the work presented here, we find SD modeling well-suited to study small farm systems as previously defined.

Modeling Agricultural and Small Scale Food Systems

Models of many types have long been used in a broad range of agricultural contexts. Crop simulation models track the lifecycle of a specific crop in a specific location, typically on a field scale, and often focus on predicting growth and yield in response to environmental and management variables. As such they are deterministic or predictive models that require extensive inputs and are focused on quantifiable results. Given their specificity, myriad crop models have been developed. One notable pioneering example is CERES, an early model of maize and wheat systems which has evolved into the DSSAT suite of crop models (Ritchie and Otter, 1985; Jones et al., 2003). Sinclair and Seligman, in their 1996 paper on the genesis of crop models, state that even at the scale of a single crop, the variables in the system are almost infinitely complex and thus it is impossible to create a universal crop model that can perform accurately across a wide array of climates or circumstances.

Agricultural models have also been developed with wider scopes, often incorporating a simple crop model as one component or “module” examined in relation to other components. The EPIC (Erosion-Productivity Impact Calculator) model combines a soil erosion model with a crop growth model (Williams et al., 1989; Williams, 1990). Models have also been used to simulate insect, weed or disease pressure in cropping systems (Wilkerson et al., 1990; Jones, 2015). CropSyst utilizes a generic crop simulator coupled with management, soil, and climate components (Stöckle et al., 2003). The APSIM model was developed to be used with different, interchangeable grain and fiber crop modules to study the long term effects on yield of factors such as management and weather, and is designed to model heterogeneous farm systems down to the field level (Keating et al., 2003; Holzworth et al., 2014).

Some models incorporate food production components in the context of a larger focus on environmental or social systems. Page, 2011, developed a farm-scale environmental sustainability assessment of organic kiwi and apple production systems in New Zealand through use of a biophysical System Dynamics model. FLORES, or the Forest Land Oriented Resource Envisioning System, also takes an environmental perspective (Vanclay, 1998). Two sites using the system are Zimbabwe (ZimFLORES) and Cameroon (CamFLORES), both focused on community-scale agroforestry systems and the impact of new agricultural development (ZimFLORES) or practices (CamFLORES) in a forest-farm mosaic including household use of land and resources (Legg, 2003; Prabhu et al., 2003).

Community and regional food system models connect agricultural production to consumption in a geographic area. These models typically have a social focus, often abstracting from the details of agricultural production and reducing the role of farms in the model to their proximity and production capacity. Examples include Metcalf and Widener's 2011 study of sustainable agriculture to address food insecurity within the food system in Buffalo, NY, and the 2009 paper by Peters et al. modeling the capacity of New York State to meet its food needs through in-state production. Roos, 2012, developed a System Dynamics model of the food availability and accessibility in an urban South African community. Gerber, 2015, built a SD model of maize production and food supply to study food security policy options in Zambia.

Farm Models

Farm models take a single farming operation as their scope. Even though an individual farm is likely first thought of as agricultural systems, it is also tied to environmental, economic and social systems which may also be included in a model depending on its purpose. The term "bio-economic farm models" is used by Janssen and van Ittersum, 2007, to describe models designed to address the management of farm systems. These models link "farms' resource management decisions to current and alternative production possibilities describing input-output relationships and associated externalities" (Janssen et al., 2010). The authors identified 42 unique farm models fitting this description in the literature that were developed using a varying methods, to address a range of different farm types and a variety of research goals. The majority of models included in the study used economic optimization as the sole driver in farmer action. The majority of models were also static, not dynamic, and therefore did not study the change in systems over time. The authors found that psychological and cultural values were widely underrepresented as a part of the farmer decision making process, and less than half of the models reviewed incorporated actual farms in their model development or validation process.

Although in the minority overall, a number of bio-economic farm models have been developed with System Dynamics modeling platforms, all for rather varied operation types. Schaber, 1996, developed a model of small scale farm operations in the Philippines to study sustainable use of their natural resource base using data collected from 13 smallholder rice farmers. Beukes et al., 2002, explored grazing systems in South Africa that incorporate vegetation, production, and financial sub-models, based on a single farming operation. Beukes later developed a "whole farm model" in the programming language Smalltalk of pasture-based dairy systems in New Zealand to be compared to experimental farm trials (Beukes et al., 2008). Tanure et al., 2014, developed a model of a Brazilian livestock production system in a single enterprise built upon one economic and three biophysical modules (animal characteristics, animal nutrition, animal-pasture integration).

Within agricultural, farm, or small-scale food system models, work on farm systems like the kind studied in the work presented here is essentially absent. Small, diverse, commercially oriented, high value producers are a small but growing portion of the market in the US and are an even less common farming system internationally. The farm models mentioned above that have used SD approaches differ markedly in biophysical, economic, and social dimensions. They are located in diverse regions of the world (Asia, Africa, South America) and cover diverse systems (livestock, cereal crops, smallholder farms). As noted by Janssen and van Ittersum, 2007, all of these models focus on economic or environmental components and fail to include a significant social dimension or to examine psychological and cultural factors. Conversely, most models that have included social components are "food system" not "agricultural" models as noted above, and detailed biophysical systems are generally lacking. In this work we seek to develop a bio-economic and social system dynamics model of a farm type of growing importance in the US food system. As framed by Janssen and van Ittersum, we wish to address farmer's resource management decisions and to incorporate social factors as an integral driver in those decisions.

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Chapter 2: Developing a Systems Model of Small Farms in Southwest Virginia to Enhance Beginning Farmer Success

ABSTRACT

Very small farms are typically complex systems in which the farmer manages both production of a diverse array of crops and marketing of those crops directly to consumers, and the failure rate in the beginning years is high. This work seeks to increase the likelihood of success for beginning farmers by understanding these complex systems better. We conducted interviews with three successful beginning farmers in Southwest Virginia. These interviews covered practical and philosophical aspects of farm production, sales and management, and the data were used to develop a wider view of farm success than profitability alone by assessing farmer values and goals. Both qualitative and quantitative data were used to map social, environmental and economic dimensions of a small farm system. These maps were designed to explore how resources (Community Capitals) and farmer management affect the system's success. We developed our farm system map into a system dynamics model in STELLA to define explicitly the relationships between system components and to simulate and observe system behavior. Our model addresses production, abiotic and biotic stressors, environmental quality, farm family and hired labor, customer attraction and retention, and sales and economics. Through model development, we learned that these successful farmers began their operations with experience and financial capital, and employed their skills, resourcefulness and cultural and social capital to charge prices for their products that could sustain their operations financially. Using our model, current and aspiring farmers, service providers, and small farm advocates will be able to simulate real or hypothetical farm systems to better understand what establishing a successful small farm might require and how to confront potential challenges.

Introduction

In recent years, consumers in the United States have greatly increased the demand for "local foods" (Martinez, 2010). This has expanded opportunities for aspiring farmers who wish to establish diverse, high value, intensively managed small farm operations (henceforth, "small farms") that can meet this demand (Hamilton, 2010). The proportion of "very small farms" as classified by the USDA (under 10 acres) has increased from 11.2% of all farms in 2001 to 15.8% in 2011 (MacDonald et al., 2013). This is a divergence from the dominant trend in the U.S. over the 20th century of farms growing larger, more mechanized, more specialized and more efficient (Paul et al., 2004). In contrast to these larger farms, very small farms have much lower financial barriers to entry for beginning farmers since they require much less land and equipment. However, small farm systems are in many ways more complex than larger systems since they often cultivate a diverse array of high value products and also market and sell them directly to customers. Beginning farmers enter an experiential learning environment in which they must quickly learn to manage a complex system with intertwined biophysical, economic and social components in order to succeed. These farmers may stand to gain from support services and programs tailored to their unique needs, but small farm research and the development of such programs has lagged behind the pace at which small farms have grown (Niewolny and Lillard, 2010). In this work we find that a systems approach is well suited to understand the complexities and interactions of farming operations taken as whole. System dynamics modeling can provide small farmers, aspiring farmers and advocates a low risk environment for exploring change and scenarios in whole farm systems.

Farm modeling has generally not taken a whole farm system focus, but rather focuses on biophysical systems with limited inclusion of economic or social components. The term "bio-economic” may be applied to describe farm models that do consider economic factors. However, any given two farm models that can be described by this term may bear little resemblance to one another. The great diversity among farm systems in scale, products cultivated and methods used will be reflected in the models that simulate them. Differences in farm models are further compounded by the array of modeling methods and tools available and because farm system components are included only selectively as suits the model’s purpose. In Janssen and van Ittersum's 2007 review of 42 bio-economic farm models, models addressed farm systems in 30 different countries with varying modeling methods, objectives, and types of systems studied. Nineteen models were built for, at least in part, the purpose of assisting farmer decision making and 23 models referenced actual farms in either model construction or validation. None of the models reviewed addressed social factors in considering the farmer’s decision-making process.

Scholarship on the re-localization of food systems has come primarily from social/community perspectives (Feenstra, 1997; Winter, 2003; Smithers et al., 2008), economic impacts (Otto and Varner, 2005; Brown and Miller, 2008; Hughes et al., 2008), and environmental sustainability (Feagan et al., 2004; Ilbery and Maye, 2005), sometimes addressing multiple perspectives. These analyses emphasize the benefits that the farmer receives (income, social connectedness) and provides (healthful foods, sustainable production methods). The farms that fill the local foods market niche have not been widely studied in their own right as unique and complex production systems. Unlike for more conventional farm systems (Turner et al., 2013; Tanure et al., 2013), decision support models addressing whole farm systems have not been developed for small farms. The diversity within and between these farms suggests that real farms should be referenced in the modeling process to accurately describe these systems. Also, in light of the scholarship emphasizing the social connections within local food systems, we must recognize that the farmer seeks and gains more from the farming operation than simple financial solvency (Dent, 1990; Lyson, 2012). Social factors such as the farmer's goals, values, and sense of place and community are a critical component of these small farm systems that must be considered in a whole farm model alongside biophysical and economic aspects.

Our objective in the work presented here is to develop a conceptual model that reflects the beginning years of a diverse, high-value, small-scale farm operation. We do so in order better to understand and reveal what it takes for the farmer managing that system to establish a successful farm. We have constructed our model primarily from interview data collected from three case-study farms who have achieved success. We developed a multi-dimensional view of success based on these farmer perspectives as well as economic viability. This paper details the framework and contents of the model and identifies some of the endogenous and exogenous factors that contribute to success. We hope that our model and our findings will be of use to farmers, aspiring farmers, and small farm advocates who work with the community through extension, outreach and education.

METHODS

Data Collection

This research is part of larger project, Mapping Sustainable Farm Systems (MSFS), funded by a Southern Sustainable Agriculture Research and Education grant from the USDA. The MSFS project seeks to better understand the learning and decision making process of beginning farmers operating in Kentucky, Tennessee and Virginia. The work explores how farmers make use of the information and forms of capital available to them and incorporate those concepts into their operation, especially their perception and adoption of sustainable practices. It considers many forms of farmer capital, including social, natural and financial, as per the

Community Capitals framework (Emery et al., 2006). Initially, listening sessions that addressed resource access and use were conducted with beginning and aspiring farmers. The topics emphasized by listening session participants were incorporated into an interview protocol for a series of case study interviews conducted with the farmers of three farms per state. The development of this protocol was the first step in the model building process. Next, an advisory board for the project identified farms to be interviewed that they considered successful and had been in operation for less than 10 years.

The interviews were conducted in two sessions of about two hours in length each and sought to explore how access to and use of capitals had contributed to success in these farms. Interviews addressed biophysical (what is produced on the farm, what tools and methods are used), economic (how was starting the farm financed, what sales outlets does the farm have) and social (what is the farmer's history and experience, how do they perceive vulnerability and risk) aspects of the system. Each farm completed a worksheet to supplement the interviews with quantitative data about production, labor, markets, income and expenses. One farm also provided four years of income and expense reports as well as their planting schedule for that year, including a detailed crop list with planting date and planting bed length for each crop.

Study Area and Participant Characteristics

The work presented here focuses exclusively on the three farms in the study located in Southwest Virginia. All farms and the farmers markets they participate in are located in Virginia's 9th congressional district which contains all counties west of Roanoke. Virginia is a socio-economically and geographically diverse state, with high density, high income areas in the northeast near Washington, D.C., high density, low income areas in the southeast near Richmond and low density, low income areas in the southwest. To the east is the Atlantic Ocean, and the landscape of the western half of the state is dominated by the Appalachian Mountains. According to 2011 Census data, the 9th congressional district has the second lowest population density in the state, the lowest per capita income ($21,055), lowest percent high school graduates (80.9%), and the second highest percent of households receiving SNAP benefits (16.3%) (US Census Bureau, 2011).

Each farm is located in a different county and they do not use the same markets or sales outlets. All three farms produce vegetables on fewer than 10 acres of land, generally on the small fertile portions of larger, unarable properties. Two participants own their farmland and purchased it in order to establish their farm, the third leases their land adjacent to a small urban area. All farms earn the majority of their income from vegetable production, although two incorporate production and sale of animal products as well. One farm sells its products entirely though an aggregator, and the others mostly sell directly to consumers through either farmers markets of a "community supported agriculture" (CSA) system in which consumers pay upfront in exchange for installments of produce throughout the growing season.

Modeling Process and Conceptual Framework

Following the modeling process of Sterman, 2000, we began the modeling process by defining the system to be modeled and its boundaries, identifying the "problem" within the system, and developing a dynamic hypothesis of that problem. These initial stages incorporated ideas from the interview protocol but not from the data collected in the interviews. We established the scope of the model as a single, small farm focused on intensive vegetable production. From this we had a sense of the basic structure and the principle components and processes we expected to find on any such farm, like a means of growing and selling crops.

The fundamental "problem" we address within these small farm systems is the difficulty of establishing a successful operation. Although we wish to study a multi-dimensional view of success in the project overall, we formulated our dynamic hypothesis in terms of economic success. At a basic level, economic viability is a necessary (though not sufficient) condition for success for all commercially oriented farms. We can conceive of a small farm's challenge to become profitable within the framework of the neoclassical economics theory of supply and demand. The relationship between the stock of food produced by the farmer, the sales price per unit of food and the rate of production (supply) can be characterized by a balancing, or negative, feedback loop (Figure 2.1), as can the relationship between food, price and sales of that food (demand). Together, these two balancing loops will very quickly drive the system to a stable point with the system dictating the price that a farmer can charge for his or her goods in a competitive environment. Taking our modern food system as a whole, large commercial producers keep the supply of food high, driving down the sales price. Even in a more realistic system including time delays and other complicating factors, these balancing loops can still persist. Thus we conclude that, in order to cover production costs and earn a living wage, the farmer must be able to modify the system to weaken the relationship between price and sales. To do so they must communicate values of their production systems that attract and retain customers who are willing to pay more in support. Starting from this concept, we used the case study interviews to understand how real small farm systems accomplish this.

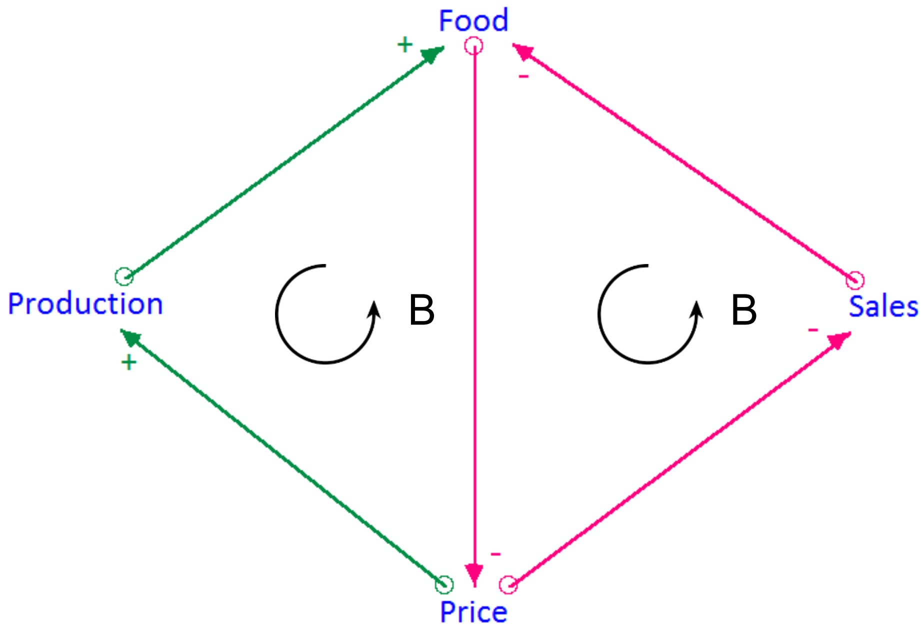


FIGURE 2.1—THE HIGHLY STABLE FEEDBACK LOOPS OF SUPPLY AND DEMAND

In addition to addressing our modeling "problem," we sought to address the following questions through the model creation process:

1. What does success mean to this farmer, and what does success look like in this operation?
2. What forms of capital are available to these farmers, and how do they make use of them?
3. What forms of capital did the farmers have when they started?

Using the protocol to plan the types of data that would be available to populate model variables, we began drafting the first iteration of a model of a basic farm. As the interviews were conducted over a period of months, insights from each interview influenced model iterations as they became available. From each farm we sought to understand the causal relationships that influence success. In particular, we identified components, processes, and flows of both materials and social capital within each farm, and constructed concept maps, adding and editing these iteratively as the interviews proceeded. After all interviews were conducted and transcribed, the transcripts were reviewed, and the similarities, differences, and unique aspects of each farm were identified. Our resulting model is a blended representation of a diverse vegetable crop production that can be modified to create a scenario which reflects each participating case study farm.

RESULTS

System Maps

To begin to construction of our dynamic, multidimensional farming system, we developed a diagram of "sectors" based on sections present in the interview protocol and initial concept maps. These sectors are sub-systems of a farm and their interconnections with a structure that is common to all three case study farms (Figure 2.2). On one level, these sectors define the system's boundaries and reflect the basic components of a small farm operation such as growing and selling crops. However, the sectors are also structured around the systems that were emphasized in the interviews that either define or contribute to the farmers' success. Each sector has unique internal dynamics to be explored as well its impacts on other sub-systems and the farm overall.

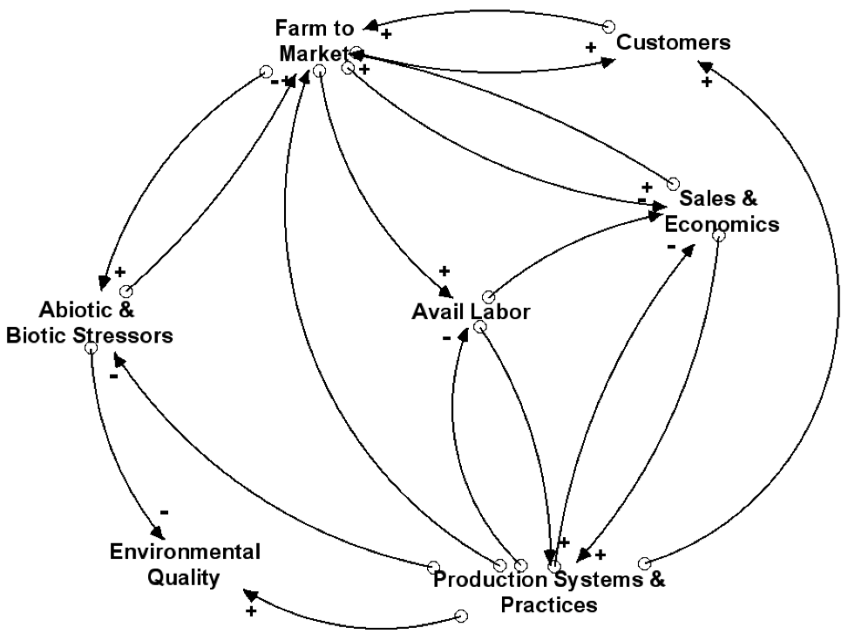


FIGURE 2.2—SECTOR DIAGRAM OF A FARM SYSTEM. A POSITIVE ARROW INDICATES THAT A CHANGE IN THE FIRST SECTOR WILL BRING ABOUT A CHANGE IN THE SAME DIRECTION IN THE SECOND SECTOR (INCREASE/INCREASE OR DECREASE/DECREASE). A NEGATIVE ARROW INDICATES THAT A CHANGE IN THE FIRST SECTOR WILL BRING ABOUT A CHANGE IN THE OPPOSITE DIRECTION IN THE SECOND SECTOR (INCREASE/DECREASE OR DECREASE/INCREASE).

We developed a causal loop diagram (CLD) based on the interview data to explore how these farmers are managing to modify the feedbacks of supply and demand presented in Figure 2.1 to set the prices they need for economic success (Figure 2.3). Unlike the sector diagram, not all entities in the CLD are themselves dynamically complex sub-systems. Some are individual variables which are highly influential in system behavior and may be exogenous or endogenous to the system. In the CLD, sales at the market are driven by customers. These customers are attracted to purchase from the farm for reasons including the farm's marketing, the relationships it has built with the community, its production methods, and the quality of its product. The farmer's efforts to attract customers "add value" beyond the supply-demand dictated price

(Hinrichs, 2000). Price is directly determined by the needs of the farmer (expenses and salary) and has a greatly diminished impact on sales.

The “success” term of the CLD captures a more nuanced view of success than economic viability alone. Farmers realistically manage their operations around many objectives beyond financial solvency and transcending supply-demand feedbacks. In addition to earning what they believe to be sufficient income to support the farm family, our interviews suggest that farmers non-economic metrics of success include environmental stewardship, establishing ties as part of their community, maximizing their time pursuing the farm labors they find most enjoyable and maintaining a healthy work-life balance. Further, we wanted to expand our view of success from the immediate term and into the future, and therefore also considered the system’s resiliency, or its ability to recover from shocks such as a poor growing season. Operating capital, customer loyalty and environmental quality can all contribute to a more resilient system and, in turn, long term success.

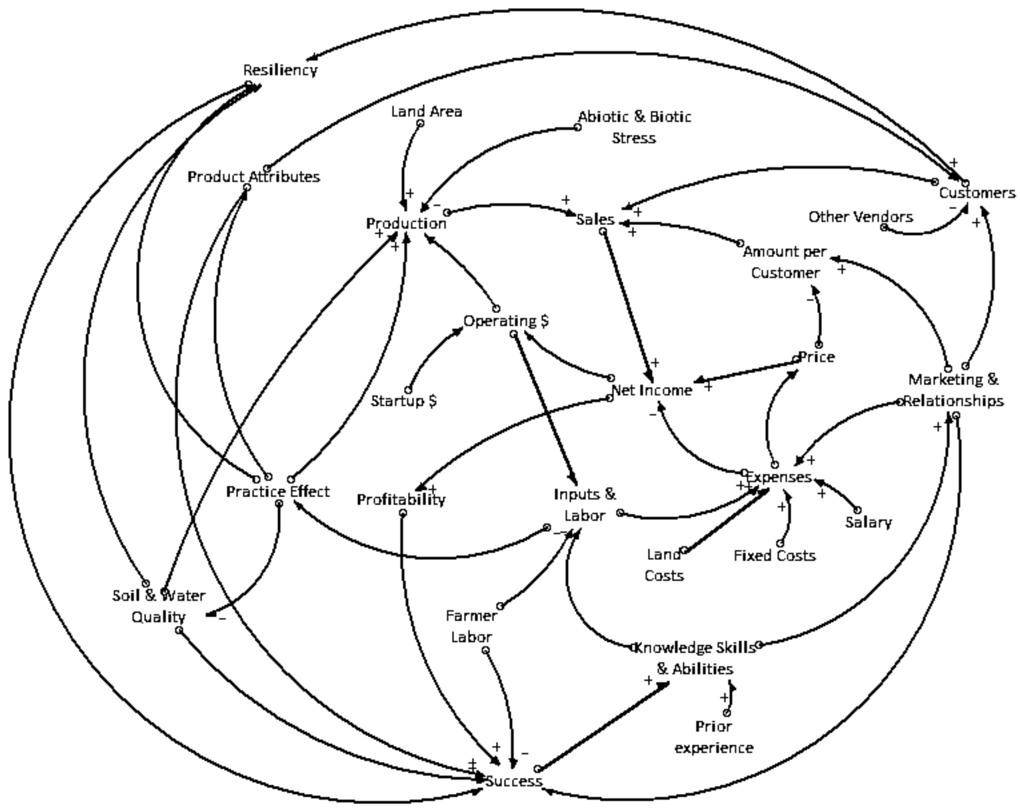


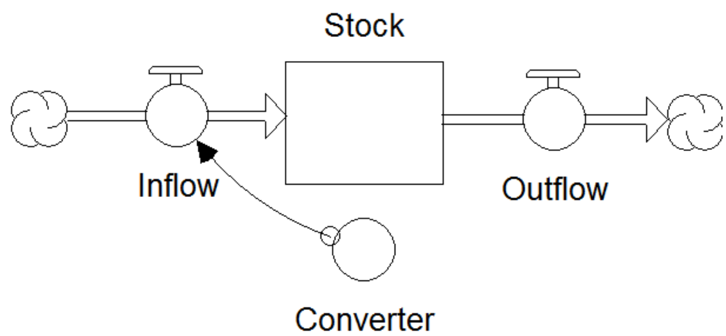
FIGURE 2.3—CAUSAL LOOP DIAGRAM FOR THE FARM MODEL

The determining factor for success is the means by which farmers make use of the resources available to them, not the resources in isolation. The CLD includes the farmers' points of intervention in the system as "Practice Effect." Farmers' management decisions and farming practices are their means of control over the endogenous factors in their system and the means through which they can use the forms of capital available to them to enhance their success.

Exogenous factors influence the system but are not part of the feedback loops controlling the system's behavior, and are thus shown as "dead ends" within the CLD. They may be things outside of the farmer's control, such as abiotic and biotic stress and market competition, or they may be factors determined or fixed when the farm begins operation, such as startup capital, land area and costs, and prior experience. Exogenous factors may play an important role in system success, but they cannot be altered once the system is in operation. Therefore, these exogenous factors, especially exogenous forms of capital, are important considerations for an aspiring farmer.

Farm Model

From the CLD, we developed a system dynamics model of a small-scale beginning farm operation in STELLA (isee systems) that incorporated the qualitative and quantitative data obtained from the interviews. As in the previous diagrams, the model is a blended representation of the three case study farms, but can also be used to simulate other real or hypothetical similar beginning farm systems. The sectors diagrammed in Figure 2.2 became discrete units of the model that exchange information by sharing variables, often across multiple sectors. This connection is indicated as an arrow between two sectors. Each subsystem is described in STELLA through use of stocks, flows, and converters (Figure 2.4). The model runs at a weekly time step and spans up to a ten-year time frame—from inception until the farm is no longer classified as "beginning." The focus is on the first 2-3 growing seasons when the success of the operation is most uncertain. The model exclusively handles diverse vegetable production systems and is best suited to commercially oriented farms that market directly to customers or aggregators and are located in or near the study region. As a system dynamics model, the results of model runs are not predictive (e.g. producing a recommended dollar amount of financial capital to ensure success) but can be used to study the direction of behavior that results from specific inputs or change (e.g. increased marketing investments show increased sales).



• Clouds – units of a given entity being modeled in the system enter or exit the model's boundaries
• Flows – control the rate of flow of units of this entity into and out of a stock
• Converters – contain variables or equations that alter the rate of flow
• Stocks – store units across time unless modified by a flow

FIGURE 2.4—STOCKS AND FLOWS IN STELLA. ALL VARIABLES ARE UPDATED AND EQUATIONS RE-CALCULATED AT EACH TIME STEP FOR CONVERTERS AND FLOWS. THIS ALLOWS CHANGED CONDITIONS IN THE MODEL (THE "EFFECT") TO ALTER THE MECHANISMS OF CHANGE (THE "CAUSE") AND CREATE FEEDBACK LOOPS.

Quantitative data from the case study interviews such as the number of employees hired, equipment used, annual income and variety of crops grown was used to develop the sub-systems in the sector diagram into an expanded picture of a farming operation. Although the case study farmers did not participate in the modeling process due to time constraints, the qualitative data from their interview responses were used to bring their voices into the model structure as well. Elements such as customer relationships, environmental quality, and monitoring farmer workload were incorporated in the model as a response to the values and goals expressed by farmers. Qualitative data also factors into the development of the model structure and equations. A model element such as the pool of labor available for hire may be constructed as unlimited, built with a low or high limit, or presented to the model user to define based on the farmers' reports of low, high, or variable labor available to hire.

A major challenge of model development was reining in the complexity that emerged as we pursued our modeling objectives within our given scope. A farm system is inherently quite complex, given that farmers must manage biophysical, economic and human dimensions of a farm. Further, the crop production systems on small farms are often very complex due to high crop diversity, low mechanization, and use of direct sale pathways to customers with diverse interests. We simplified complexities in the model though use of aggregations and scenarios. Tracking the 41 crops grown by one case study farm through the model for their growth, yield, loss, varying input needs depending on management decisions, price, demand, sales across multiple outlets, etc., quickly creates overwhelming complexity for both the modeler and the prospective model user. Instead, these 41 crops were aggregated into six groups (early season, full season, peak season, late season, potatoes and onions) that share similar traits, generally by taking weighted averages of the properties of the individual crops (Table 2.1).

TABLE 2.1—CROP AGGREGATIONS. [1]CROPS INCLUDED IN BOTH EARLY AND FALL SEASON PLANTINGS TO AVOID MID-SUMMER HEAT STRESS. [2]FULL SEASON CROPS ARE PLANTED MULTIPLE TIMES THROUGHOUT THE GROWING SEASON TO PROVIDE A CONTINUOUS SUPPLY FOR SALE.

Crop Type	*Crops included*
Early	broccoli, cabbage[1], carrot[1], cauliflower, celeriac, celery, kale[1], peas, spinach, swiss chard
Full[2]	beet, bok choy, lettuce, radish, turnip
Warm	beans, cuke, eggplant, parsnip, peppers, rutabaga, summer squash, tomatillo, tomato
Fall	daikon, cabbage[1], carrot[1], collard, kale[1], raab, spinach[1], swiss chard[1], tatsoi, turnip
Onion	(early planted)
Potato	(early planted)

Scenarios help simplify when elements of the model combine producing complex interactions. We identified nine "practices" within the model that each have between 2-5 options for the farmer, which means there are over 4000 unique combinations of practices that have impacts throughout the system. We used a simplified Scenario Planning approach to create a scenario matrix using the nine practices (Schoemaker, 1995). The matrix combines four "use of inputs" options based on use of conventional or organic inputs and three "management priority" options based on the farmer values (business/profits or lifestyle/stewardship) that drive management decisions (Table 2.2). These combinations create 12 different production system scenarios based on farm management, each corresponding to a series of practices that alter system attributes within the model, impacting crop losses from biotic and abiotic stresses, environmental quality, labor requirements and expenses, and the attractiveness of crops to customers.

TABLE 2.2—PRODUCTION SYSTEM SCENARIOS

Use of Inputs / *Management Priority*	Conventional Fertilizers and Pesticides	Mixed (some non-certified organic inputs)	Non-Certified Organic	Certified Organic
Business Oriented	Conventional tillage, no rotations, no soil testing	Conventional tillage, no rotations, no soil testing	Conventional tillage, no rotations, no soil testing	Conventional tillage, rotating (required), no soil testing
Balanced	Conventional tillage, soil testing, mulching of crops	Conventional tillage, soil testing, mulching of crops	Conventional tillage, rotating, soil testing, mulching of crops	Conventional tillage, rotating, soil testing, mulching of crops
Lifestyle Oriented	No till, rotation, soil testing	No till, rotation, soil testing	No till, rotation, soil testing	No till, rotation, soil testing

The interviews are not the sole source of quantitative data in the model. Some of the data needed for the model to run comes from the model user. We selected variables across the sectors that allow the model user to customize the model to simulate their own farm, possible changes to their farm, or a hypothetical farm system. Most of these variables are difficult to estimate or generalize across farm systems. We deliberately limited the amount of information that we asked for and the manner in which questions were asked in order to make completion easier for the potential model user. We also included initial default values should the model user not have full data or only have interest in a small set of variables. Much of the data can be easily input via "sliders" in which the model user chooses a numerical option which may correspond to a “multiple choice”-type question or may indicate a relative value (e.g. a scale ranging from poor to excellent).

Since the production data we collected during the interviews was general in nature, the data available for modeling production systems was incomplete. This required that we fill the data gaps with information from external sources to complete our picture of a diverse small farm. One of our three case study farms provided detailed records of their weekly planting schedule and of their farm budgets, but did not include data necessary to determine yield and the availability of crops for sale throughout the growing season. We supplemented this data using the CSA scheme developed by Gruver, n.d., to provide conceptual framing and estimates of missing data. We combined the farm’s budget data with small farm enterprise budgets available from Penn State Extension and from *The Organic Farmer’s Business Handbook* (Penn State Extension, Wiswall, 2009) . No farm had detailed information about labor hours contributed by the farm family or a breakdown of how different equipment or management decisions translate into labor hours. We obtained estimates of this information from Wiswall, 2009, as well.

MODEL STRUCTURE

Interface

The model’s interface passes user-input data into the model and, during and after runs of the model, returns data from the model that we believe the model user will find useful in decision-making Figure 2.5—Model Interface LayerFigure 2.5). Users select the number of the management system, as described above, that best describes their operation, and the degree to which they are implementing that system. Users also provide characteristics of their farmland (soil productivity, texture, slope), a self-assessment of their experience and education, and their confidence in their preparedness or to find help in managing their farm. We ask that they provide goals for environmental quality and customer trust and to compare how their products and marketing compare to the competition. Numbered responses for factors such as management system and soil texture correspond to enumerated options. Questions regarding goals and comparisons with competition are numbered as a part of a rating scale (from 1-5: "much less than" to "much more than") and therefore represent relative values.

Users are asked to provide economic and labor data, including startup costs and startup capital, farming equipment, the number of employees hired, their wages and hours, and the number of farm family members who contribute their labor on farm as well as a target workload and annual salary for the farm family. Users may input the number of customers available to become the farmer's customers for each sales outlet: CSAs, F2F (face-to-face, meaning farmer's markets or farm stands), aggregators, or wholesalers, which "export" farm products from the local foods system although initial numbers are provided. We also ask for the number of acres in cultivation and the price per pound charged for each crop type for each market. The user may "turn off" any sales outlets or crop types that they do not wish to use by inserting a value of zero. Thus the model does not require the farm grow the maximum diversity of crops or to participate in local food systems, allowing the user to opt into or out of sales outlets as they see fit (LeRoux et al., 2010).

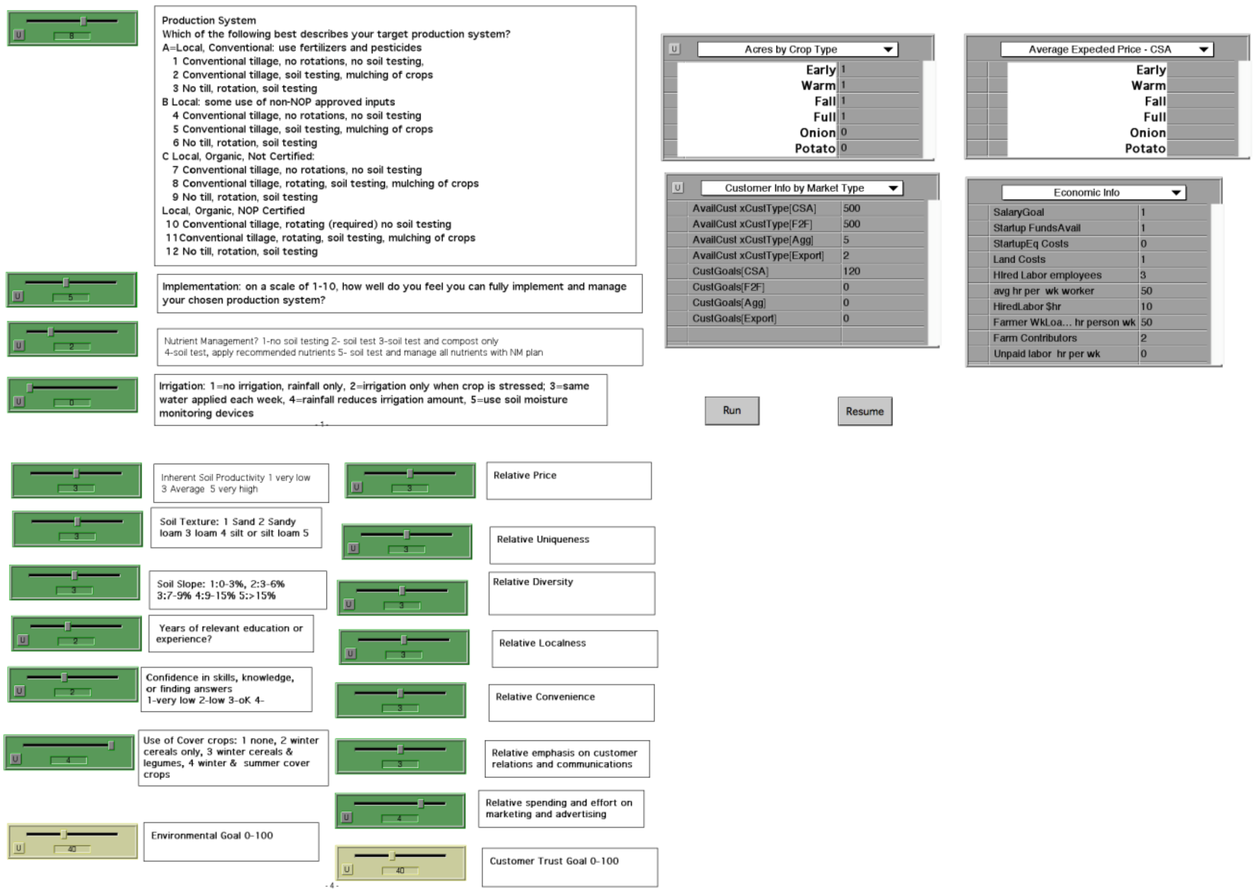


FIGURE 2.5—MODEL INTERFACE LAYER

Practices and Management

The farmers are able to exert control over their systems through their use of practices and how they choose to manage their operation. This sector takes the management scenario, degree of implementation, nutrient management, and use of cover crops as selected by the model user in the interface and determines values for how management influences attributes across the model. These attributes include market appeal, soil protection, soil organic matter building, weed control, pest control, disease control, pesticide risk, nutrient management and labor hours. All attributes are referenced by or influence every other sector throughout the model.

Farm to Market

The most fundamental component of vegetable-focused farms is the growing and selling of crops. The Farm to Market sector simulates the planting, maturation, harvesting and selling of crops through the four market pathways (Figure 2.6). Maximum yield by crop is exogenously limited by soil productivity of the farm and abiotic (water, temperature) and biotic (pests, diseases) factors. These impacts can be, in part, mitigated through the implementation of practices selected by the model user via production systems scenarios. The effectiveness of implementation is determined by their management skills as gained through experience, education or resourcefulness. Since production data is expressed in terms of yield, the units for growth, harvest, and losses are all expressed as pounds of yield.

As crops move to market, they may be sold in the sales pathways chosen by the farmer through the interface. Crops will exit the system as unsold by default unless demand is available. If total demand is in excess of supply, the model fulfills CSA obligations first, then prioritizes by assumed highest price (i.e. next F2F, then aggregators, and lastly export).

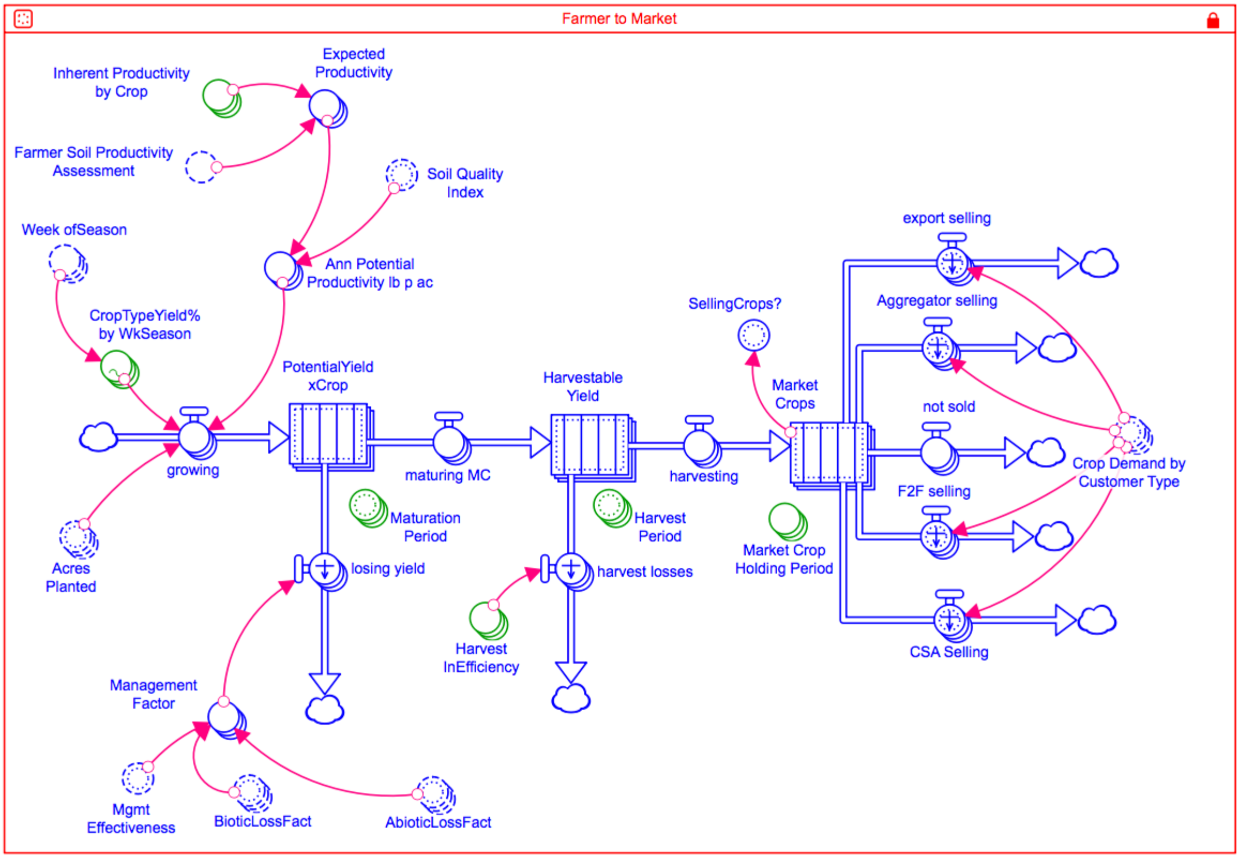


FIGURE 2.6—FARM TO MARKET SECTOR

Abiotic and Biotic Stressors

Plants can only grow within a certain range of conditions, and are most productive within a yet narrower range. Abiotic stress (lack of nutrients, temperature or soil water too high or low) and biotic stress (weeds, insects and diseases) reduce yield. We aggregate these individual stresses to calculate an abiotic loss factor and a biotic loss factor which together reduce the yield of crops in the Farm to Market sector. Water stress (drought and flood) and temperature stress (heat and cold) are ultimately influenced by precipitation and temperature data for the region imported into the model. Weekly weather data is generated by applying a randomly generated variation from the average monthly data. The purpose of including generated weather data is to introduce random variations which test the resiliency and management choices of the farmer.

Nutrient stress is based on nutrient management and soil organic matter building practices, and may be induced by leaching. Depending on soil texture and the available water holding capacity, water from irrigation and precipitation will infiltrate (becoming plant-available) or runoff (if flooded). Although most farmers will likely use irrigation to reduce risk of drought stress, the model allows users to simulate rainfed-only production or various irrigation methods (e.g. scheduled additions or based on stress monitoring). Temperature stress is tied to a threshold temperature based on each crop type's sensitivity to heat or cold. These individual abiotic factors are modeled by considering all possible combinations of stress, and assigning a loss factor for each combination. Actual weather conditions during the week (temperature and available water) are used to select the appropriate abiotic loss factor from this table of conditions. For example, early frost (cold stress) for the warm season crop type will result in an abiotic loss factor of 1 (or 100%, meaning complete loss). Although water infiltration and its environmental effects are calculated year round, the abiotic loss factor will only affect crop growth and yield during the growing season, as shown in Figure 2.6.

Weed, insect and disease pressure each vary depending on time of year. This variation is modeled as relative level of pressure a curve over time for each crop type. These pressure curves are then compared with how effectively the selected practices protect plants from loss. The combination pressures and control results in a biotic loss factor for weeds, insects and diseases. These factors are weighted and summed to produce an aggregate biotic loss factor on a scale of 0 to 1 (Figure 2.6).

Environmental Quality

To ensure long term productivity, farmers must be aware of the environmental impact and the sustainability of their practices. The environmental quality sector produces an environmental quality indicator which can be compared to the farmer's environmental goals. This indicator combines a soil quality index with a water quality index, placing greater weight on soil quality since this factor provides a feedback loop affecting soil productivity. Both indicators are products of soil retention and nutrient retention which are affected by the farmer's management practices as well as soil texture, slope, and abiotic conditions leading to leaching or runoff, Soil quality is also impacted by soil organic matter building and water quality by pesticide use, each derived from practices.

Farm Family and Hired Labor

Farm work is mostly done by either members of the farm family or by hired labor, and in some cases by interns or volunteers. The labor sector considers supply and demand of labor on the farm. Labor demand is the sum of administrative labor, marketing labor, other farm-wide physical labor, and crop-specific labor. Administrative labor is tied to the scale of the operation, including the number of acres in cultivation, the volume of crops being sold, and amount of non-family labor. Marketing labor calculates and aggregates total marketing labor across all market types based on pounds of crops sold. Farm-wide labor includes all work done to maintain farm land and infrastructure that is not directly related to growing crops, including the planting of cover crops, and is connected to the management scenario.

Crop-specific labor is the sum of crop production labor and harvest and processing labor, scaled to the number of acres in production by crop type. Production labor is divided into tasks, or discrete labor activities. Use of tasks varies by crop type and depends on management scenario and practices selected by the model user. Labor for each task per acre varies by equipment available (if done by hand, with a walk-behind or two-wheeled tractor or with a utility tractor). Total production labor is thus the sum of all task labor hours in the system, and is only calculated when crops are grown. This is added to harvest and processing labor, which is calculated as hours per pound harvested by crop type with additional labor required when crops have experienced significant biotic damage.

Demand is compared to labor supply in order to calculate the balance of labor hours. Total demand is compared to the "labor base" of all farm family workers, based on ideal workload. The balance is then compared to the non-farm family labor available from volunteers, interns, or employees. As employees are hired their labor becomes available but is only used (and paid for) when there is labor demand. If total labor demand exceeds both the on-farm labor base and available off-farm labor, the farm family must then work "overtime" hours beyond their goal. If labor demand still exceeds the capacity of the farm family to work overtime (estimated at 80 hours/week/farmer), the model indicates to the user that demand remains unmet.

Customers

Customer recruitment and retention in the face of competition are important part of sales for all farms, but is especially crucial for small farm systems that rely heavily on direct, small sales to individual consumers. Customer flux is simulated for each sales outlet chosen by the model user (CSA, face-to-face, aggregators or exporters) (Figure 2.7). We have structured customer flux using a modified Bass Diffusion Model which simulates adoption of new products within a population (Bass, 1969; Morecroft, 2007). Potential customers of each market outlet begin the simulation in an "uncommitted" category and may become customers of this modeled farm, the farms competing with this farm, or, for CSA and face-to-face customers, the "conventional food system," such as supermarkets. Customers can only commit to one seller at a time (e.g. the modeled farm or competition) and can only switch between sellers, not sales outlets (e.g. CSA customers cannot become face-to-face customers). The farms considered competition are profiled as non-certified organic producers with a “balanced” management priority (Table 2.2) producing high-quality produce often found at farmers markets. It is assumed that these farms will be more similar to the modeled farming operation, and thus a greater challenge, than the “conventional food system.” However, the distinction between the modeled farm and its competition is not entirely controlled by the model—it is up to model users to determine and input the market size (i.e. the number of customers being competed for) and the pressure from competition that they perceive exists.

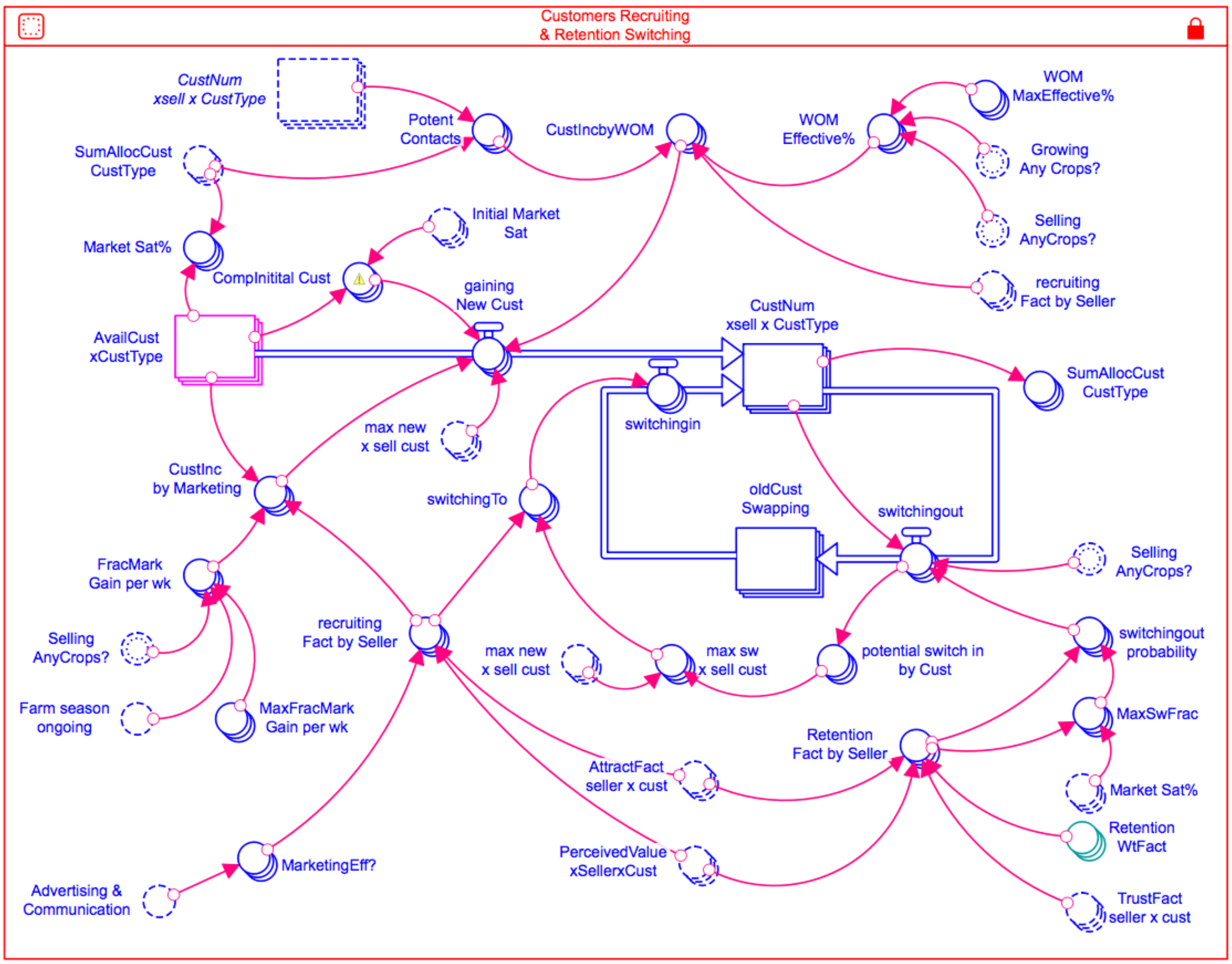


FIGURE 2.7—THE CUSTOMER RECRUITING AND CUSTOMER SWITCHING SECTOR

At the start of the simulation, the model user can input a fixed number of available customers for each sales outlet they wish to use who are initially "uncommitted" to either the modeled farm or its competition. With time, these customers are gained by the farm or competition and may be retained indefinitely, or can switch back out to an "uncommitted" pool and then again back again as customers. Customers are gained from the initial uncommitted pool first by marketing (advertising, websites, etc.), and then also by word-of-mouth of committed customers. As market saturation increases, these methods become less effective. Customers can continue to be gained until the pool of available customers is exhausted or until the modeled farm has met its goals for customer number in a given market type.

After customers are initially recruited, the rates at which they un- and re-commit are ultimately determined by the customer's perception of attractiveness, trust and value for each seller. A single "attractiveness factor" for the modeled farm is based on a combination of the multiple dimensions of how attractive the farm and its products are to customers, relative to competition, reported by the model. These attributes are the price, uniqueness and diversity of products, the quality of relationships and communication with customers, the effort and spending on marketing and advertising, and the "localness" of the farm. "Localness" implies that customers both perceive the farm to be physically local and perceive the farmer or farm family as members in their community.

The model user reports each farm attribute as relative to their competition. Using a direct sale or CSA perspective, Competitive farms are then ranked as "average" and the conventional food system is generally ranked as "much less than," except for convenience. The attributes are weighted relative to one another and summed for each group. The trust factor is a weighted sum of customer relations, localness and market appeal. The perceived value compares the modeled farm's relative price to competitive farms which have been set at a baseline price and the conventional food system set at a cheaper price. Although local food is widely perceived as more expensive than conventional food, studies do not always support this claim, although it is generally true in this region (Amy Kremen et al., 2004; Pirog and McCann, 2009).

The attractiveness factor, trust factor and perceived value are weighted equally into a customer retention factor. As this retention factor increases, the probability of switching out becomes equal among the modeled farm and competition, and switching ceases. After customers have switched out, they will immediately re-commit to a seller. Switching to a seller is driven by attractiveness factor, perceived value, and relative marketing effort, as determined by investments in marketing, in order to create a probability of recruitment for each seller for each market. This probability is related to attractiveness of the other sellers for that market and is multiplied by the number of customers who have switched out. If the modeled farm has met its customer goals, or if its expected supply of products for a particular market cannot support new customers, attracted customers will be "turned away" and become customers of the competition.

Total sales are driven by total demand, which is calculated by taking the number of customers for each market type and multiplying that figure by the pounds demanded per customer per crop per week. It is possible to model demand based on local market surveys, but this requires extensive knowledge on the part of the farmer and the addition of many inputs into the model. Instead, we use a diet-based approach to calculate per-person demand for each crop based on the number of weekly servings, in pounds, as recommended by the USDA MyPlate Dietary Guidelines, as calculated for individual crops by Smith, 2014. Per-person demand is scaled up for aggregator and exporter customers who purchase to meet the demand of hundreds to thousands of individual consumers.

Sales and Economics

Since the model is designed for commercially oriented small farm systems, it is necessary to monitor the farm's finances to measure its economic viability as a metric of success. Finances are monitored as a stock of operating capital from which income is added and expenses are subtracted. Income is added from sales, and additional startup capital may be added as an exogenous variable. Total sales income is a sum of the pounds sold of each crop type through each sales outlet multiplied by the sales price per pound of each as entered by the user.

In a typical year, expenses are the sum of farm family salary (based on the user input goal), fixed expenses and variable expenses, deducted on a weekly basis. Fixed expenses are calculated with annual numbers but deducted weekly, and include equipment replacement costs, land costs (i.e. mortgage or rent), fees, insurance, utilities, and administrative or office expenses. Variable expenses are arrayed by crop type and are calculated as the sum of marking expenses which are scaled to pounds sold by market type and production expenses which are scaled to acres grown. Production variable expenses include the cost of hired labor, the cost of fuel and repairs for equipment, and input costs that vary based on which tasks are executed for crop production. In the first year, expenses also include the initial costs of equipment required to complete the tasks on the farm.

The stock of operating capital is allowed to go negative, putting loan acquisition or other means of acquiring debt outside the scope of the model and allowing for more flexibility in scenario testing. The target salary specified by the model user is deducted continually throughout the year, regardless of operating capital. At year's end, cumulative income and expenses for that year are compared to report to the model user whether or not that annual salary goal was truly met by surplus farm income in a particular year.

DISCUSSION

As we have stated above, in order for farmers to succeed, they must break the feedback loops of supply and demand that allow the market to dictate the sales price of their crops. Farmers must find a means of "adding value" to sell their crops for above the supply/demand-dictated price. In establishing successful operations, our case study farms have accomplished this. Farms must produce food that caters to the values of their customer bases. Our case study farms produce organically, both certified and unofficially, use environmentally conscious practices and participate in local markets where customers share these values. Further, farms must make potential customers aware of these desirable attributes of their products through marketing and advertising. Our farms advertise their organic practices and create attractive and inviting market displays, as well as using websites and social media to market their farm. It's also helpful if farmers can gain cultural capital with their customers on the basis of common passion and values for promoting local food. Through participating in local markets, community activities, and establishing CSAs, two of our farms present themselves to customers as participants in the local food system. Once customers have made their first purchase, they must be maintained. Customers must perceive your products to truly be worth your price in that they are high quality, produced using sustainable practices, fresh, and taste good. Our interview participants reported establishing repeat customers at their market because customers thought they had the best tasting products. Also, as farms continue their presence at the market and in the community, they establish social capital as community members and gain the loyalty and trust of their customers. These success factors largely align with the tenets of what Lyson, 2012, terms Civic Agriculture—an agricultural practice that emphasizes high quality products and fostering connections with the community in which they are marketed.

This formula to economic success is not without caveats. Adding value to crops to achieve a higher sales price based on financial needs can only work within limits. Farms must manage their operations carefully to keep expenses reasonable and keep their salary goals realistic. They must also be able to competently manage their biophysical production and non-family labor sources. All of our participant farms had previous experience interning or managing other farms before beginning their current operations. Even as these farms participate in competitive markets, they have been able to escape the price constraints of the supply/demand curve by adding perceived value to their crops and through the talent and experience that have made them good production and business managers.

Beyond economic success, our interviews revealed that farmers were motivated by their enjoyment of the farming lifestyle and passion for being a part of the food system. Farmers value being trusted by their customers and being good stewards of the environment. However, since farming can become an all-consuming job, farms also sought to maintain a healthy work-life balance. These factors have been present in the modeling process throughout its construction. Loyalty and environmental quality factors are built into the model and can be compared to goals set by the model user. The user can also set a desired number of hours of work per week and can see if this goal can be met as the model runs.

Planning and recordkeeping of production and across the farming enterprise emerged as goals for which only one farm was successful. Within the growing season, farm management can be hectic and recordkeeping can prove difficult. Natural systems are prone to fluctuation and can thus be difficult to manage according to plan, but good managers are talented at understanding how their farm system is responding to environmental variables, customer interests, and using adaptive management. However, these adaptations often go unrecorded despite their value as a reference in the future. Further, detailed sales data can be extremely helpful in planning quantity and timing of each crop for the next market season, as noted by the farm that had them available.

Exogenous capitals seemed to be important across the case study farms in establishing successful enterprises. Two farms started their operations with considerable financial capital that they had earned and saved from other professions. According to their financial records, one of these farms operated at a loss the first year, with a small profit the second year, and only earned salary-level income after their third year of operation. Even at this small scale, land and startup costs prove to be a barrier that must be overcome. Human capital is also an important exogenous attribute. All farmers were experienced and well equipped with crop production knowledge before they began their operations. Natural capital is exogenous as well. The model user must specify soil texture and a personal assessment of soil productivity relative to top yields for their crops. This factor can hinder or enhance the expected productivity of all crops and its effect can be amplified or diminished by production systems and practices chosen. All our farmers carefully researched the land on which they chose to farm, all selecting plots that had previously been farmed and were among the most productive soil types within a geographic region not known for its productive soils. Further, they all employ production systems and practices used to build soil productivity. Endogenously, farmers may gain social capital over time through their presence at markets which can further enhance their success. Farmers can also acquire cultural capital through shared values and experiences with customers and volunteers which they may re-invest in the success of their farming system. These social components are included in the model as a “trust factor” which contributes to recruiting customers but can also be monitored independently relative to the model user’s goal.

We incorporated many indicators throughout the model that emphasize important information to the model user. The economic success indicator for the whole farm system calculates the degree to which funds are available to meet the salary goal as well as whether the system's annual income exceeds expenses in the first five years or the operating capital is positive after year 5. The resiliency indicator sums the operating capital with funds deducted for salary and equipment replacement costs. We calculate an estimated hourly wage for farm family labor by comparing the farm's annual salary to the farmer family's cumulative labor contribution for the year. This helps the model user put into perspective how much they earn for their time. The unmet labor indicator does not diminish the productivity of the farm but indicates to the model user that they have demand for labor likely in excess of what the farm family is able to supply. Other indicators are more straightforward, communicating to the model user whether or not goals for salary and farm family workload limits have been met.

CONCLUSIONS

Through the process of model development as a means of working with our farmer interview data, we have learned much about the nature of small farm systems. We were able to construct a conceptual model using quantitative and qualitative data about farmers and their systems, including beliefs and value systems. Through this process, we have more clearly revealed the means available to farmers to overcome the price controls of the supply-demand feedback loop and other pathways to farm success. Through the construction of the model's interface layer we also managed to identify and isolate, across the complexity of the model, the key variables that shape the farm system. Further, we feel we have selected these input variables in a way that we feel is approachable and manageable for the model user.

In order to further the model's use as a learning tool for current and aspiring farmers, service providers and small farm advocates, we are in the process of preparing the model for simulations. This requires continued parameterization, iterative review and revision as needed, and populating the model with data. This will allow for policy testing, or the manipulation of model inputs to observe model reaction for scenarios of interest. Our research team and future model users will be able to observe system behavior in exploring such questions as return on investment for equipment or marketing, consequences of entering a highly competitive or small market, and consequences of using conventional production inputs on factors such as customer recruiting, retention, production, and environment.

Through this process, the structure, equations and assumptions as presented here in the model will be tested and challenged and the limits of model use will be defined. We hope to use simulation runs of the model to verify and further strengthen the conclusions made here using qualitative methods.

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Chapter 3: Conclusions

SUMMARY

Presently, the model has been fully developed and parameterized, meaning data and equations have been populated throughout the model. As stated in Chapter 1, the modeling process is iterative, and so continuing through the final steps of the modeling process and subsequent revisions to the current model are a matter of future work. We can now begin testing the model, verifying expected behavior, and can soon begin putting the model to use to test scenarios and questions. In the work presented here, we have reached the point in the modeling process when we can start learning from the results of model simulations so that the model gains value as a learning tool beyond a means of organizing and representing our mental models and thoughts through systems thinking, concept mapping and developing stock and flow diagrams.

Beyond beginning to answer our questions about small farmer success, we have pursued a unique model formation process which has been a learning experience in itself. We have used our interviews as rich sources of many kinds of data to inform our modeling process. This was not a mediated or group modeling project in which the model's "client" participates as a modeler. In developing our model, we minimized the time commitment of our clients (the farmers) to two interviews and the line of communication between modeler (us) and client (farmer) did not remain open. However, our interviews still allowed us to learn and incorporate the value systems and mental models of the interview participants in addition to being a source of quantitative data. We hope to present the model and our thinking behind it to the case study farmers at a later date, both as verification that what we learned about their systems is correct and to allow them to use the model to test questions they may have.

As we transitioned to model construction from concept maps, it was necessary to go through each sector or "sub-system" that we had mapped and express and define its components in STELLA. We were repeatedly challenged by finding ever-expanding complexity in the details of components that were critical to developing a comprehensive model of a whole farm system. In each case we had to determine the level of detail that would best serve our modeling purpose and could manageably be modeled, while minimizing data input from the model user. We then also had to create a technical solution to make this simplification possible. Much of this complexity is unique to these small farms as systems that grow a diverse array of crops, use a wide range of management techniques, and often execute their practices without large equipment. These characteristics of small farm systems greatly complicate their ability to be modeled compared to a large, less diverse, highly mechanized farm. As mentioned in chapter 2, the solution was often to reduce the number of interactions by clustering components together, requiring a fraction of the data but populated for pre-determined combinations. Although this in some respects reduces customization of the model (notably, a model user cannot input specific combinations of most individual crops and planting dates and observe changes in the potential impact on the farm's competitive advantage at market) the simplification also eliminates some assumptions that would need to be made at such a fine resolution (for instance, assumptions about the competitive advantages of individual crops). The model could be extended to other crops if future users find this essential.

In large part because of these complexities, the modeling process took much longer than initially anticipated. Our first draft of the model generally did not anticipate these complexities. It was only through the process of refining each section that we encountered issues that required unique solutions, and as we moved on to refine other sections, such situations continually emerged. This is characteristic of the iterative modeling process. As the model is drafted and re-visited at increasing levels of detail, the system grows increasingly complex.

EXAMPLE RESULTS OF MODEL RUNS

Example Tests to Verify Model Behavior

Using default parameters for all other interface values, does the model behave as expected for the following conditions in a simulation for a single year:

1. The soil productivity rating given by the model user should be directly correlated to yield (very high productivity = high yield, very low productivity = low yield)

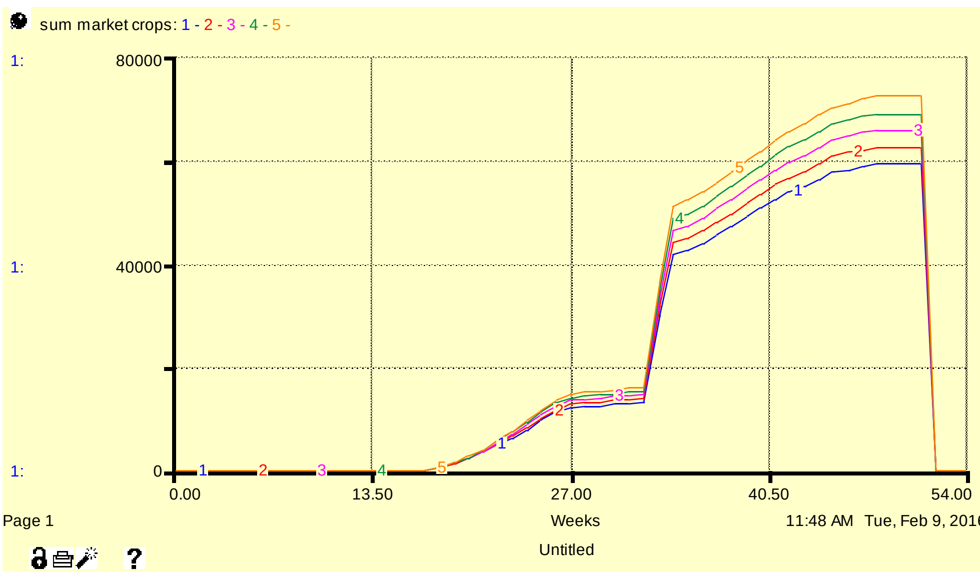


FIGURE 3.1— CUMULATIVE TOTAL POUNDS OF ALL CROPS HARVESTED AND AVAILABLE TO MARKET IN A SINGLE MARKET SEASON.

In the preceding graph, the number of the lines corresponds to the productivity rating selected by the model user, with 1 indicating very poor productivity and 5 indicating very high productivity. All levels follow the same pattern, with incremental increases in productivity corresponding to incremental increases in yield.

2. The number of acres planted of each crop type should affect the pounds of crops available at different times during the market season.

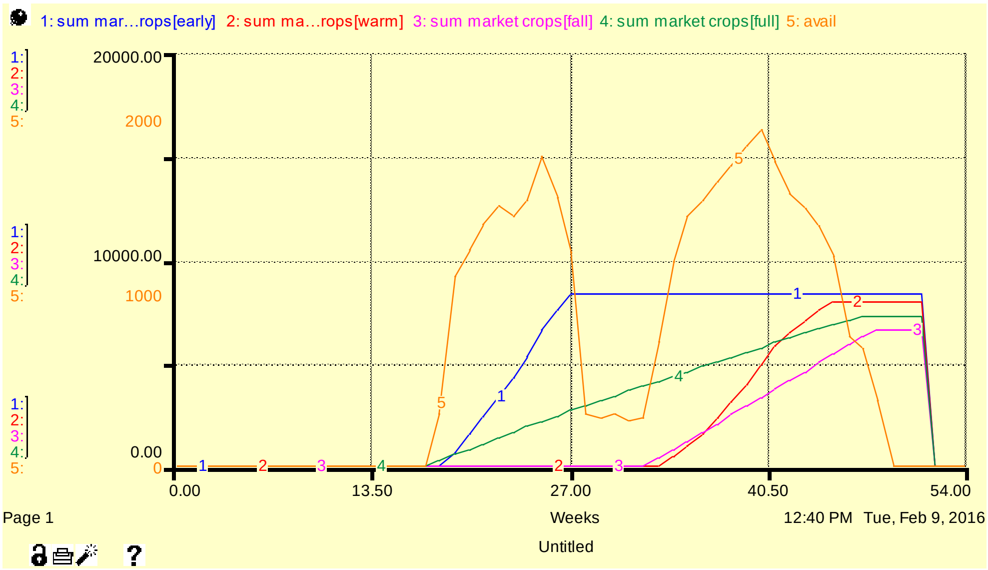


FIGURE 3.2—CUMULATIVE POUNDS BY CROP TYPE (EARLY, WARM, FALL AND LATE) AND WEEKLY TOTAL POUNDS (DIFFERENT SCALE) FOR CROPS HARVESTED AND AVAILABLE TO MARKET IN A SINGLE MARKET SEASON GIVEN 1 ACRE PLANTING AREA EACH.

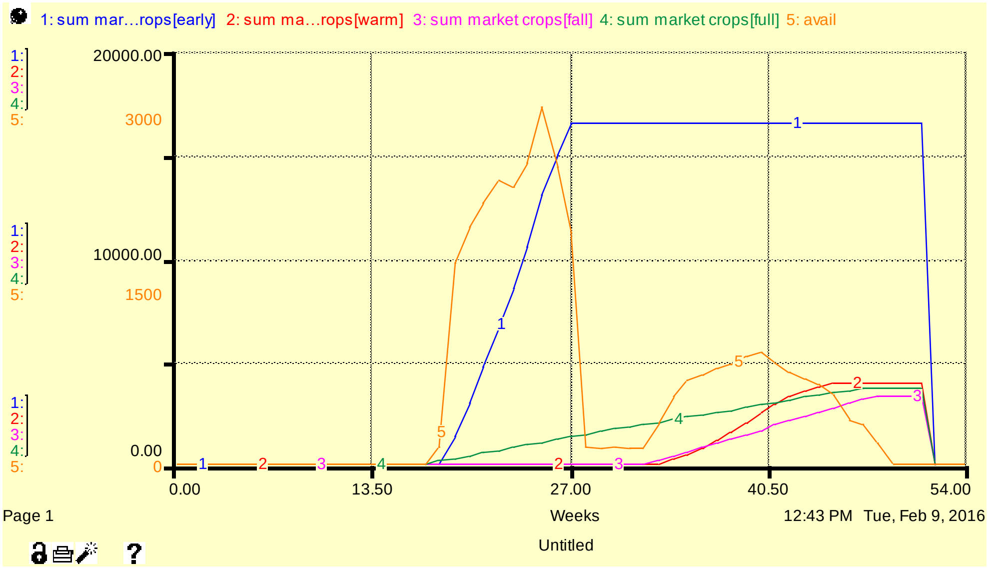


FIGURE 3.3— CUMULATIVE POUNDS BY EACH CROP TYPE AND WEEKLY TOTAL POUNDS FOR CROPS HARVESTED AND AVAILABLE TO MARKET IN A SINGLE MARKET SEASON GIVEN 2 ACRES OF EARLY SEASON CROPS (LINE 1 IN BLUE) AND .5 ACRES OF ALL OTHERS.

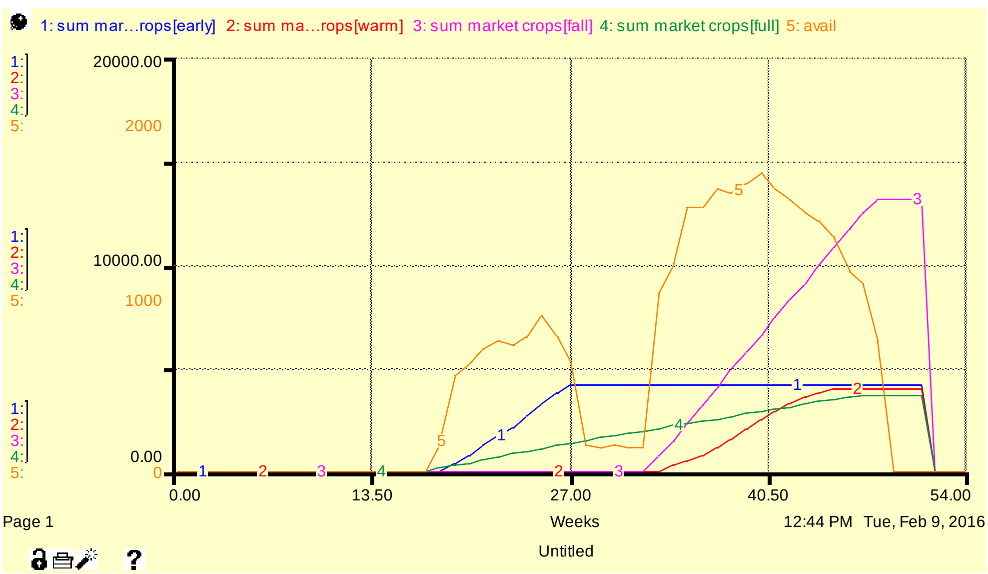


FIGURE 3.4— CUMULATIVE POUNDS BY EACH CROP TYPE AND WEEKLY TOTAL POUNDS FOR CROPS HARVESTED AND AVAILABLE TO MARKET IN A SINGLE MARKET SEASON GIVEN 2 ACRES OF FALL SEASON CROPS (LINE 3 IN PINK) AND .5 ACRES OF ALL OTHERS.

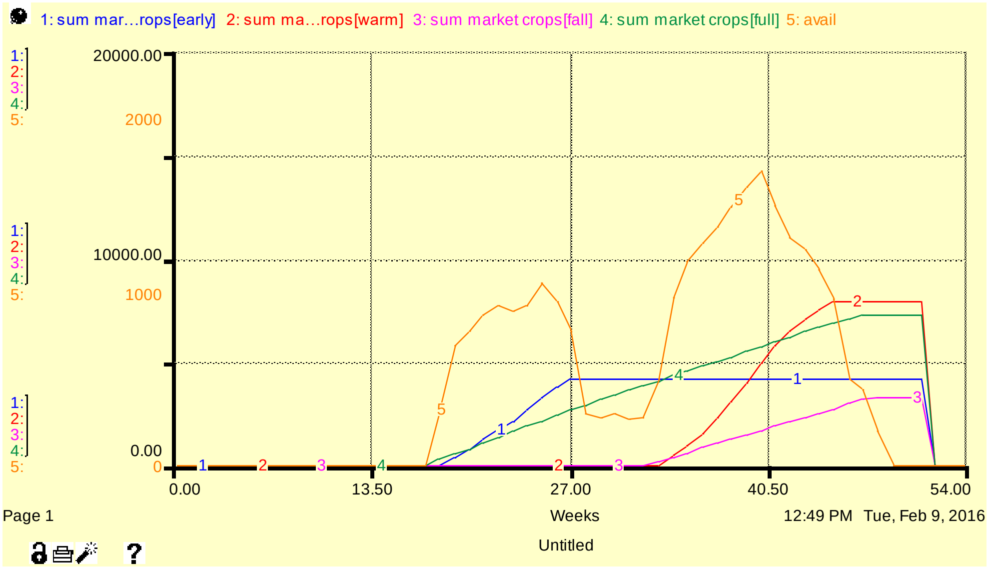


FIGURE 3.5— CUMULATIVE POUNDS BY EACH CROP TYPE AND WEEKLY TOTAL POUNDS FOR CROPS HARVESTED AND AVAILABLE TO MARKET IN A SINGLE MARKET SEASON GIVEN 1 ACRE EACH OF WARM AND FULL SEASON CROPS (LINES 2 AND 4) AND .5 ACRES OF EARLY AND FALL CROPS.

When all crop types are set to the same numbers of acres planted, the pounds of crops available for sale at market each week forms two distinct peaks separated by a depression (Figure 3.2). The shape of this curve depends on the number of acres planted for each crop type specified by the model user. This effect is exacerbated by higher relative acres of early and/or fall season crops (Figure 3.3 and Figure 3.4) and can be mitigated through increasing relative levels of warm and/or full season crops (Figure 3.5).

Example Tests to Explore Policy Questions

3. How might a farmer's choice in production management practices affect other components of the farm system?

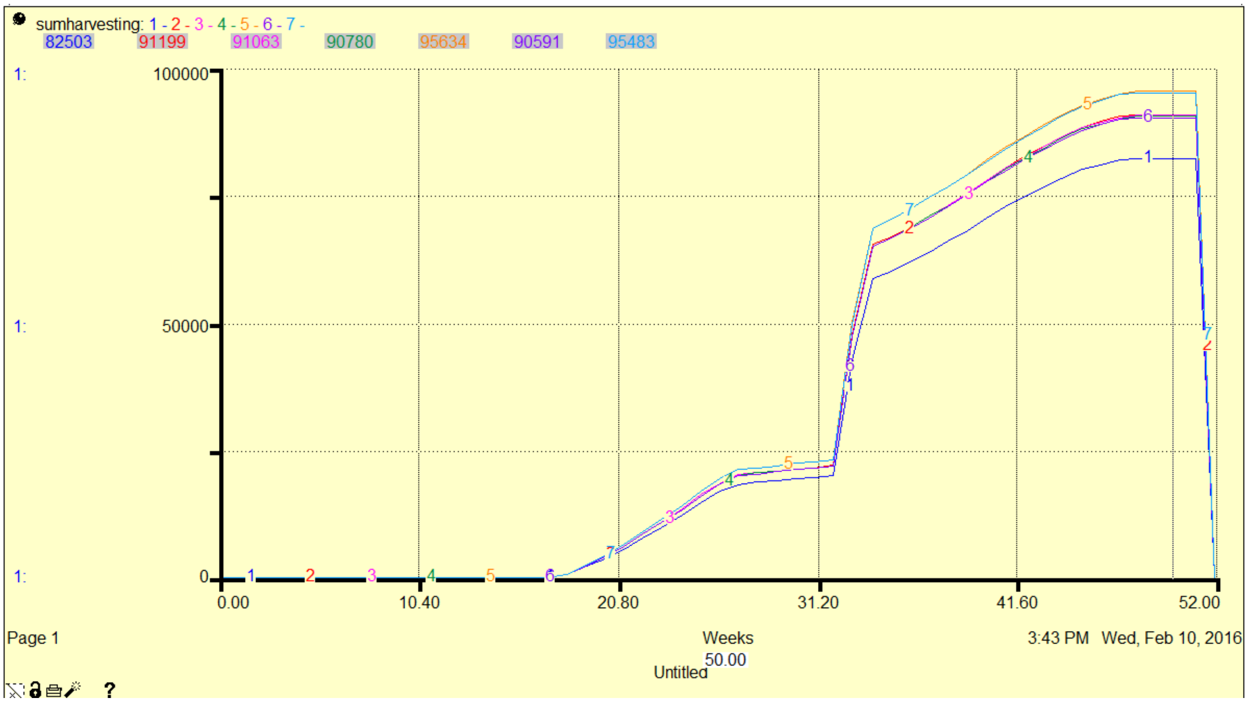
On the interface, model users are asked to select a scenario that best represents their production practices. Each scenario is associated with a set of attributes that have implications for the yield, input costs, environmental quality, perceived attractiveness of crops by customers, and labor required on the farm, among others. There is no single optimal scenario; they each have trade-offs and it is up to the farmer or model user to determine which fits best with their values and their idea of success.

Out of the twelve total scenarios, we chose to include a sample of seven chosen to cover the most likely scenarios (Table 3.1, the "balanced" management options numbered 2, 3, 4 and 6) as well as the most extreme options (Table 3.1, options 1, 5 and 7). We test the most "conventional" scenario, every input level (conventional to organic) with tillage, soil testing and mulching, as well as certified and non-certified no till, rotation and soil testing scenarios. Other inputs were set to default values and were held constant for each trial.

TABLE 3.1—PRODUCTION SYSTEM SCENARIOS. BOLD INDICATES INCLUSION IN SIMULATION, NUMBER CORRESPONDS TO GRAPHICS.

	Use of Inputs			
Management Priority	**Conventional Fertilizers and Pesticides**	**Mixed (some non-certified organic inputs)**	**Non-Certified Organic**	**Certified Organic**
Business Oriented	*(1) Conventional tillage, no rotations, no soil testing*	Conventional tillage, no rotations, no soil testing	Conventional tillage, no rotations, no soil testing	Conventional tillage, rotating (required), no soil testing
Balanced	*(2) Conventional tillage, soil testing, mulching of crops*	*(3) Conventional tillage, soil testing, mulching of crops*	*(4) Conventional tillage, rotating, soil testing, mulching of crops*	*(6) Conventional tillage, rotating, soil testing, mulching of crops*
Lifestyle Oriented	No till, rotation, soil testing	No till, rotation, soil testing	*(5) No till, rotation, soil testing*	*(7) No till, rotation, soil testing*

The three indicators we observe based on scenario selection are yield (Fi gure 3.6), soil quality (Figure 3.7), and CSA customers recruited (Figure 3.8). Yield and soil quality index follow the same pattern. The scenarios that are highest-yielding and have the highest soil quality indicator values are 5 and 7, the lowest is 1, with most falling inbetween idential or near-identical values. For customer acquisiton, scenario 6 and 7 both come closest to achieving the goal with scenario 1 again as the lowest.



FI GURE 3.6—CUMULATIVE YIELD FOR ONE YEAR. NUMBERS INDICATE YIELD IN POUNDS FOR EACH SCENARIO.

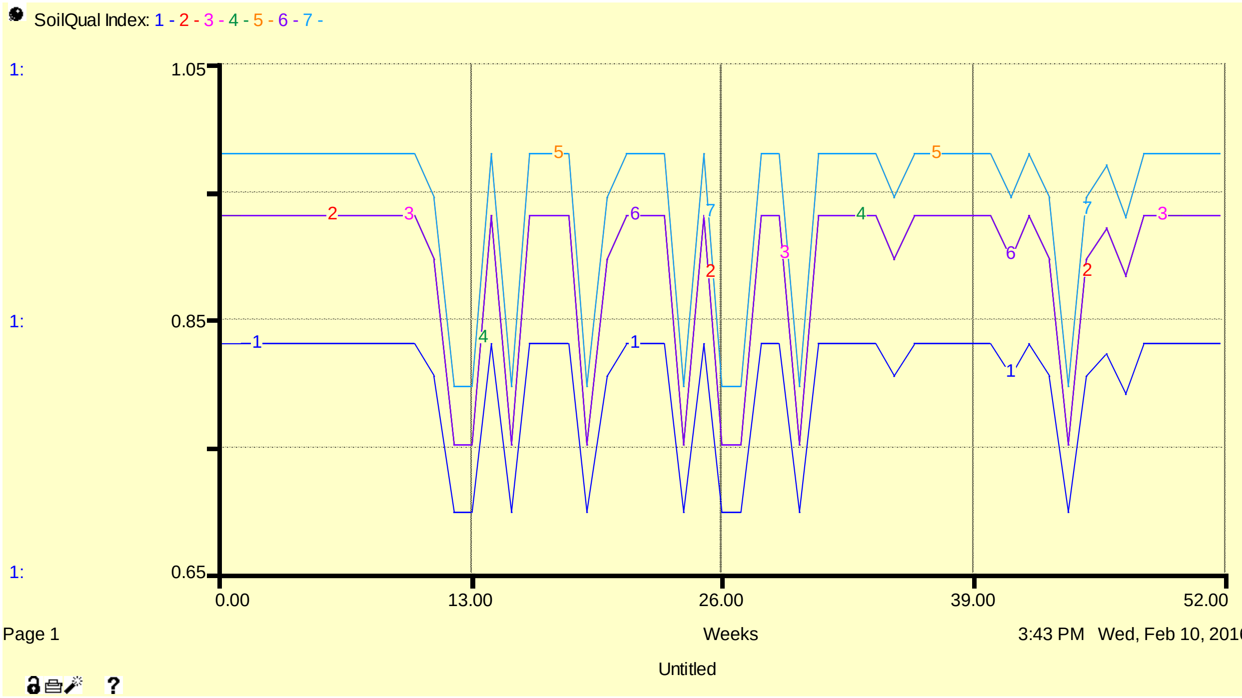


FIGURE 3.7—VARIATIONS IN SOIL QUALITY INDICATOR (VALUES 0-1) BY SCENARIO FOR ONE YEAR.

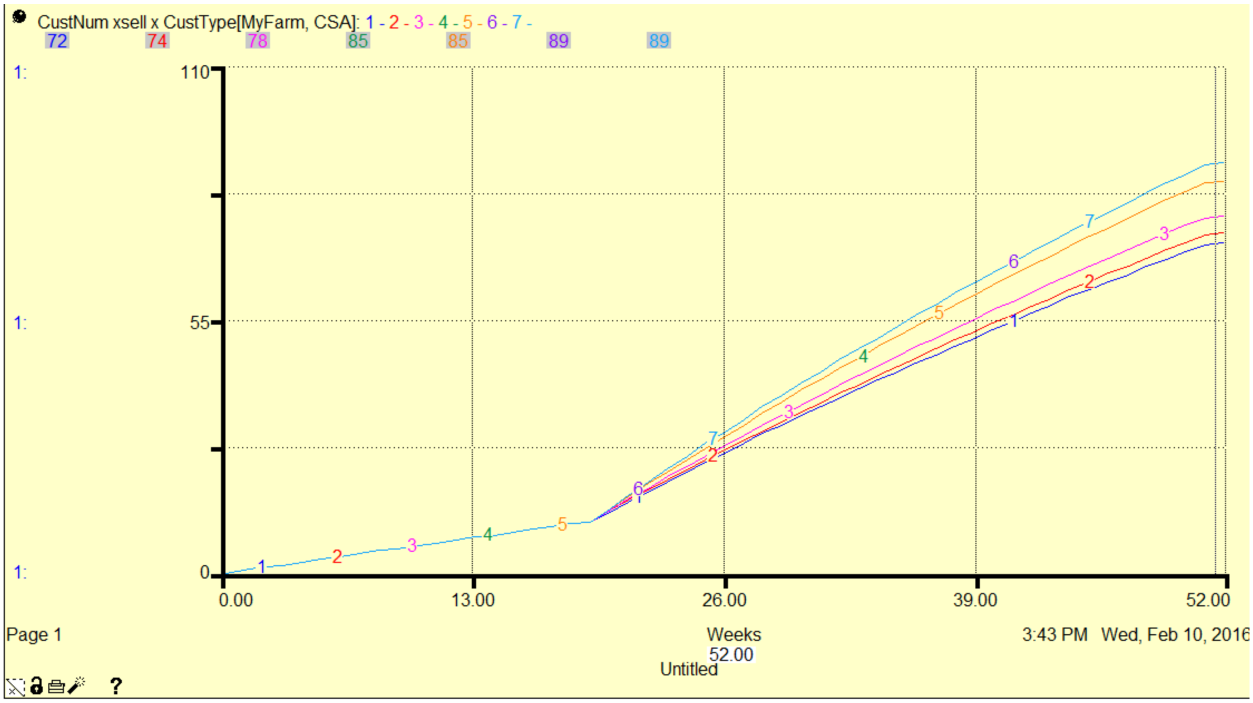


FIGURE 3.8—NUMBER OF CSA CUSTOMERS RECRUITED BY THE FARM IN THE FIRST YEAR, WITH A GOAL (CAP) OF 100.

Although 7 is the most optimal system based on this simulation, the simulation was far from complete. Yield and customers should give some indication of sales, however other factors such as sales price per pound and pounds sold per customer need to be addressed as well. Expenses were not considered in this simulation since they are still being tested, and so we were unable to compare profitability of scenarios. Although a system may be high-yielding, it may have higher production expenses on a per pound yielded than other scenarios. Labor requirements vary greatly by scenario since hand weeding is a much more labor intensive process than the application of herbicides. Were the expenses associated with labor included in the scenario, it is likely a different scenario may have seemed optimal.

NEXT STEPS

The model contains many, many more components that require testing and may be useful to answering policy questions than the components featured here. These examples serve only to illustrate how relationships in the model may be tested and how the model can be used to explore specific policy questions that are narrow in scope. Model users will also be able to construct much more comprehensive farm system scenarios by modifying the full array of interface variables. This will allow beginning farmers to use the model to as a planning tool to simulate their hypothetical farming system. They can then adjust selective inputs and observe how the system responds in order to learn which exogenous and endogenous factors are most critical to achieving their vision of success. They can also adjust inputs to run simulations that push and test the limits of their system. Practicing farmers can input variables similar to their current farm systems and can modify the inputs to observe how the model responds to proposed changes. These may include testing how hiring an additional employee will affect the farm's profitability and the farmer's labor load, whether the purchase of equipment combined with increasing acres will reduce labor expenses and increase profits, and if the adoption of a cover cropping practice will provide environmental benefits that outweigh the financial costs of labor and inputs. They can also test the strength of relationships between endogenous factors and the metrics of success they care about. Extension agents and other small farm educators and advocates will be able to use the modeling tool alongside farmers, or will be able to use it on their own to simulate and better understand how small farm systems operate.

Regardless of model completion, through the model development process as we have completed it so far we have learned a great deal about small farm systems and come a long way in answering our research questions. We have learned about farmer values of work-life balance, customer relationships, and environmental stewardship outside of the farmer’s need to establish a profitable farm. We have also learned that farmers are able to set prices for their crops that help them achieve economic success by producing food in a way that caters to the value systems of their customers, using marketing and advertising to make this known and the farm attractive, producing food that is perceived as high quality by the consumer, and by building trust and relationships with customers. Also, our successful farmers began their operations with farming experience and financial savings but have established their farm as a recognized presence at farmers markets over time. We hope to further strengthen and refine our understanding as we continue the modeling process to develop the model as a learning and research tool to be used by others.

APPENDIX A: COMPLETE CROP LIST

Season	Crop	# plantings	RowFeet	Frac
E	Basil	2	350	5.8%
E	broccoli	2	400	6.6%
E	cabbage	5	600	9.9%
E	carrot	4	1000	16.5%
E	cauliflower	1	200	3.3%
E	celeriac	2	300	5.0%
E	celery	4	400	6.6%
E	fennel	1	250	4.1%
E	kale	2	700	11.6%
E	parsley	1	250	4.1%
E	peas	4	400	6.6%
E	spinach	4	1000	16.5%
E	swiss chard	1	200	3.3%
			6050	
Fall	diakon	4	300	4.7%
Fall	cabbage		1500	23.3%
Fall	carrot	2	2000	31.1%
Fall	collard	1	225	3.5%
Fall	kale	2	900	14.0%
Fall	raab	1	100	1.6%
Fall	spinach	1	1000	15.6%
Fall	swiss chard	2	100	1.6%
Fall	tatsoi	6	300	4.7%
			6425	
Full	Beet	8	1800	29.8%
Full	bok choy	12	750	12.4%
Full	lettuce	10	1700	28.1%
Full	radish	12	700	11.6%
Full	turnip	13	1100	18.2%
			6050	
O	onion	1	2000	
			2000	
W	bean	3	1200	9.0%
W	cuke	8	3100	23.3%
W	eggplant	2	900	6.8%
W	parsnip	1	400	3.0%
W	peppers	2	1200	9.0%
W	radish	3	150	1.1%
W	rutabaga	1	300	2.3%
W	summer squash	6	2600	19.5%
W	tomatillo	1	250	1.9%
W	tomato	4	3200	24.1%
			13300	

3	Soil Productivity: 1- Very low, 3 Average, 5 very hiigh
U 3	Soil Texture. 1: Sand, 2: Sandy loam, 3: loam 4: silt or silt loam, 5: clayey
U 2	Soil Slope% 1: 1-2%, 2: 3-5%, 3: 5-7%, 4: 7-15%, 5:>15%
U 3	Years of relevant education or experience? 0 to 10
U 3	Knowledge, skills and abilities, and finding help
U 2	Use of Cover crops: 1 none, 2 Winter cereals only, 3 Win. cereals & legumes, 4 Win. & Sum. cereals, 5 Win. & Sum. cereals & legumes
75	Environmental Goal 0-100%
75	Customer Trust Goal 0-100%

How does your farm compare to your competition?
For the following attributes, is you farm?
1 much less than
2 much more than
3 about the same
4-more than
5-much more than
competing farms?

3	Relative Price
3	Relative Uniqueness
3	Relative Diversity
3	Relative Localness
3	Relative Convenience
3	Relative emphasis on customer relations and communications
3	Relative spending and effort on marketing and advertising

Which of the following best describes your target production system?
A=Local, Conventional: use fertilizers and pesticides
1-- Conventional tillage, no rotations, no soil testing, 2 --Conventional tillage, soil testing mulching of crops, 3 --No till, rotation, soil testing
B Local: some use of non-NOP approved inputs
4 Conventional tillage, no rotations, no soil testing, 5 Conventional tillage, soil testing, mulching
6 No till, rotation, soil testing
C Local, Organic, Not Certified:
7 --Conventional tillage, no rotations, no soil testing. 8 --Conventional tillage, rotating, soil testing, mulching of crops. 9-- No till, rotation, soil testing
D. Local, Organic, NOP Certified
10 - Conventional tillage, rotating (required) no soil testing,
11-Conventional tillage, rotating, soil testing, mulching of crops, 12-- No till, rotation, soil testing

8

U 6	**Production System Implementation: On a scale of 1-10, how well do you feel you can fully implement and manage your chosen production system?**
U 3	**Nutrient Management: 1-All nutrients from compost only, 2-All beds receive the same nutrient additions, 3- Use compost, some fertilizers (Org. or Min.) as needed to improve growth, 4- Apply all nutrients and lime based on soii test and crop specific N, 5-Plan (written) and use crop specific amounts, sources, timing, and**
2	**Irrigation: 1=no irrigation, rainfall only, 2=irrigation only when crop is stressed; 3=same water applied each week, 4=rainfall reduces irrigation amount, 5=use soil moisture monitoring devices**
2	Equipment Type 1: Hand tools only 2: Two wheel tractor&1, 3: Small tractor &1

Acres by Crop Type	
Early	1
Warm	1
Fall	1
Full	1
Onion	0.5
Potato	0

Customer Info by Market Type	
MARKET SIZE -CSA	500
Face to Face	500
Aggregators	3
Exporters	2
MY GOALS -CSA	100
Face to Face	150
Aggregators	0
Exporters	0
STARTUP CUSTOMERS- CSA	0
Face to Face	0

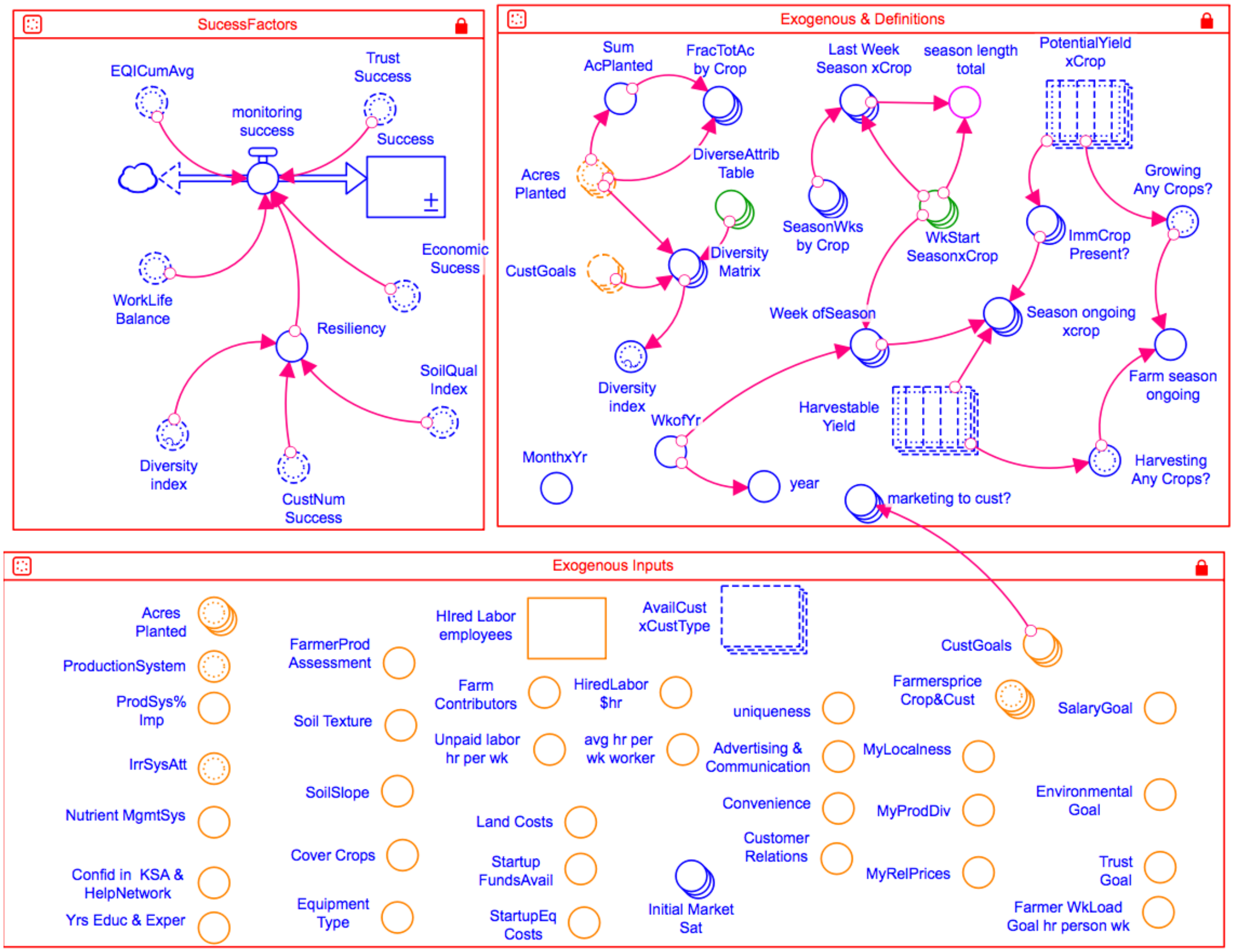
Run

Resume

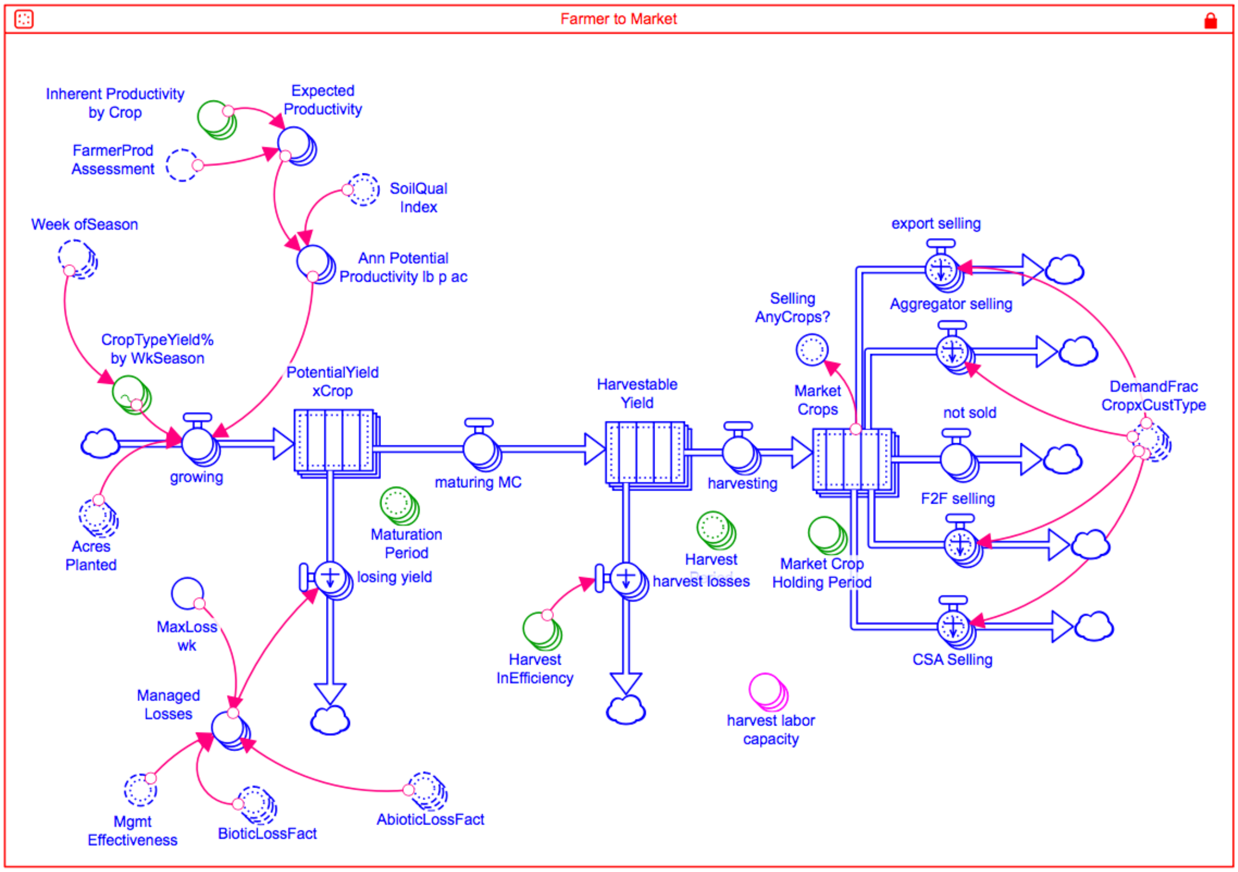
Economic Info	
Salary Goal (all salaries)	0
Startup Funds Avail	0
Startup Equip Costs	30000
Land Costs	0
Hired Labor # employees	3
Average hr/wk/ employe	40
Hired Labor wage $/hr	10
Farmer work goal hr/wk	50
Number Farm Contributors	2
Unpaid labor hr/wk season	0

Average Expected Price - CSA	
Early	2
Warm	2.5
Fall	2.5
Full	2
Onion	1.5
Potato	0

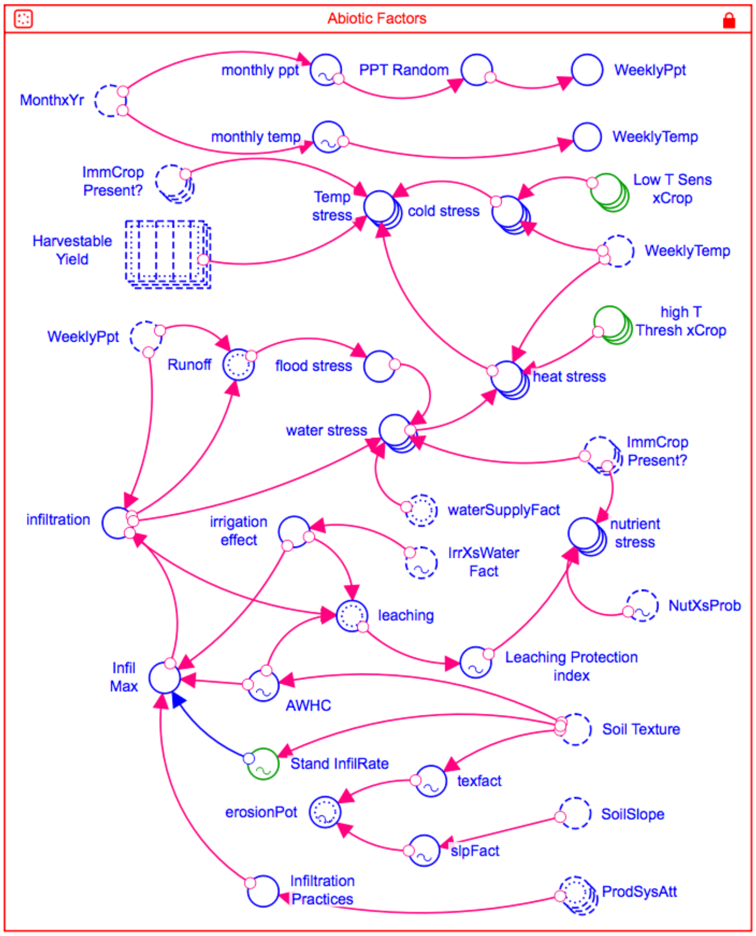
This table has a Dropdown menu (downward pointer beside CSA in table header.) Click there to enter expectedprices for other market types to which you will sell.

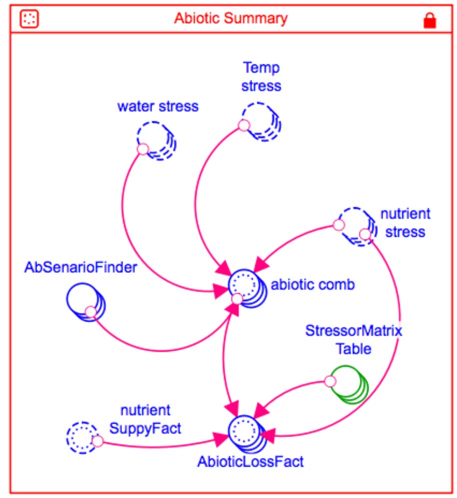


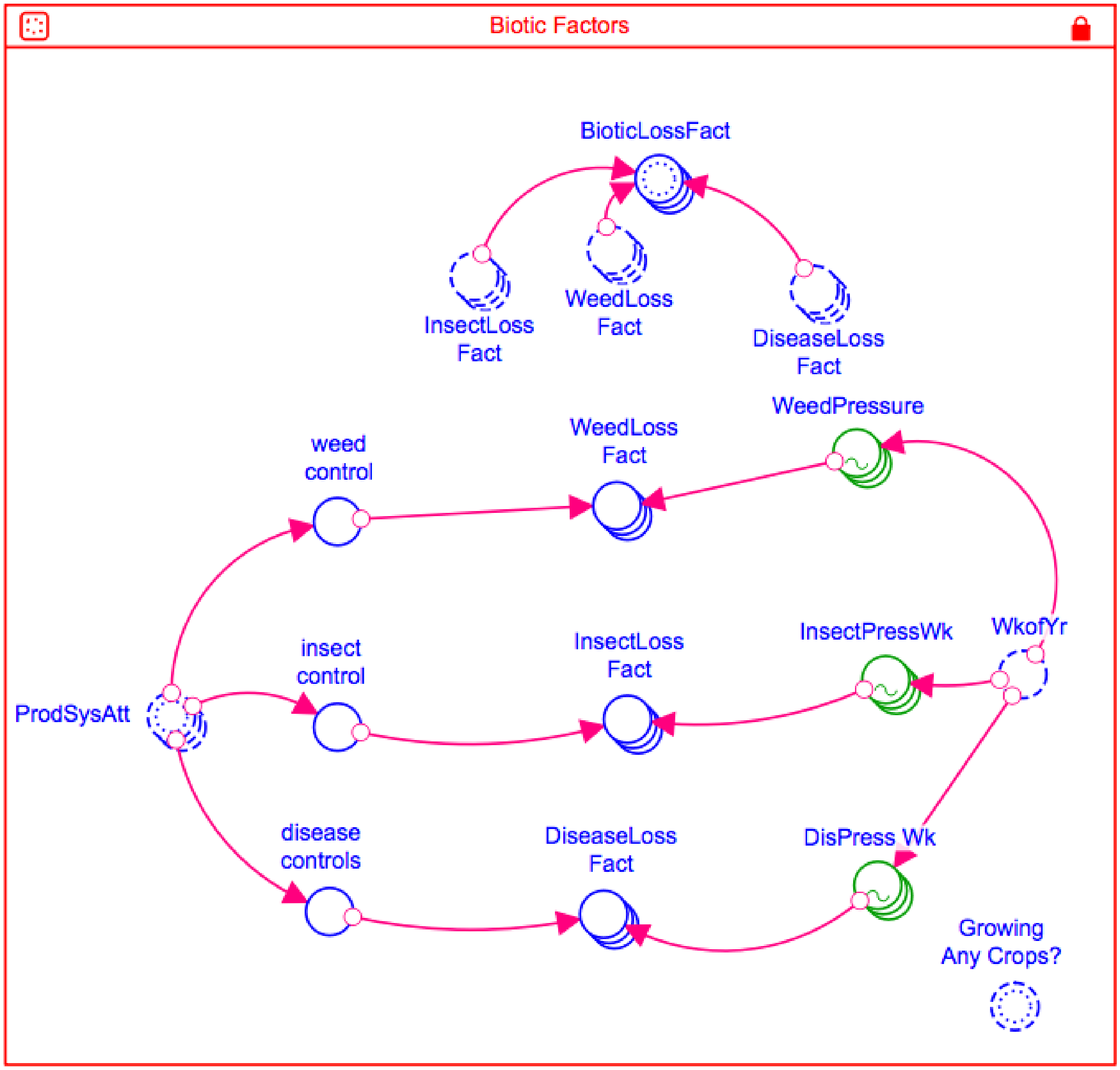
SucessFactors
EQICumAvg
Trust Success
monitoring success
Success
WorkLife Balance
Economic Sucess
Resiliency
SoilQual Index
Diversity index
CustNum Success
Exogenous & Definitions
Sum AcPlanted
FracTotAc by Crop
Last Week Season xCrop
season length total
PotentialYield xCrop
Acres Planted
DiverseAttrib Table
SeasonWks by Crop
WkStart SeasonxCrop
Growing Any Crops?
ImmCrop Present?
CustGoals
Diversity Matrix
Week ofSeason
Season ongoing xcrop
Diversity index
WkofYr
Harvestable Yield
Farm season ongoing
Harvesting Any Crops?
MonthxYr
year
marketing to cust?
Exogenous Inputs
Acres Planted
ProductionSystem
ProdSys% Imp
IrrSysAtt
Nutrient MgmtSys
Confid in KSA & HelpNetwork
Yrs Educ & Exper
FarmerProd Assessment
Soil Texture
SoilSlope
Cover Crops
Equipment Type
HIred Labor employees
Farm Contributors
HiredLabor $hr
Unpaid labor hr per wk
avg hr per wk worker
Land Costs
Startup FundsAvail
StartupEq Costs
AvailCust xCustType
Initial Market Sat
uniqueness
Advertising & Communication
Convenience
Customer Relations
CustGoals
Farmersprice Crop&Cust
MyLocalness
MyProdDiv
MyRelPrices
SalaryGoal
Environmental Goal
Trust Goal
Farmer WkLoad Goal hr person wk

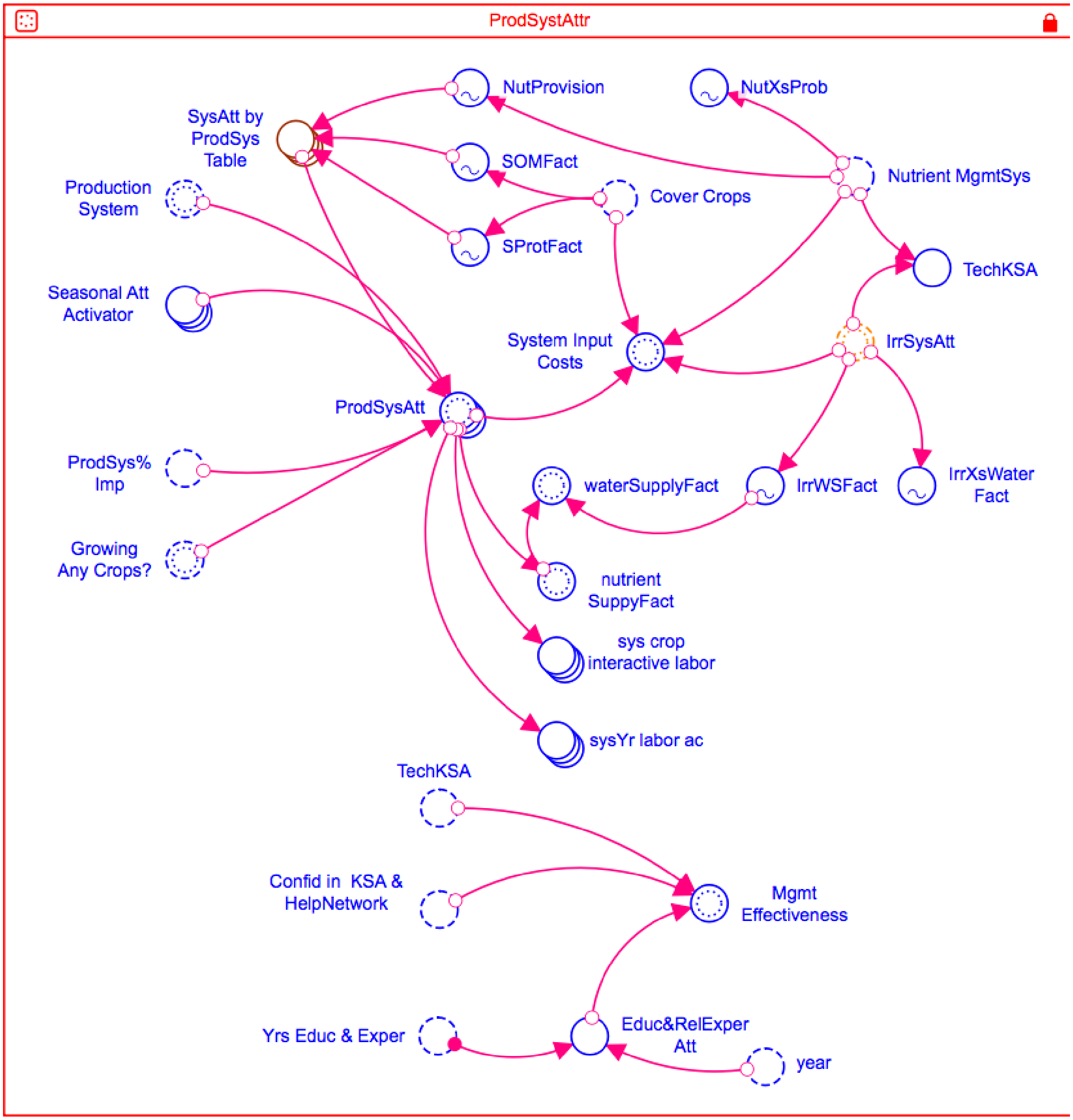


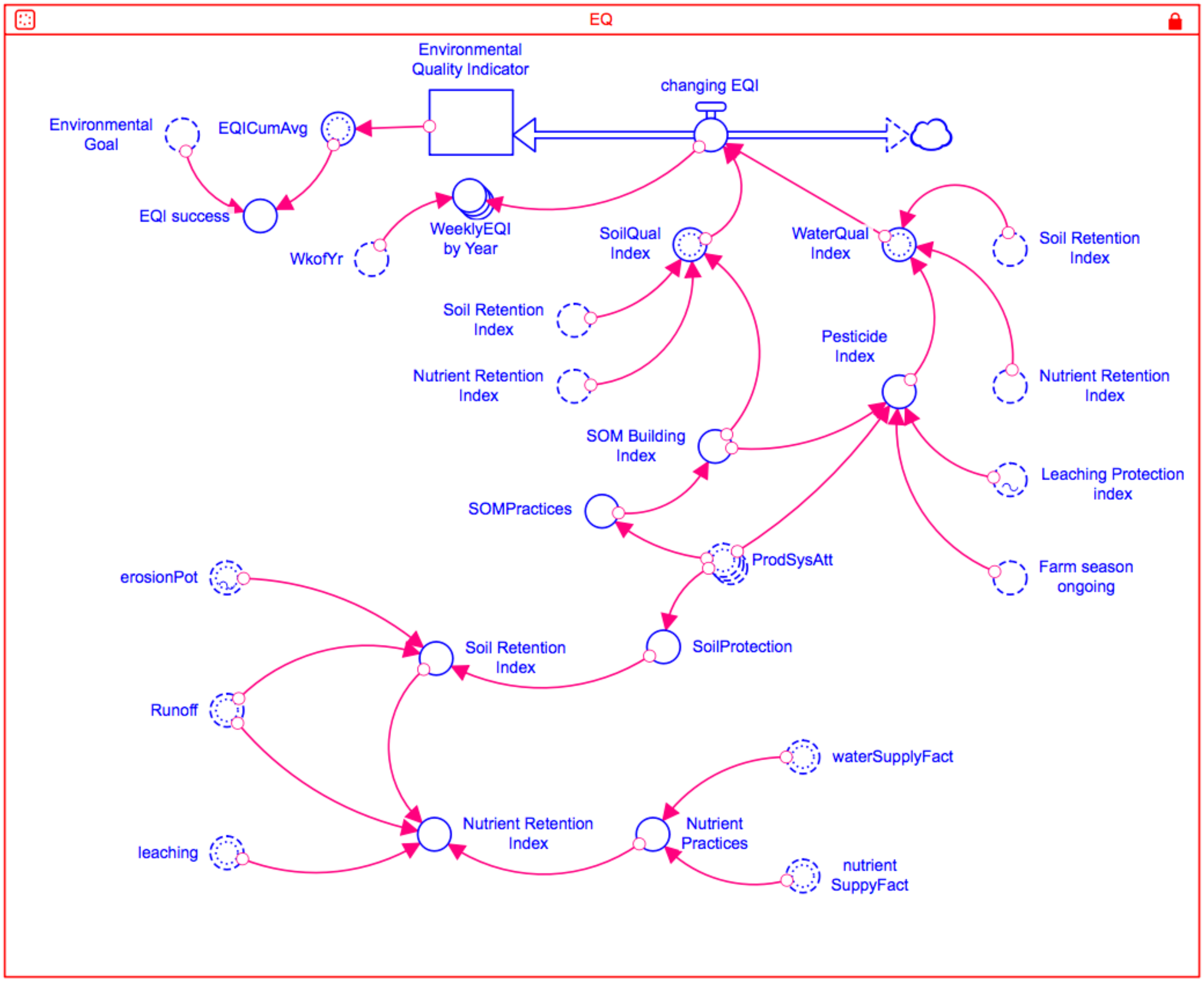
Farmer to Market
Inherent Productivity by Crop
Expected Productivity
FarmerProd Assessment
SoilQual Index
Week ofSeason
Ann Potential Productivity lb p ac
CropTypeYield% by WkSeason
PotentialYield xCrop
growing
Acres Planted
maturing MC
Maturation Period
losing yield
MaxLoss wk
Managed Losses
Mgmt Effectiveness
BioticLossFact
AbioticLossFact
Harvestable Yield
harvesting
Harvest
harvest losses
Harvest InEfficiency
harvest labor capacity
Selling AnyCrops?
Market Crops
Market Crop Holding Period
export selling
Aggregator selling
not sold
F2F selling
CSA Selling
DemandFrac CropxCustType

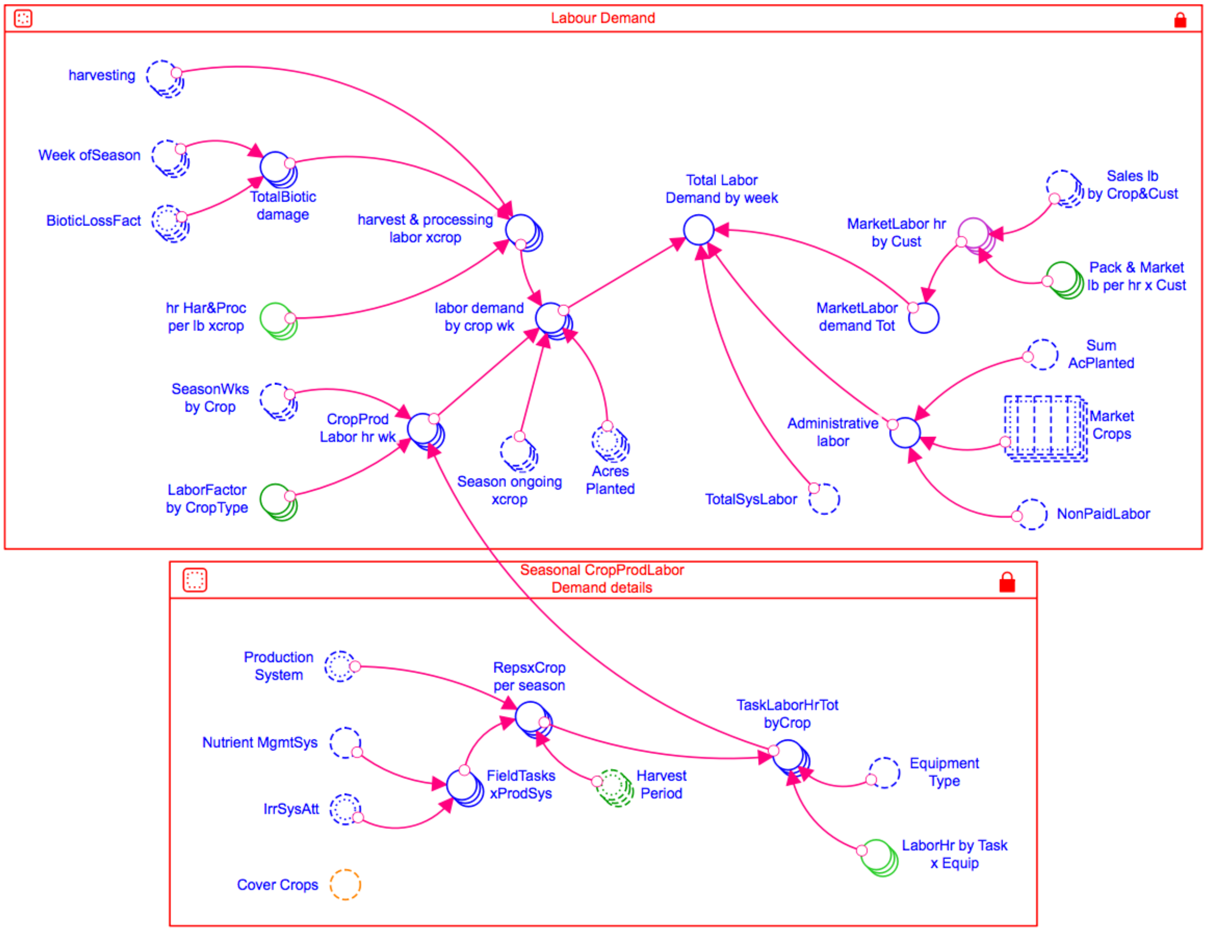

Abiotic Factors
MonthxYr
monthly ppt
PPT Random
WeeklyPpt
monthly temp
WeeklyTemp
ImmCrop Present?
Temp stress
cold stress
Low T Sens xCrop
Harvestable Yield
WeeklyTemp
high T Thresh xCrop
WeeklyPpt
Runoff
flood stress
heat stress
water stress
ImmCrop Present?
waterSupplyFact
infiltration
irrigation effect
IrrXsWater Fact
nutrient stress
leaching
NutXsProb
Leaching Protection index
Infil Max
AWHC
Soil Texture
Stand InfilRate
texfact
erosionPot
SoilSlope
slpFact
Infiltration Practices
ProdSysAtt

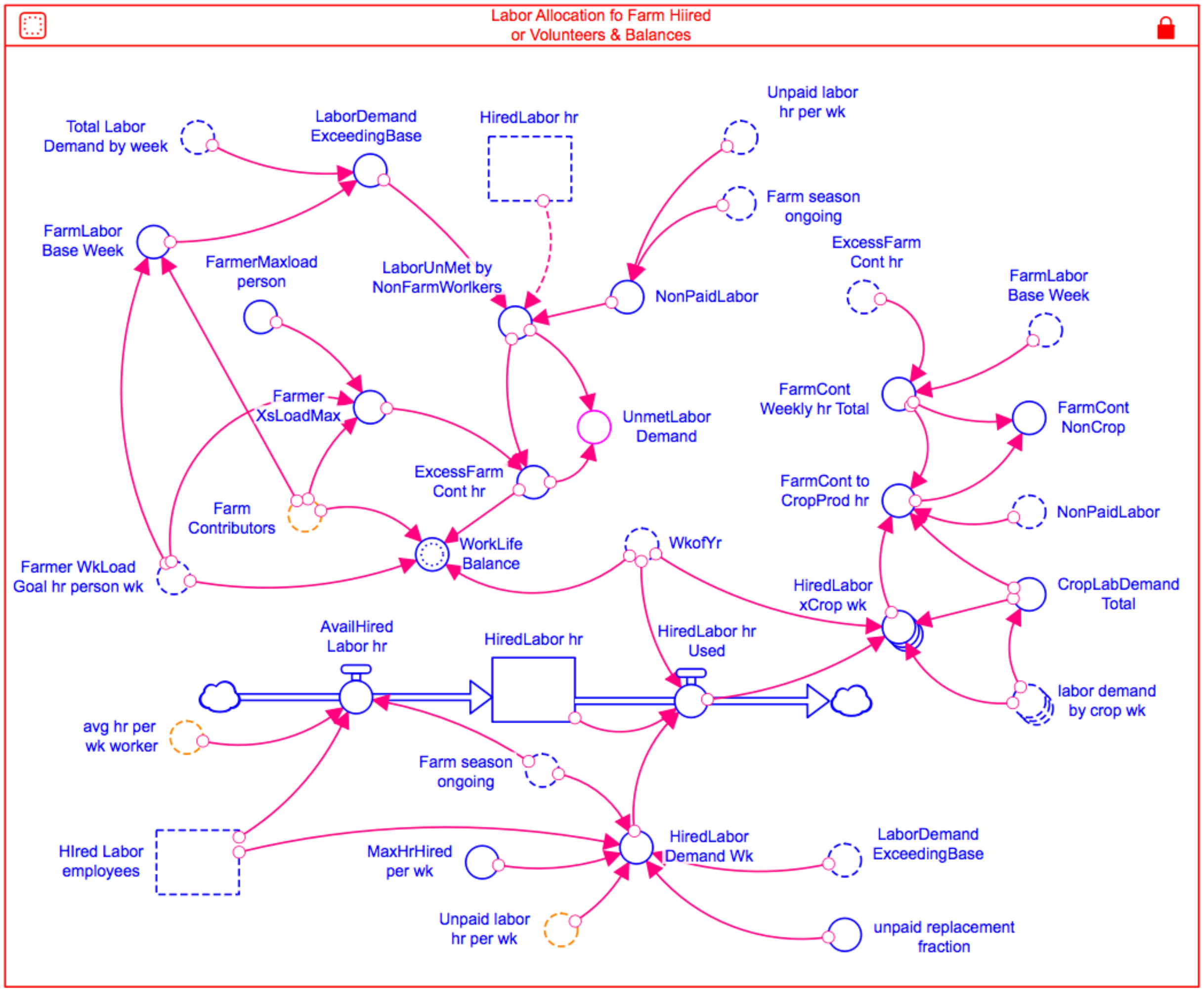

Abiotic Summary
Temp stress
water stress
nutrient stress
AbSenarioFinder
abiotic comb
StressorMatrix Table
nutrient SuppyFact
AbioticLossFact

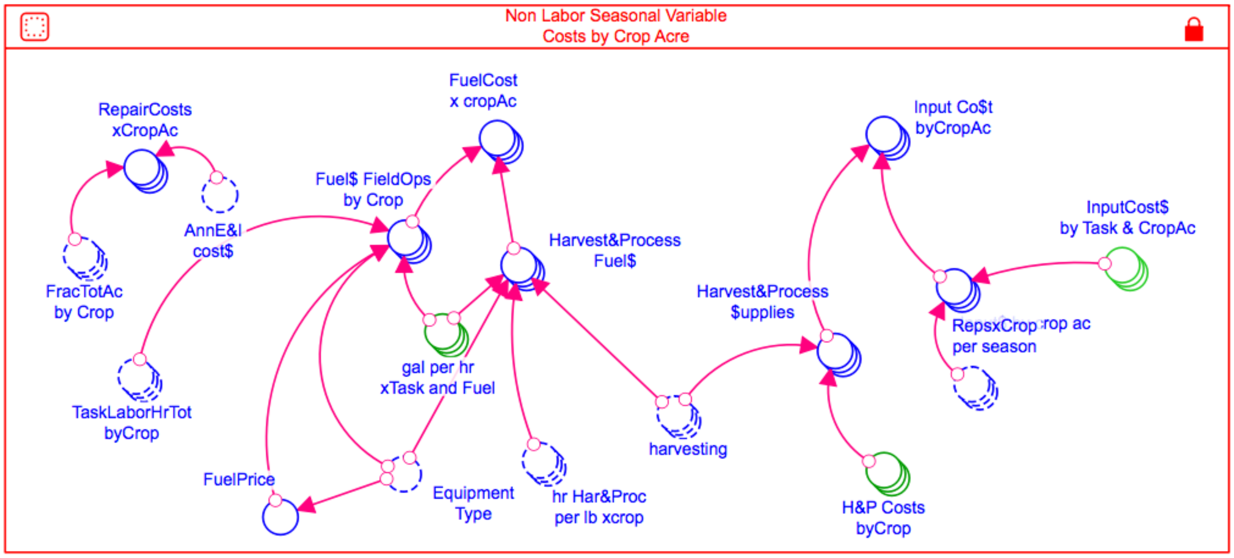

Biotic Factors
BioticLossFact
InsectLoss Fact
WeedLoss Fact
DiseaseLoss Fact
WeedPressure
weed control
WeedLoss Fact
insect control
InsectLoss Fact
InsectPressWk
WkofYr
ProdSysAtt
disease controls
DiseaseLoss Fact
DisPress Wk
Growing Any Crops?


ProdSystAttr
NutProvision
NutXsProb
SysAtt by ProdSys Table
SOMFact
Nutrient MgmtSys
Production System
Cover Crops
SProtFact
TechKSA
Seasonal Att Activator
System Input Costs
IrrSysAtt
ProdSysAtt
ProdSys% Imp
waterSupplyFact
IrrWSFact
IrrXsWater Fact
Growing Any Crops?
nutrient SuppyFact
sys crop interactive labor
sysYr labor ac
TechKSA
Confid in KSA & HelpNetwork
Mgmt Effectiveness
Yrs Educ & Exper
Educ&RelExper Att
year

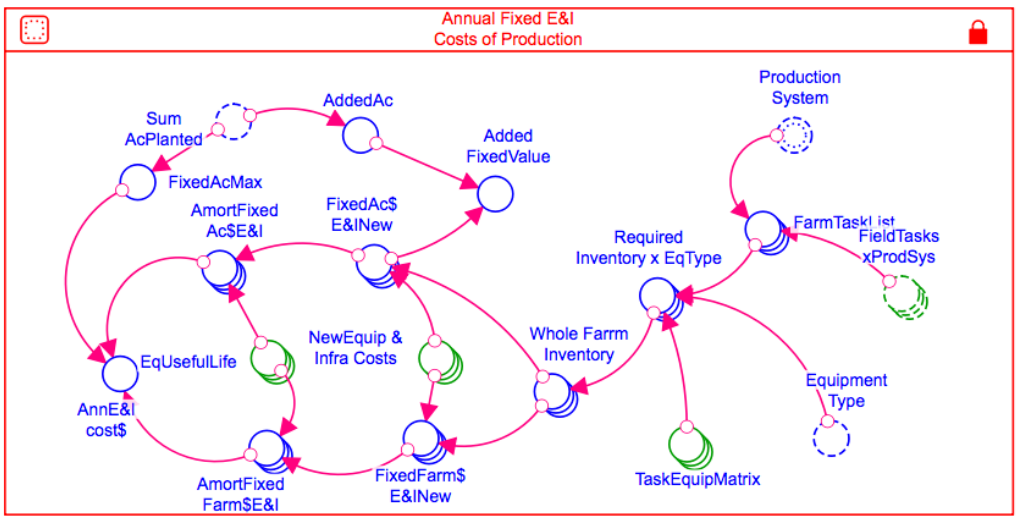

EQ
Environmental
Quality Indicator
changing EQI
Environmental
Goal
EQICumAvg
EQI success
WeeklyEQI
by Year
WkofYr
SoilQual
Index
WaterQual
Index
Soil Retention
Index
Soil Retention
Index
Nutrient Retention
Index
Pesticide
Index
Nutrient Retention
Index
SOM Building
Index
Leaching Protection
index
SOMPractices
ProdSysAtt
Farm season
ongoing
erosionPot
Soil Retention
Index
SoilProtection
Runoff
waterSupplyFact
Nutrient Retention
Index
Nutrient
Practices
leaching
nutrient
SuppyFact


Labour Demand
harvesting
Week ofSeason
BioticLossFact
TotalBiotic damage
harvest & processing labor xcrop
hr Har&Proc per lb xcrop
labor demand by crop wk
SeasonWks by Crop
CropProd Labor hr wk
LaborFactor by CropType
Season ongoing xcrop
Acres Planted
Total Labor Demand by week
MarketLabor hr by Cust
Sales lb by Crop&Cust
Pack & Market lb per hr x Cust
MarketLabor demand Tot
Sum AcPlanted
Market Crops
Administrative labor
TotalSysLabor
NonPaidLabor
Seasonal CropProdLabor Demand details
Production System
RepsxCrop per season
TaskLaborHrTot byCrop
Nutrient MgmtSys
FieldTasks xProdSys
Harvest Period
Equipment Type
IrrSysAtt
LaborHr by Task x Equip
Cover Crops

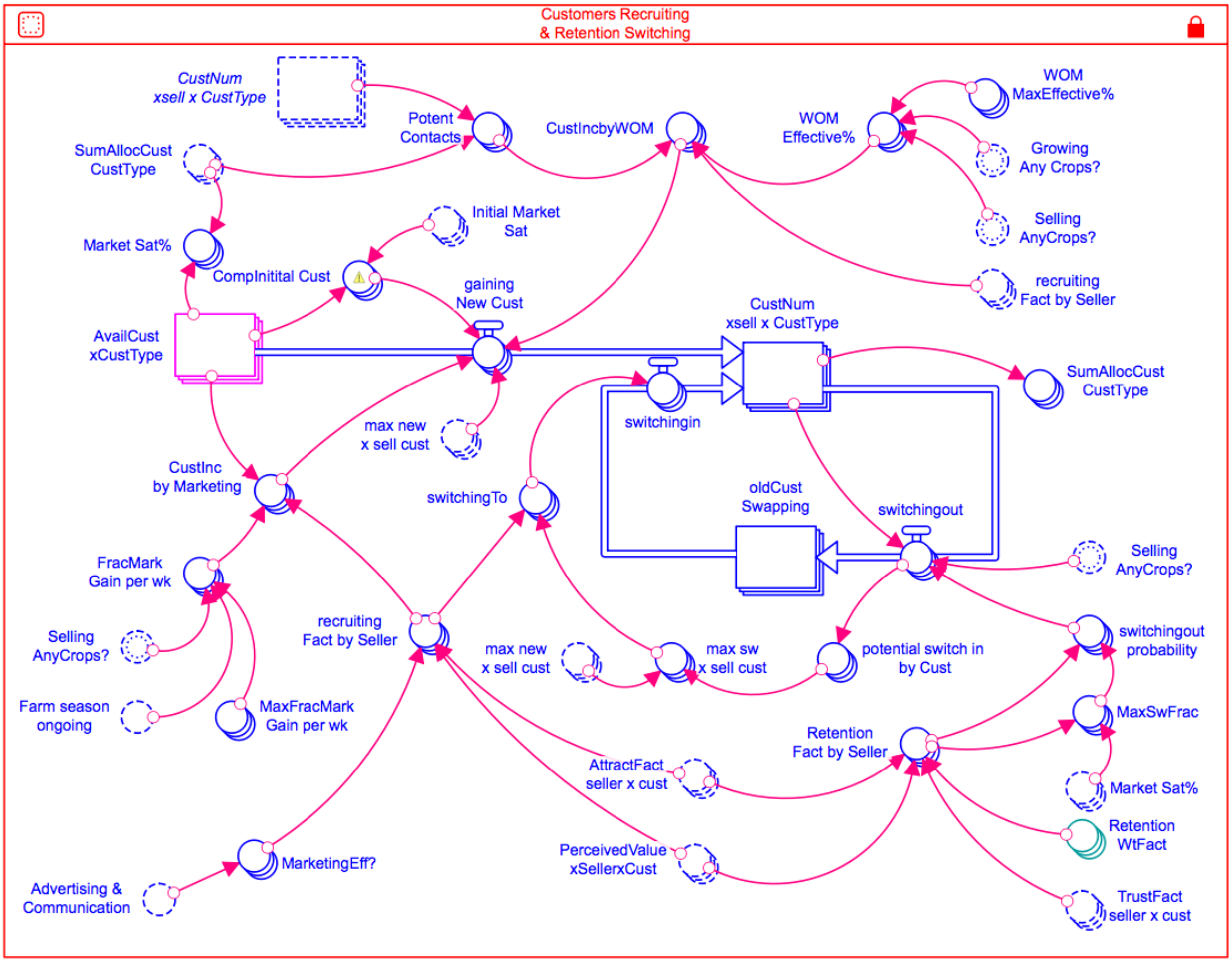

Labor Allocation fo Farm Hiired
or Volunteers & Balances
Total Labor
Demand by week
LaborDemand
ExceedingBase
HiredLabor hr
Unpaid labor
hr per wk
Farm season
ongoing
FarmLabor
Base Week
FarmerMaxload
person
LaborUnMet by
NonFarmWorlkers
NonPaidLabor
ExcessFarm
Cont hr
FarmLabor
Base Week
Farmer
XsLoadMax
UnmetLabor
Demand
FarmCont
Weekly hr Total
FarmCont
NonCrop
ExcessFarm
Cont hr
FarmCont to
CropProd hr
Farm
Contributors
NonPaidLabor
WorkLife
Balance
WkofYr
Farmer WkLoad
Goal hr person wk
HiredLabor
xCrop wk
CropLabDemand
Total
AvailHired
Labor hr
HiredLabor hr
HiredLabor hr
Used
labor demand
by crop wk
avg hr per
wk worker
Farm season
ongoing
HIred Labor
employees
MaxHrHired
per wk
HiredLabor
Demand Wk
LaborDemand
ExceedingBase
Unpaid labor
hr per wk
unpaid replacement
fraction

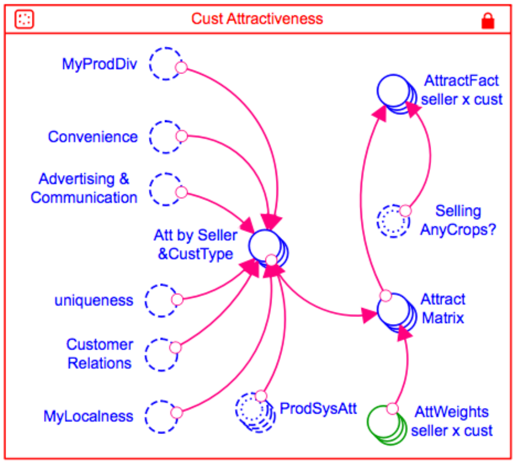


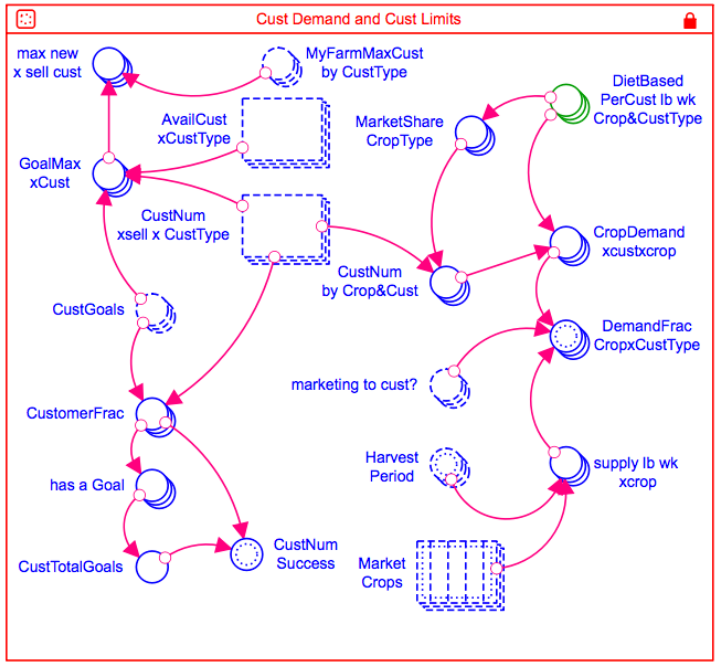
Non Labor Seasonal Variable
Costs by Crop Acre
RepairCosts
xCropAc
FuelCost
x cropAc
Input Co$t
byCropAc
Fuel$ FieldOps
by Crop
AnnE&I
cost$
InputCost$
by Task & CropAc
Harvest&Process
Fuel$
FracTotAc
by Crop
Harvest&Process
$upplies
per season
gal per hr
xTask and Fuel
TaskLaborHrTot
byCrop
harvesting
FuelPrice
Equipment
Type
hr Har&Proc
per lb xcrop
H&P Costs
byCrop

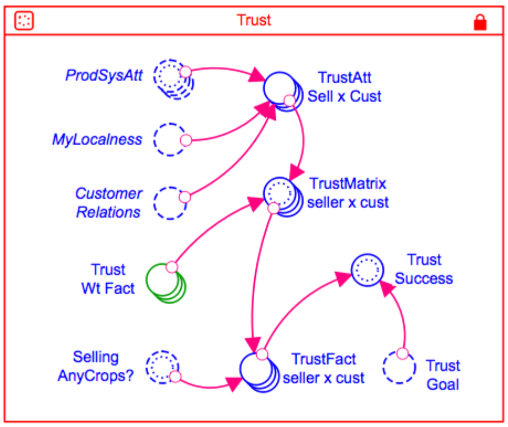


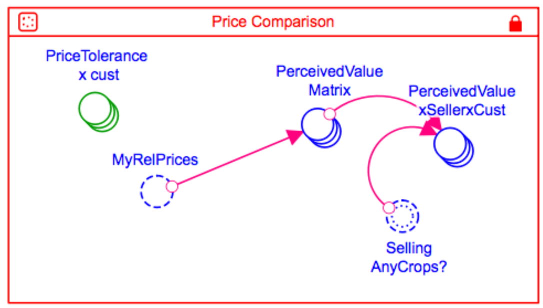
Annual Fixed E&I
Costs of Production
Production
System
AddedAc
Sum
AcPlanted
Added
FixedValue
FixedAcMax
AmortFixed
Ac$E&I
FixedAc$
E&INew
Required
Inventory x EqType
FieldTasks
xProdSys
NewEquip &
Infra Costs
Whole Farm
Inventory
EqUsefulLife
AnnE&I
cost$
Equipment
Type
AmortFixed
Farm$E&I
FixedFarm$
E&INew
TaskEquipMatrix

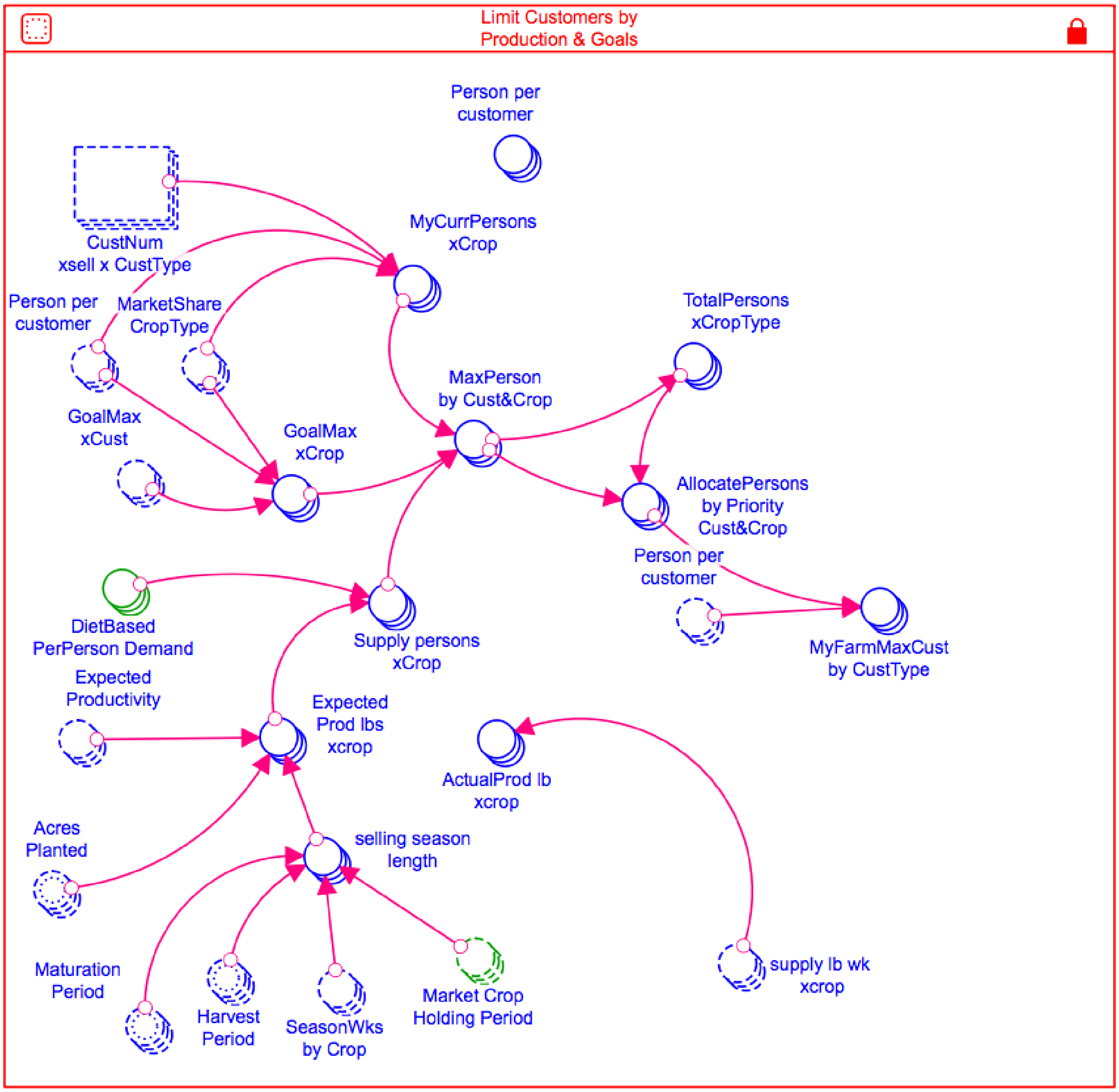

Customers Recruiting
& Retention Switching
CustNum
xsell x CustType
Potent
Contacts
CustIncbyWOM
WOM
Effective%
WOM
MaxEffective%
Growing
Any Crops?
Selling
AnyCrops?
SumAllocCust
CustType
Market Sat%
Initial Market
Sat
CompInitital Cust
gaining
New Cust
recruiting
Fact by Seller
AvailCust
xCustType
CustNum
xsell x CustType
SumAllocCust
CustType
switchingin
max new
x sell cust
CustInc
by Marketing
switchingTo
oldCust
Swapping
switchingout
Selling
AnyCrops?
FracMark
Gain per wk
recruiting
Fact by Seller
switchingout
probability
Selling
AnyCrops?
max new
x sell cust
max sw
x sell cust
potential switch in
by Cust
Farm season
ongoing
MaxFracMark
Gain per wk
MaxSwFrac
Retention
Fact by Seller
AttractFact
seller x cust
Market Sat%
Retention
WtFact
PerceivedValue
xSellerxCust
MarketingEff?
Advertising &
Communication
TrustFact
seller x cust


Cust Attractiveness
MyProdDiv
AttractFact seller x cust
Convenience
Advertising & Communication
Selling AnyCrops?
Att by Seller &CustType
uniqueness
Attract Matrix
Customer Relations
MyLocalness
ProdSysAtt
AttWeights seller x cust

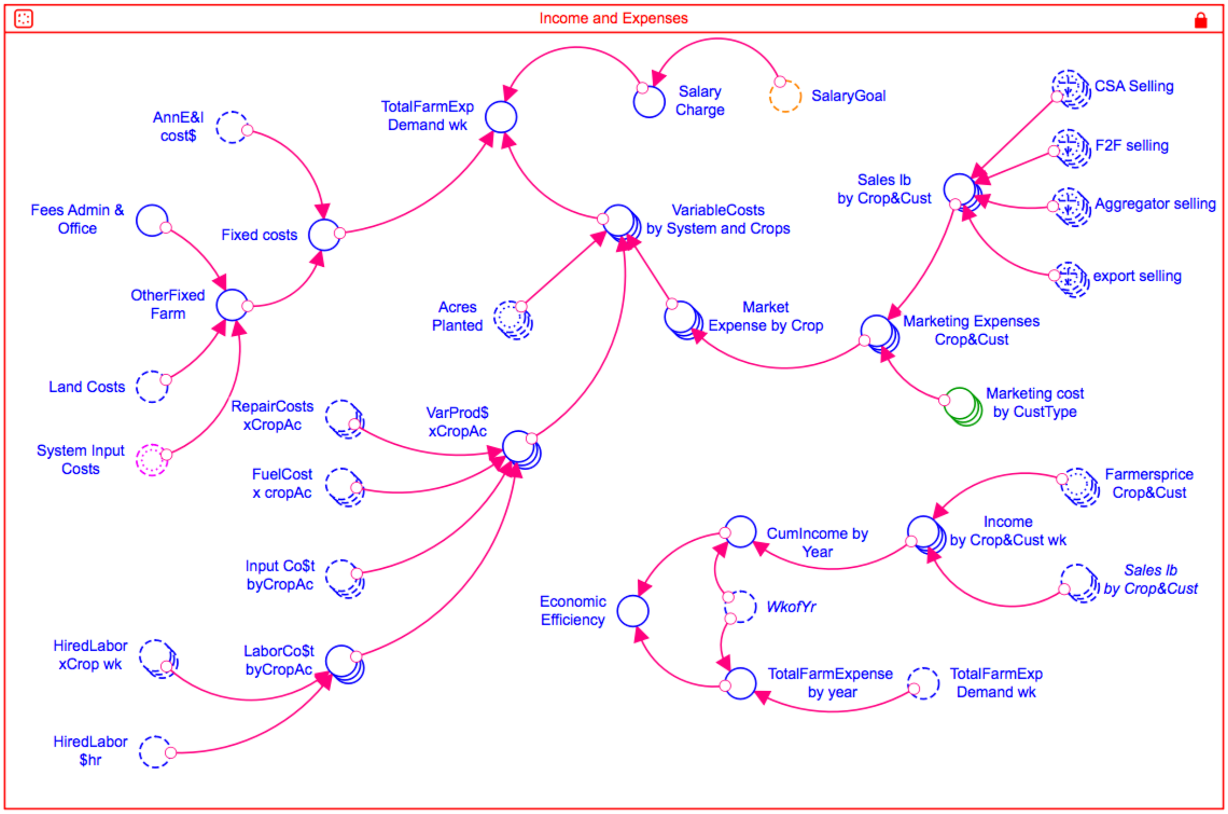

Cust Demand and Cust Limits
max new x sell cust
MyFarmMaxCust by CustType
DietBased PerCust lb wk Crop&CustType
AvailCust xCustType
MarketShare CropType
GoalMax xCust
CustNum xsell x CustType
CropDemand xcustxcrop
CustNum by Crop&Cust
CustGoals
DemandFrac CropxCustType
marketing to cust?
CustomerFrac
Harvest Period
supply lb wk xcrop
has a Goal
CustNum Success
CustTotalGoals
Market Crops

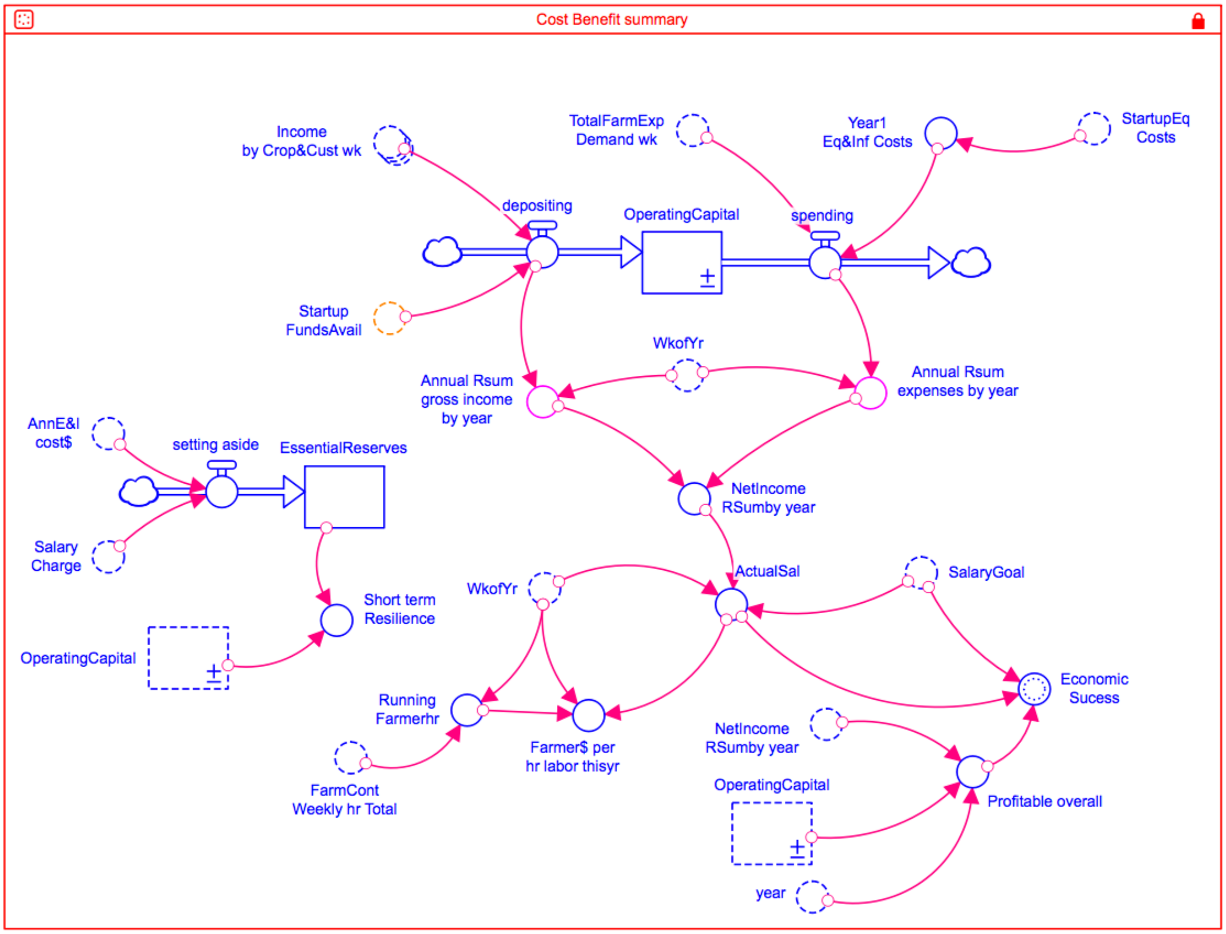

Trust
ProdSysAtt
TrustAtt Sell x Cust
MyLocalness
Customer Relations
TrustMatrix seller x cust
Trust Wt Fact
Trust Success
Selling AnyCrops?
TrustFact seller x cust
Trust Goal


Price Comparison
PriceTolerance x cust
PerceivedValue Matrix
PerceivedValue xSellerxCust
MyRelPrices
Selling AnyCrops?



Limit Customers by
Production & Goals
Person per
customer
CustNum
xsell x CustType
MyCurrPersons
xCrop
Person per
customer
MarketShare
CropType
TotalPersons
xCropType
MaxPerson
by Cust&Crop
GoalMax
xCust
GoalMax
xCrop
AllocatePersons
by Priority
Cust&Crop
Person per
customer
DietBased
PerPerson Demand
Supply persons
xCrop
MyFarmMaxCust
by CustType
Expected
Productivity
Expected
Prod lbs
xcrop
ActualProd lb
xcrop
Acres
Planted
selling season
length
Maturation
Period
Harvest
Period
SeasonWks
by Crop
Market Crop
Holding Period
supply lb wk
xcrop


Income and Expenses
Salary Charge
SalaryGoal
TotalFarmExp Demand wk
AnnE&I cost$
CSA Selling
F2F selling
Sales lb by Crop&Cust
Aggregator selling
Fees Admin & Office
Fixed costs
VariableCosts by System and Crops
export selling
OtherFixed Farm
Acres Planted
Market Expense by Crop
Marketing Expenses Crop&Cust
Land Costs
RepairCosts xCropAc
VarProd$ xCropAc
Marketing cost by CustType
System Input Costs
FuelCost x cropAc
Farmersprice Crop&Cust
Income by Crop&Cust wk
CumIncome by Year
Input Co$t byCropAc
Sales lb by Crop&Cust
Economic Efficiency
WkofYr
HiredLabor xCrop wk
LaborCo$t byCropAc
TotalFarmExpense by year
TotalFarmExp Demand wk
HiredLabor $hr



Cost Benefit summary
Income
by Crop&Cust wk
TotalFarmExp
Demand wk
Year1
Eq&Inf Costs
StartupEq
Costs
depositing
OperatingCapital
spending
Startup
FundsAvail
WkofYr
Annual Rsum
gross income
by year
Annual Rsum
expenses by year
AnnE&I
cost$
setting aside
EssentialReserves
NetIncome
RSumby year
Salary
Charge
ActualSal
SalaryGoal
WkofYr
Short term
Resilience
OperatingCapital
Economic
Sucess
Running
Farmerhr
Farmer$ per
hr labor thisyr
NetIncome
RSumby year
FarmCont
Weekly hr Total
OperatingCapital
Profitable overall
year

APPENDIX C: INTERVIEW PROTOCOL

Protocol Overview

First Visit

The goal of the first visit is to gain a general overview of the farm enterprise, and gather preliminary information to set up the structures of the enterprise (“populate top level of the model”).

Project overview and consent process

The site visit starts with sitting down (likely at the kitchen table) to administer informed consent, give an overview of the project, and answer any questions the farmer may have.

Brief history

Immediately following informed consent, the interview begins at kitchen table with a brief introduction to the farm’s history and management.

- What do you know about the history of this farm?
    - Who owned and/or operated it before you?
    - What did they grow or raise?
    - Do you know anything about how the farm used to be managed?
    - Has any past usage or management practices affected what is grown here now?
    - Any other key changes in the farm in its history?

Current Operation

- What is the management and general decision making structure of the farm?
    - Who are the key decision makers?
    - Who are other people that have a say in what happens on this farm?
    - Who do you consult when you need advice to make decisions about the farm?
- What is your current land tenure situation?
    - How many acres are rented and owned
- What are the major elements of the current farm enterprise?
    - What products do you sell (any value added?)
    - What are your market outlets?
- What do you see as current challenges to achieving your ideal farm enterprise?
    - Are there any bio-physical challenges?
    - Do you face any challenges or obstacles to accessing the type or scale of markets you would like?

- Are there any aspects of the organization or managerial practices that you would like to change or develop?

Farm Walk

The purpose of the farm walk is to generate an overview of the bio-physical and built/mechanical resources of the farm enterprise. Interwoven in this narrative will undoubtedly be some aspects of management philosophy and farm history.

- What do you grow here?
    - What crops do you currently have planted?
    - Can you describe your rotation?
    - How do you decide what lands are best for particular agricultural practices?
    - Do you have any lands on our farm that you would consider not suited for cultivated agriculture?
        - What do you do there?
    - Do you soil test?
    - How do you prepare your soil for planting?

- Describe your soils on the farm.
    - What is your soil quality, and how do you manage for that (any particular management techniques or systems)?
    - Do you have any issues with productivity related to soil quality?
    - Do you soil test?
    - How do you prepare your soil for planting?
- What livestock do you have on the farm?
    - If you have livestock, please describe how you balance the crop and livestock production on the farm.
    -
- What are your water resources?
    - Where do you get your water?
    - Is there enough?
    - Describe the water quality and quantity on the farm.
        - What do you do to manage for water quality?
    - What irrigation equipment do you use?
- What kind of equipment do you use?
    - Walk through equipment usage and timing.
    - How much does it cost and how did you learn to use it?
    - How did you obtain these equipment?

Points to observe and note during farm walk:

Condition of land:

- Evidence of erosion
- Crop/pasture rotation
- Beneficial habitat
- Wind Breaks
- Slope
- Soil type(s) (with aid of NRCS Web Soil Survey)
- Water source(s) on property
    - Livestock fencing
    - Riparian boarders

Enterprise Overview

Following the farm walk, return to the kitchen table to round out the key elements of the farm enterprise.

Farmer history

- Can you tell us the story of how you got in to farming?
    - Are there moments or experiences you can point to as key turning points?
    - What formal or informal training did you have before starting?
        - Who first taught you how to farm?
- How would you describe your approach (philosophy) to farming?
    - What does 'good farming' look like?
    - How has your philosophy of farming changed over the years?
        - What have you learned since starting to farm that has changed your thinking?
    - Is there anyone you especially admire in the farming community (locally or beyond?)
    - Are there any past experiences that you can point to as having a significant influence in your farming philosophy?

Record Keeping

- What sort of records do you keep for your production?
    - Production?
    - Fertility?
    - Pest and weed management?
- What sort of financial records do you keep?
    - What do you use to keep records? (e.g., Excel, book keeping software, notebook)
- Who keeps the books?

    - How did the person learn how to keep the book?
- Do you have a business plan?
    - How did you develop it?
    - How regularly do you update it?
- Do you have a marketing plan?
    - How did you develop it?
    - How regularly do you up date it?

Market outlets

- Where do you sell your products to?
    - Can you give us a rough idea of your annual sales in each market?
    - What are the opportunities afforded by each market outlet?
    - What do you see as key challenges or limitations of your current market outlets?

Finance

- How did you finance the startup of your farm enterprise?
- What financial contribution does the farm enterprise need to make to the overall household economy?
- Do you have any short or long term goals or concerns about the financial elements of your enterprise?

BMP's

- What current practices are you using that might be considered "best management practices"?
- Why do you consider these practices as BMPs?
- How long have you been using them?
- How did you learn these practices you're using?
- What challenges do you face in using these BMPs?
- Who do you consult or what resources do you use to perfect these BMPs?

Near & long term goals

    - Identify 2 near and 2 long term goals for the enterprise
    - What is the motivation or rational for these goals?
        - Key opportunities
        - Key Challenges

Homework: Worksheets

- Whole farm planning? (Financial) (Margarita?)
- Physical/Mechanical inventory
- Enterprise lines

Second visit – populating with more specific data

At the second visit, we will present the preliminary model of the farm enterprise, and flesh it out with more specific data. The model will serve as a concrete reference point for elucidating the farmer's concept and practice of sustainability.

Bio-physical specifics

- Can you walk us through your farming system(s) from beginning to end of the production cycle?
    - What particular challenges do you face in regards to:
        - Weeds
            - How do you manage them?
            - Do you use cultivation for weed management, and if so, how?
        - Insects
            - How do you manage them?
            - What beneficial insects do you see on your farm?
        - Diseases
            - How do you manage them?
        - Any other pests
            - How do you manage them?
- How do you gauge the environmental 'sustainability' of your system?
    - Looking at model, where are the points they focus on or monitor, and what levels/categories/measures do they use to determine 'sustainability'?

Best Management Practices

- Have you noticed any changes on the farm as a result of implementing the best management practices?
    - Changes in bio-physical conditions?
    - Changes in economic conditions?
    - Changes in labor?
    - Changes in personal attitude or perspective?
    - Changes in how other farmers view you or your farm enterprise?
- Are there any best management practices that you have heard about that you are considering implementing?
    - How did you hear about them?
    - What interests you in these practices?
    - Do you foresee any challenges in implementing them?

Management

- Are there people or experiences that have influenced the way you manage your farm or what you produce?

- Did you do any apprenticeships or internships?
- There's a lot of talk about 'sustainability' in the world of food and agriculture right now, would you describe what a "sustainable" farm means to you?
- We talked earlier about the environmental sustainability of your enterprise, are there other forms of 'sustainability' that you feel are important for your farm?
  - What are you doing on your farm that you feel contributes to this idea?
  - Are there ways you feel your farm could be more sustainable?
  - People often talk about a 'social' dimension of sustainability. Is this something that resonates with your farming philosophy? Are there aspects of your farm that you feel support its social sustainability?
- Please tell me about a time you changed the way you did something or implemented a new management practice on your farm?
  - Walk me through from the beginning, how you learned about the new practice, what influenced your decision to management, and how you went about implementing and evaluating it.
- Where would you like to see your farm enterprise in five years, and what is it going to take to get there?
  - Production, Markets, Personal? (Work/life balance?)
  - What financial barriers do you foresee for achieving these goals?
  - What technical barriers do you foresee for achieving these goals?
  - What sort of skills or knowledge will you have to obtain to achieve these goals?
  - What people, organizations, or other resources will you rely on to address these barriers and achieve these goals?

- How do you negotiate your relationship with your partner (or close friends/family) and the farm operations?
- How would things on the farm be different if (partner/friend/relative) were not around?

Community, family, and consumer

- What is your relationship with the other farmers in the area like?
  - Are there any farmers you talk with regularly?
  - Are there any farmers you share any resources or labor with occasionally?
- Do you belong to any farming related organizations?
  - What are the benefits you see from membership in each organization?
    - Social
    - Economic
    - Knowledge/Resource
  - Are you a member of any other groups? (please explain)

- Who helps you on a regular basis? What is their job? Have they done a good job (why/why not)? What other skills or assets do they have?

- How well do you feel that you are connected to the overall community in [this county]? Are there other type of community, besides your neighbors or county, that you feel more connected?
- What kind of involvement have you had with your community's decision making processes, either with the local government, or other key groups/organizations (e.g. Agricultural Development Board, Parent Teacher Association, etc)
- Do you have any opinions on current state farm and food policy? Do you think it supports your farm enterprise?
    - Specific policies that are good/bad?

Marketing

- How did you find or gain access to the different market outlets?
    - How do you evaluate a potential market outlet?
- About how much time goes into tending to each market outlet?
        - Transportation
        - Administration/logistics
- What is your relationship like with the people or organizations you sell your products to?
    - Do they ask you about your management practices?
    - Do you feel you have a relationship to the 'end user' of your product?
- Are you looking to grow sales of any of your products?
- Are you looking to grow the share of your sales in any specific market outlet?
- How do you decide the price for your products?

Finances

- Do you feel like you have access to enough capital to develop your farm enterprise as you'd like?
    - Can you describe your comfort level with debt, like how much you are comfortable taking on, and under what kinds of conditions?
    - What would you like to do on the farm that you cannot because of lack of access to capital?
- Do you have any loans out for the farm?
    - How did you access those loan funds?
        - Personal relationship with loan officer?
        - What documents did you have ready?
    - Were you ever turned down for a loan?
- Do you currently, or have you ever used grants or government programs to finance an improvement to your farm?
    - What programs or grants?
    - How did you access them?
- How many hours off farm do you work?

        - Would you like to be full time on the farm?
        - Does working off farm affect how you manage your farm, or your choices of what to produce?
    - Does anyone else in your household work off farm?
- What would economic sustainability look like for your farm?

Vulnerability and risk

- How much "wiggle room" do you have for the farm to have a bad year?
    - Are there particular enterprises that are more sensitive to bad years than others? If they fail/were to fail how do they affect other aspects of the farm?
    - Are there enterprises that are your "safety net" that help you take other risks in your system?
    - What experiences and ideas have helped you figure out how to create "buffers" in your system?
- Do you have any nagging worries about your farm? Can you share some of them with us?
- Could you tell me about times that you had to recover from a major setback or obstacle? Did anyone help you?

Farm Overview Worksheet

Please provide us with some information about your farm.

Land Usage

Year the Piece of Land was Acquired	Source (family, advertisement, etc.)	Owned (# acres)	Rented (# acres)

	Land Use	Acres
Row Crops	**Total acres in Row Crops**	
	Corn	
	Soybeans	
	Wheat	
	Cotton	
	Other	
Horticulture	**Total acres in Horticulture**	
	Fruits	
	Vegetables	
	Other	
Forage	**Total acres in Forage**	
	Alfalfa	
	Other	
Pasture	**Total acres in Pasture**	
Forest	**Total acres in Forest**	

Livestock

Livestock	**Number of Head**
Beef Cows	
Dairy Cows	
Stockers	
Feeder cattle	
Swine/hogs	
Sheep	
Goats	
Horses	
Poultry	
Other Livestock	

Barns/Outbuildings

Name ('Main Barn', 'South Barn')	**Function(s)**	**Year built (estimate)**	**Square feet**

Irrigation

Year Acquired	Irrigated acres of crop land	Irrigated acres of pastureland, rangeland, other crop land	Type of irrigation (drip, center pivot, etc.)

Equipment (Tractors and attachments, etc.)

Make/Model/Year	Year Acquired	Owned, leased, borrowed (from whom)	Primary purpose	Secondary uses

Other Machinery, Facilities, or Equipment

Name (Make/Model/Year, if applicable)	Year Acquired	Owned, leased, borrowed (from whom)	Primary purpose	Secondary uses

Income from Farm Related Sources

Source	Dollars ($)	% of total income from each source (first year of operation, 2009)	% of total income from each source (2013)
Row crop sales			
Horticulture sales			
Livestock sales			
Agri-tourism and recreational services			
Payments received from cash rent			
Other (please write in)			

Farm Labor

Type of Labor	Number	Days per year work in the farm
Hired labor		
Contract labor		
Unpaid labor including family members		
Migrant workers		
Other (please write in)		

Production Expenses

Source	Dollars ($)	% total expenses (first year of operation)	% total expenses (2013)
Fertilizer, lime and soil conditioners			
Chemicals purchased such as insecticides, herbicides, fungicides, other pesticides			
Seeds, plants, vines, trees, etc.			
Breeding livestock purchased or leased			
All other livestock and poultry purchased or leased			
Feed purchased for livestock and poultry			
Gasoline, fuels, and oils purchased			
Labor			
Rent			
Other (please write in)			

	Market Outlet	Do you use the following marketing methods? (please check which ones you use) In the first year of operation?	In 2013?	IF YES, please estimate the percentage of sales made through this method (each column should total 100%) In the first year of operation?	In 2013?
Direct Sales to Consumers	On farm sales				
	Farmers' markets				
	Community Supported Agriculture (CSA)				
	Roadside stands				
	Pick-your-own				
	Other direct sales (please describe)				
Sales to Intermediaries	Grower cooperatives				
	Wholesale buyers/brokers/packers				
	Other farmers				
	Other intermediaries (please describe) Organic Seeds to Seed Companies = $13,924				
Sales to Retail Outlets	Grocery stores				
	Food cooperatives				
	Restaurants				
	Institutions (such as schools and hospitals)				
	Other retail outlets (please describe)				
Sales of Row Crops	Sales to end users (i.e., feed, flour mills)				
	Sales to grain elevators/terminals				
	Other row crop sales (please describe)				
Sales of Livestock	Direct sales to consumers				
	Sales to feed yards				
	Sales to packing plants				
	Sales to processing plants (i.e., milk)				
	Other livestock sales (please describe)				