EXPLORATION OF FOOD SECURITY VIA A MESO SCALE MODELING APPROACH: JAMAICA AS AN ILLUSTRATIVE CASE

By

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The purpose of my study is to examine the interactions within a food system and between that system and its socioecological environment in order to reveal management or policy strategies that strengthen food security conditions. Using Jamaica as a case study my interdisciplinary project developed and tested a computer model, QnD:Jamaica, that fuses technology with lessons from complex systems theory in order to promote adaptive management of food systems. An iterative collaborative design process based on soft systems approaches was employed during model design. The problem situation as understood by key stakeholders was investigated through informal strategic dialogues. These qualitative descriptions were conceptualized by a formal framework to identify a limited number of quantifiable parameters and drivers of interest for the scenario model. The model incorporates ecosystem and sociopolitical issues into a user-friendly framework to analyze the spatially explicit dynamics of food, money and people in terms of their effects on food security conditions. Illustrative scenario simulations were performed and the implications for systemic features were explored. The results of my study provide insight into conceptualizing food systems in general and the

Jamaican food system specifically. My thesis serves as an explicit example of integrated soft research methods and analytical tool development and will guide future modeling efforts.

CHAPTER 1
INTRODUCTION

This modern mind sees only half of the horse-the half which may become a dynamo, or an automobile, or any other horse powered machine. If this mind had much respect for the full-dimensioned, grass eating horse, it would never have invented the engine which represents only half of him. *- Allen Tate, in Berry, 2002*

"…de IMF a de tiefingest ting-dem lend you money fi buy tin mackerel, but not fi help small farmers plant. Every country where dem go it mash up." Small farmer in St. Mary, Jamaica, 2001(Weiss, 2004a)

In our current global food system, most countries are dependent on trade with distant agro-ecosystems for their food supply. While international trade is beneficial for many societies and 100% reliance on local food is neither practical nor desirable, it is important to recognize and manage the trade offs that occur between local and external food supply dependence (Sundkvist et al., 2005; Lyson and Green, 1999; Costanza et al., 1995). Food systems by their nature embody ecological, social and economic issues and the global changes taking place both climatically, culturally and economically are having profound effects on how food is produced transported, understood, valued, prepared, and consumed. Food security offers itself as an interdisciplinary set of criteria for exploring the complex issues involved in food systems. Food security encompasses all of the mechanisms that allow individuals to maintain command over their food consumption (Sen, 1981; Corral et al., 2000). This definition allows food security to be viewed in its broadest sense as a rich picture of societal well-being and natural resource viability.

Dynamic Collaborative Models for Food System Exploration

The direct and indirect synergistic relationships within the process of food procurement from field to fork are highly unknown and unpredictable and make exploration of food system vulnerabilities a complex task. New tools for assessing, planning and communicating about food security should embrace this uncertainty and aim to facilitate creative collaborative exploration of the system and its contextual environment (D. H. Walker, 2002). Methods that investigate patterns between interactions and emergent properties in problematic situations promise insight into improved management strategies (Kasperson and Kasperson, 2001; Walker et al., 2004).

Adaptive management strategies were first developed from the recognition that systemic socioeconomic and ecological knowledge is and always will be imperfect and incomplete (Berkes et al., 2003; Dyball et al., 2005; Holling and Gunderson, 2002). Unforeseen drivers, interactions and outcomes are virtually guaranteed. Rigid policies prevent adjustment to these changing situations and can create conditions where unsustainable and highly deleterious behaviors continue. Adaptive collaborative techniques offer a methodological structure with flexibility and space to explore, evaluate and select the most beneficial policies as unpredicted issues arise. This structure is iterative in nature and includes cycles of policy experimentation, reflection, evaluation and modification (Keen and Mahanty, 2005).

Many have suggested scenario modeling as a tool that could aid exploration of possibilities and encourage creative thinking and collaboration amongst stakeholders (Walker et al. 2002; Carpenter et al., 1999; Janssen et al., 2006). Scenario-based models can provide analyses of trade-offs between socioeconomic and environmental goals. Scenario modeling does not aim to predict the future but rather to explore the potential ramifications of a range of policy options (Baker et al., 1999).

The proposed research project is one of the first national food security analyses to employ a simulation model nested in a collaborative design process in order to reveal patterns in a food system's socioecological interactions (Pothukuchi and Kaufman, 2000). This approach is based on the adaptive management argument that the emergent properties which characterize complex systems, food systems included, are so dynamic that they currently can not be managed statically or for single indices. Rather, management requires planning tools that envision multiple relationships at once and a range of possible states of these relationships.

Using Jamaica as a case study, this interdisciplinary project developed and tested an exploratory computer model that fuses technology with lessons from complex systems theory in order to promote adaptive management of food systems. This model, QnD:Jamaica, uses the Questions and Decisions (QnD) modeling system that allows simulation of biological and abiotic components of a system (Kiker and Linkov, 2006). QnD is also appropriate to this project because of it facilitates collaborative discussions through its easily manipulated structure and game-like format. This thesis takes the approach that when a broad definition of food security which includes a rich picture of societal well being is applied to food system management, the most appropriate policy options will consider diverse socioecological dynamics together at the meso scale.

Jamaica as a Case Study

Like many Caribbean nations, Jamaica has a small open economy remnant of the plantation system that is vulnerable to major changes in the world economy (Beckford, 1972). Throughout the 1980s and 1990s the dominate prescriptions of international financial institutions revolved around the theory that free markets will increase food security by ensuring cheaper and more consistent food supplies (Weiss, 2004a). However, Jamaica is now one of the most indebted nations, both in terms of financial and material imbalances. Historically driven by cash crop exportation, two main symptoms indicate negative shifts in the Jamaican food system: increasing loss of market for exports as well as large-scale importation of cheap food leading to Jamaican farmers' inability to compete in their own domestic market (FAO, 2003).

As Jamaica's Minister of Finance has conceded, the country is now operating in 'crisis mode' (Davies, 2000 in Weiss, 2004a). Assumptions about Jamaica's comparative advantages in certain sectors come into question with the present and potential international trade shifts and global climate changes. The Jamaican food system needs to be reevaluated with a cross-disciplinary multi-scalar lens that captures the interplay between bottom up and top down features present in a small open economy.

Objectives

The purpose of this study is to explore the interactions within Jamaica's food system and between that system and its socioecological environment in order to reveal management strategies that strengthen food security conditions. Of concern are the implications for agricultural production, income opportunities and nutritional consumption patterns.

Accordingly this research has six objectives:

- Conduct a literature and data review of Jamaican food security
- Use soft systems analysis to survey interests involved in problematic situation
- Translate the interview results, literature concepts and available data into a functioning simulation model
- Test the model against selected historic conditions
- Explore plausible scenario simulations to enrich understanding of food system links
- Provide insights into future model development and use

CHAPTER 2
PROBLEM BACKGROUND

This section reviews complex systems theory and the parallel development of softer approaches for exploration into complex systems that seek to generate relevant, timely and adopted knowledge and its associated technologies and policies. A discussion of complex systems theory as applied specifically to the management of food systems follows. Finally, the evolution of decision support technology, specifically dynamic modeling, as it seeks to apply the complex systems paradigm is reviewed.

Hard and Soft Methods for Understanding Complex Systems

The contemporary research community is not only internally fragmented but also increasingly distant from the institutions at large who apply research findings (Pidd, 2004; Douthwaite et al., 2000; D. H. Walker, 2002). This distance inhibits the efficiency and practicality of the application of research findings (Ibid.). Misunderstandings, distrust, non-adoption or conflict generally characterize the ineffective knowledge transfer between research and implementation communities around the world (Ibid.).

The interdisciplinary movement has intensified the discussion of how a particular research strategy can either assist or inhibit the eventual uptake and practical application of newly acquired information by the community at large (Douthwaite et al., 2000; D. H. Walker, 2002; Kiker et al., 2003). This discussion offers new research paradigms that aim to decrease the inefficiencies that plague the integration of the research, development, and implementation communities involved in socioecological systems management (Roux et al., 2006; Gunderson et al., 1995). The combination of soft and hard methods in research approaches is being explored as one way to bridge divides and inefficiencies by providing both <u>decision</u> and <u>process</u> support throughout a project (Eden and Ackermannn, 2004).

Wicked Problems

Scholars of ecology as well as engineering and management science agree that large scale management of socioecological systems has been largely unsuccessful at maintaining resilient communities (Holling, 1996; Costanza et al., 1995). This failure can be attributed to shortcomings within both (1) the classical reductionist scientific process and (2) society's institutional capacity to translate scientific knowledge into real change (Simon, 1962; Forrester, 1961, Ackoff, 1974; Meadows and Robinson; 1985). Both of these problematic issues are intrinsically linked by the nature of the managed situations as "wicked problems" or "messes" (Rittel and Weber, 1973; Ackoff, 1974). According to Conklin and Weill a wicked problem exhibits the following (Pidd, 2004):

- The problem is ever evolving and cannot be confined to a single definition.
- Because there is no definitive Problem, there is no definitive Solution
- There are many stakeholders involved, making the problem "solving" process fundamentally social.
- The physical and social constraints on the solution change over time

Complex Systems Theory

Attempts to deal with these problematic situations in an integrated manner have been driving a core paradigm shift across management communities, from natural resource to operations management for the past fifty years (Folke, 2006). The new paradigm, referred to here as complex systems, developed from general systems theory. It is a reaction against the classical reductionist approach to science and management that assumes that complex phenomena can be broken down into smaller units that can be managed independently (Churchman, 1979; von Bertalanffy, 1968; Ackoff, 1974; Simon, 1962; Forrester, 1968). Rather, general systems theory views the whole as greater than the sum of its parts. This shift is from a "bounded rationality", "positivist", "determinist", or "hard" approach to a "soft" or "procedural rationality" framework for knowledge formulation and application (Simon, 1962; Checkland, 1979; Douthwaite et al., 2001; Lyons, 2004).

Since the conception of complex systems theory, researchers have struggled to develop a systematic strategy that can address both the biophysical and the human aspects of complex systems. Obviously there are fundamental differences between each type of system; biophysical systems are inherently spatial and transfers occur in material and energy terms, social systems are often non-spatial and transfer knowledge and information. Some of the early attempts at formal integrated analysis guidelines focused on both systems' hierarchical structure (Simon, 1962; van Bertallanffy, 1968).

Forrester and H.T. Odum are two of the major contributors to complex systems theory (Pavoa-Zuckerman, 2000). Both scientists developed symbolic languages to represent system components and dynamics in order to facilitate modeling of the components in complex systems (Ibid.). Forrester, an engineer and computer scientist, combined ideas from cybernetics, control engineering, and organizational theory to develop a guiding philosophy for simulating complex, non-linear, multi-loop feedback systems initially applied to the management of industrial firms (1961). Odum, an ecologist drawing from Forrester, used similar theories to explore humans within natural systems (1983).

The complex systems framework assumes that all materials and information are transferred through positive and negative synergistic couplings that produce emergent effects such as delays and thresholds (Forrester, 1961). Additionally, complex systems are understood as open systems that interact freely with their environment, resulting in disequilibrium and an unbounded set of interactions (Holling, 1986). Despite the fact that complex systems theory does not have an agreed upon method for inquiry, it still provides the most helpful perspective to address management of messy issues (van der leeuw and Aschan-Leygonie, 2005).

Two Social Facets of Complex Systems Management

The complex systems framework has strong implications for the types of tools and techniques used to explore problematic situations. For example, ecology scholars are working to develop a common currency between natural and social interactions in order create a language that allows for more holistic assessments (Folke, 2006). Similarly, social scientists have been investigating the development of new soft methods of inquiry as well as the possible integration of these methods with classical hard methods in order to uncover and assess complex problems (Pidd, 2004).

The complex systems framework acknowledges that not only are problematic socioecological situations integrated by nature, but also the political and institutional capacity of each domain is highly linked to the others even if not intentionally (Schipper and Pelling, 2006). These two types of integration reveal two social facets of complex systems management arising from: (1) The internal inherent features of socioecological systems (2) the social institutional structure that exists to facilitate exploration and management of socioecological systems.

Complex systems inherent social features

Prior to the mid 1990s most ecosystem management studies were framed exclusively in “natural” or “human” terms (the former usually occurring in biology or ecology, the latter in economics) (van der leeuw and Aschan-Leygonie, 2005). However, following increasing evidence that neither the social nor the natural system is paramount, the focus shifted to the <u>interactions</u> between the equal but heterogeneous components of what became termed as socioecological systems (Gunderson et al., 1995; Holling and Gunderson, 2002; Berkes et al., 2003; Walker et al., 2004). This progression from restrictive to holistic understandings has been described as an evolution of the role of humans in socioecological relations moving from re-active prior to the 1980s, through pro-active during the 1990s, and residing currently as an inter-active understanding (van der leeuw and Aschan-Leygonie, 2005).

Holling's work in ecological resiliency has fueled much of the methodological theory for integrating social and natural systems' studies (Holling, 1973; Folke, 2006). The importance of temporal and spatial scales of analysis and the mechanisms that transcend these levels is at the core of resilience concepts. Holling posits that only two criteria must be met for resilience concepts to be applied to studies beyond ecology: (1) the systems need to be described in dynamic terms, and (2) the systems must have more than one potential state of equilibrium (1985).

While these developments supply concepts for research into complex systems, they do not sufficiently address the second social facet of complex systems management. This additional side to the management problem rests in the process support needed to guide the institutional machine performing and applying the research.

Managing the managers

Management of issues in complex socioecological systems (i.e. food security) involves not only a conceptualized system's variables and their interactions but also the issues that arise from stakeholders' dynamic perceptions of the situation. Communities must strive to navigate the logistical social aspects of managing a problematic situation by being "conscious of and competent at dealing with, the differences between individuals (or collective interests) that comprise the group with respect to a host of issues surrounding the situation" (Bawden, 1995 in Ison et al., 1997, 266).

Research in the social management disciplines has used complex systems theory to inform new methods of inquiry that transcend the reductionist model of research in order to offer process as well as decision support (Eden and Ackermannn, 2004; Pidd, 2004). Rather than attempting to discover, quantify, predict and control the situations that arise from complex systems by way of hard methods, soft frameworks offer flexible options for problem exploration and management. As Ison et al. concisely summarized, “A given problem does not occur in isolation or exist objectively-‘out there’. It is socially constructed on the basis of different perspectives and is part of an interrelated network of problems” (1997, 260). In accordance with the notion of wicked problems, preference for a particular strategy to address such a problem thus reflects a certain situational understanding. Obviously this understanding will differ and change between individuals, communities, and disciplines making it difficult to agree on a single strategy of action. However, using the existence of multiple perspectives as the ideology itself, as the complex systems paradigm assumes, provides for a system of analysis that “prepares for mutual understanding and negotiation of the problem(s) in question” (Ison et al., 1997, 260). Collaborative modeling is one type of decision tool that can apply the complex systems framework to support research within a holistic socioecological problem structure while simultaneously alleviating the inefficiencies that arise from the social nature of problem solving.

Food Systems as Complex Systems

Food systems can be understood as one type of complex system where systemic vulnerability is embodied in temporary conditions of food insecurity. These potential conditions emerge from a spectrum of possible interactions between internal and external socioeconomic components of the food system. Like all complex systems, food systems behave synergistically. Actors at all levels of the food system must deal with both changing ecological and socioeconomic conditions. Additionally these actors create change leading to feed back within the system both to themselves and to actors at levels above and below them.

Food security issues occupy a unique meso scale location in the planning field because food and agriculture possess distinctive qualities regarding quality of life, cultural decisions and environmental and land use effects. Recognizing that poverty and hunger occur at the household level as family decisions often determine how limited resources are utilized, much recent effort has been put into micro level household scale studies to determine how communities deal with limited resources and how shifts in access efficiencies or practices would change resource use and quality of life. Yet macro scale indices remain the most common measure of community/national health in the planning arena (Pothukuchi and Kaufman, 2000).

In order to evaluate food security the linkages or pressure points between the field and the fork must be holistically assessed (Ericksen, 2006a and 2006b). Increasing food security requires asking the following questions: Who are the actors being relied on at all levels from production to consumption of the food system? How does reliance on those actors affect a population's interests? How could each actor transform or change? And what are the potential adaptations/coping strategies of a population in the face of the actors' potential transformations?

Agricultural and Food Policy Decision Support

Traditional agricultural research and food policy has failed to produce a global food system with adequate levels of food security, leading the food and agricultural research community, like other socioecological sectors, to move away from methods and institutions based on reductionist frameworks (Fraser et al., 2005; Sundkvist et al., 2005; O'Brien and Leichenko, 2000; Costanza et al., 1995; Meadows, 1985). With the advent of sustainable development principles, a gradual shift is taking place whereby issues of agriculture are no longer analyzed separately but are integrated into the assessment of the entire food system in terms of the roles it plays in rural welfare, environmental effects and consumer welfare (Eakin, 2005; Andreatta, 1998; Ford, 1992). In this context, the biological and socioeconomic transmission mechanisms that govern the availability and accessibility of food can be analyzed within a coherent framework (Fraser et al., 2005).

Twenty five years ago, Amartya Sen introduced new ideas to address poverty and food security. He moved the concept of food accessibility to the forefront of the food security discussion (1980). Twenty years ago, Donella Meadows, a systems analyst, described the chronically inadequate food systems that failed to support much of the world's population despite the existence of thousands of detailed formal analyses (1985). She made the crucial insight that this malfunctioning was due to posing questions that were "not being applied to the total system" and that "in their underlying assumptions and limitations cannot lead to the answers one really wants to find" (1985, 161). As an example of a proper perspective, Meadows cites a Dutch international food system simulation model called MOIRA that integrated environmental and socioeconomic change in 1979! However movement since then towards the posing of the types of holistic questions that could lead to better analyses and management of food systems has been slow.

Despite these early promises of success, agricultural research and food policy communities largely continue to manage by way of limited single goals such as aggregate calorie per capita availability and overall crop productivity. Just as Holling showed that the use of static target variables in ecosystem management leads to pathologically vulnerable ecosystems, scholars of food systems have begun to show how the failure to use integrated social and environmental assessments have increased food insecurity (1978, O'Brien and Leichenko, 2000; Schipper and Pelling, 2006). Dynamic modeling is a potential tool for more integrated assessments of food systems.

Modeling Complex Systems for Decision Support

The systems engineering community that develops technologies to bridge the divide between research and policy institutions has been traversing a paradigm shift parallel to ecological and social research scholars (Pidd, 2004; Lyons, 2004; Eden and Ackermannn, 2004). As the complexity of problematic situations under investigation is increasingly recognized, technology's role in guiding formulation of strategies for situational improvement is changing. For example, a feature of complex systems is their unpredictability, tools that claim to make predictions become irrelevant (Lyons, 2004). In the same vein, the increasing recognition of the importance to account for competing versions of reality or worldviews in order to create knowledge that is relevant and adopted, necessitates technology that aids in formulation of cohesive community problem definition or at least increases understanding between the various stakeholders of different perspectives (Eden and Ackermannn, 2004; Douthwaite et al., 2001).

Decision Support Paradigm Shift

Widespread disenchantment characterizes the general sentiment towards decision support systems, (DSS)[1] (D.H. Walker, 2002). Research reveals non-delivery, irrelevance, inflexibility, inaccessibility, lack of confidence, institutional and political boundaries, and negative impacts on decision making processes as reasons for decision support systems' limited adoption and perceived minimal impact on decision making processes (D. H. Walker, 2002; Cox, 1996; Davis, 1989; Meadows and Robinson, 1985).

These findings are not surprising as the classical view of manager is one of impartial controller (Stacey, 2001; Lyons, 2004). The new managerial paradigm emphasizes flexibility

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[1] Although a decision support system is traditionally understood as a probabilistic computer tool that aims to reveal optimized solutions to decision makers and predict the impact of a given policy on a single variable, DSS is understood in this thesis in its broadest sense as an overarching situational strategy that aids in decision making through multiple flexible tools and methods as defined in D. H. Walker (2002).

rather than control as well as the need to develop approaches and tools which are relevant in the wider decision-making context (D. H. Walker, 2002). The DSSs must not only aim to deepen our understanding of a particular system's components and dynamics but should also serve as devices that bring cohesion to a group of diversified stakeholder groups. A key feature of a particular DSS should be to broaden understandings of other interests involved. Its functions should include exploration of how others view the problem situation, followed by facilitating initial agreement upon problem situation. However, it should contain provisions whereby this initial vision can be modified as viewpoints or interests change or increased technical knowledge surrounding the problem is introduced. Often DSS tools are considered successful even when they are not widely employed because they facilitate learning between developers and managers (D. H. Walker, 2002). In fact, DSS that fail to facilitate experiential learning have limited utility (Ison et al., 1997).

Modeling

Certain modeling strategies can transcend the traditional difficulties associated with DSS relatively easily. Models' inherent qualities as representations of perceived reality allows them to serve as "transitional objects" that help people see their own and others' mental models (Morecroft, 2004). Not only can a model provide insights into the system under question but the very creation and design process can serve as tools to learn about the system as well as the managerial stakeholders involved (Walker et al., 2002).

It is important to note that there is no "right" model of a system, just more and less useful ones (Janssen et al., 2006). Because models are merely simplifications of the real system they cannot test hypotheses they can only describe the reality the modeler wishes to describe (Levins, 1966 in Pavoa-Zuckerman, 2000). While they are not able to prove or disprove any theory, a model's greatest utility lies in its ability to serve as a learning tool.

Models are useful when integrating multiple disciplinary concepts "because models serve as conceptual tools in the formulation of theories, helping one to visualize the patterns and processes of the ecosystems being represented" (Pavoa-Zuckerman, 2000, 36). Models allow us to transcend our restrictive understanding of what is possible and help us "expand our linear expectations to include all the possible futures we may encounter" (Farrell, 1998 in Lyons, 2004, 39). Model exercises can reveal trends in the expected importance of certain system features for implicating resiliency to certain events (Janssen et al., 2006). These models can also reveal systematic processes for collecting future data about socioecological systems (Ibid.).

Models should attempt to "identify thresholds, their nature, and what determines their positions along the driving variables" (Walker et al., 2002). They should be simple, multi-scalar and temporal, and scenario based (Ibid.). They should 1) Act as tools of negotiation, 2) Create/unearth choice, and 3) Define a context for trade offs (Schrage, 2000). Developers of models should be aware of how stakeholder interests and assumptions are integrated with system features before they can adequately develop a tool for systematic learning about a problematic situation and potential improvement options (Bunch, 2003; Zhu and Dale, 2000).

This larger scene in which model development is nested is eloquently described by Meadows and Robinson, "Modelers are human beings with human strengths and failures. To the extent that their work can be structured to bring out their strengths and correct for their failures, they can contribute immensely to human understanding of how the world works, to social decision-making, and to the shaping of an uncertain future" (1985, 15). One such modeling structure is the explicit employment of soft methods consisting of iterative cycles of inquiry and reflection that revolve around how the stakeholders seeking to learn about and improve a problematic situation understand the issues involved (van der Heijden, 1996).

Hard and Soft Methods for Model Development

Multiple frameworks exist to guide systems' engineers towards creating tools of greater relevance and impact (Parker et al., 2002; D. H. Walker, 2002; van Ittersum et al., 1998; Meadows and Robinson, 1985). These all stress the importance of iterative flexible development, transparency, integration of scales, issues and stakeholders, qualitative as well as quantitative concepts and communication facilitation (Ibid.). Most importantly these frameworks emphasize the need for continual monitoring and investigation into the process of technology development in order to move towards best practice guidelines.

Soft systems methods

Checkland and Holwell make the astute distinction between hard and soft approaches and hard and soft skills (2004). While a soft approach assumes an infinite number of possibilities, a hard approach assumes only one. In this sense a soft perspective is the only appropriate approach for wicked problems. Soft approaches, however, can accommodate hard skills within them. When assessing soft vs. hard skills, such as qualitative vs. quantitative research techniques, there is the possibility of fluid and equal integration between soft and hard (Ibid.; Pidd, 2004; Eden and Ackermann, 2004). Eden and Ackermann propose the use of combined soft and hard methods in order to foster both decision and process support (2004). This type of approach provides a space where group and individual interests can be explored simultaneously just as a forest can be seen as a whole without losing site of the trees.

In traditional system management theory the objectives of a given system were assumed obvious (Checkland, 1979). If the management objectives were not met, it was believed to be a result of system inefficiency, and planners set out to engineer solutions. However, as this reductionist thinking failed to solve the increasing problems occurring between humans and their environment (Capra, 1996), managers began to wonder if they should not only be asking, "how should the system work?", but also "what should the system provide? And why?" (Checkland & Scholes, 1990). The answers to these questions are never "right" and always contain degrees of inherent uncertainty (van der Heijden, 1996). Soft systems methods such as scenario planning (van der Heijden, 1996) and the soft systems methodology, SSM (Checkland, 1979), directly address the existence of multiple worldviews and provide ways to engage with them (Checkland, 1999). The systems modeling method nested in a softer methods approach offers potential to overcome traditional DSS limitations. (Bunch, 2003; Zhu and Dale, 2000)

Iterative cycles of tool development

Douthwaite et al. characterize traditional technology development as positivist-realism associated with a uni-directional information flow from the engineer or knowledge possessor to the user (2001). This approach is built on the hard science paradigm that assumes "an independent reality" (Ibid., 2) that can be experimented upon to produce quantifiable results. Douthwaite has developed an iterative tool development process structured in cycles of learning rather than uni-direction information flow (Ibid.). This approach is known as the Follow the Technology approach as opposed to the Transfer of Technology approach employed in traditional tool development (Ibid.).

At any step during tool development new information could come to light, or forward movements become stalled, and revisiting a previous step becomes necessary. In order to explicitly account for these inevitable situations, this approach utilizes ongoing cyclical exploration and analysis. These cycles of innovation are best described in Figure 2-1 based on Douthwaite's tool fitness diagram.

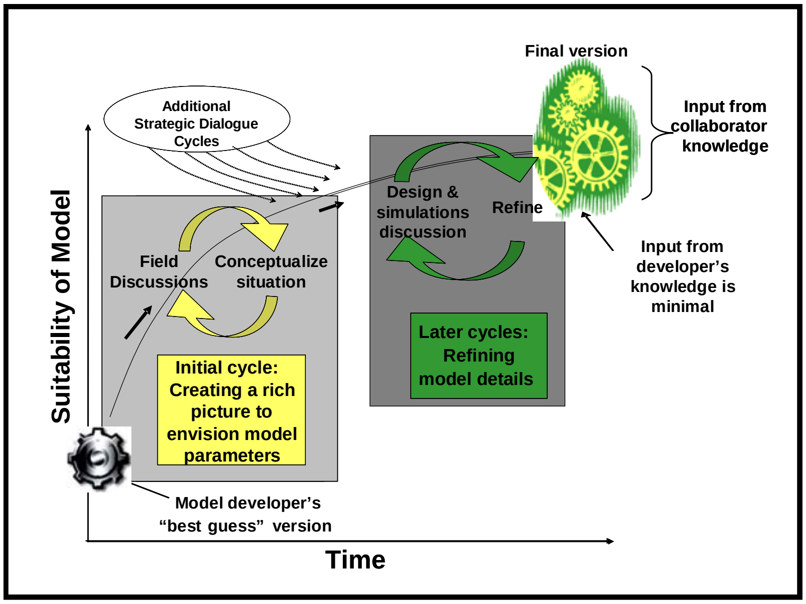

Figure 2-1 Iterative collaborative cycles in a tool's development process (after Douthwaite et al., 2001).

Cross Disciplinary Convergence and Systems Modeling

It is interesting to note the convergence of the ideas contained in the frameworks from technology engineering with those from other disciplines that also seek to address complex system management. For instance in the field of vulnerability analysis researchers are moving away from black box analytical models of process and outcome that do not allow for the exploration of the dynamic and integrative nature of risk (Adger, 2006). The idea of continual evaluation of processes stressed above forms the backbone to the entire theory of ecological adaptive management (Holling, 1978; Kiker et al., 2003). Researchers of resilience theory, mostly ecologists by training, have illuminated four steps for complex system assessment that mirror the frameworks suggested by the engineering community. These include 1) development of a conceptual model; 2) Identification of possible future scenarios: 3) Exploration of interactions; 4) Stakeholder evaluation. (Walker et al., 2002).

The similarities between frameworks across disciplines have positive implications for the continued and improved cooperation necessary in complex systems management. Likewise agreement within the DSS community as well as across many other disciplines about the appropriateness of modeling nested in collaborative methods for revealing concepts in complex systems promises enhanced technological decision support experiences (Walker et al. 2002; Carpenter et al., 1999; Janssen et al.,. 2006; van der Leeuw and Aschan-Leygonie, 2005).

CHAPTER 3
AN APPROACH TO FOOD SYSTEM MODELING

Food System Models

A number of model-based analyses have been performed to assess socioecological interactions involved in food production and consumption (Young and Kantor, 1999; Duchin, 2005). Duchin, developer of a global food system analytical model, The World Trade Model, describes how public food security is intimately tied to nutritional, environmental and economic policy, yet all have failed it (2005). Nutritional and environmental educational campaigns often have less than desired impact while political elements face competing forces of public and private interests. She stresses that in this tension, the solution lies: the environmental and nutritional communities must work together to bridge the public, governmental and corporate divides. Duchin suggests simulation modeling as a way to organize the interests of these groups.

She described the difficult resolution decisions that modelers everywhere often face during the design and development processes. For instance, in the case of designing a diet scenario she wondered if it should contain 30, 300 or 3000 food categories. She applied what natural ecologists have said about modeling complex environmental systems to the creation of stylized models of human production and consumption activities, “Greater abstraction, or sacrifice of detail, is necessary to describe the workings of much larger complex systems…Creating templates to describe alternative diets or production strategies requires levels abstraction not generally required for representations based only on direct measurement” (2005, 110). An average quantitative description works because it “is a stylized representation that succeeds when it captures the characteristics most important for the analysis” (2005, 110). In her words, successful sets of variables require “attending to the distinctive properties of different variables” (2005, 110). This identification of the qualitative “distinctive properties” of variables allows one to “tunnel” to the appropriate inclusion or exclusion of systemic features and avoid unnecessary duplication.[2]

Soft systems methods along with the review of empirical evidence guided the identification of the appropriate systemic features to represent the multiple interests of the Jamaican food system in the simulation model, QnD:Jamaica.

Approach

The systematic study of how interactions between external influence and structural mechanisms of a socioecological system affect emergent properties is a new approach for policy planning methods. More specifically, assessment of food systems as socioecological units is a new approach to food security management (Pothukuchi, and Kaufman 2000). The purpose of this study is to explore the interactions within Jamaica’s food system and between that system and its socioecological environment. Of concern are the implications for food production, income opportunities and nutritional consumption across rural and urban population groups. In order to address these issues, a complex systems framework was employed. This framework was applied through a dynamic modeling exercise that employed soft system methods for model development.

This research effort has two distinct objective phases: 1) Research Phase and 2) Design and Evaluation Phase shown in Table 3-1.

Table 3-1 Project phases.

I. Research phase	II. Design and evaluation phase
Uncover key food security concerns as perceived by stakeholders	Design and develop a computer- based scenario simulation model
Formally translate these concerns to a parameters and drivers format	Test model’s parameters through scenario simulations

[2] However, as ecologists have recently noted, a feature that only appears to be a duplicate might be the one key that possesses unique qualities that provide systemic resilience.

Soft Systems Methods

Soft systems approaches use iterative and collaborative techniques to envision the driving forces which could move a system one way or another (van der Heijden 1996). These approaches such as scenario planning (van der Heijden 1996) and the Soft Systems Methodology (SSM) (Checkland 1979, 1999), provide tools to tease out a system's potential pressure points and explore how possible interventions around these points might improve the problem situation (Checkland 1999). By allowing modelers to actively engage with stakeholders' assumptions and the inherent uncertainties in complex systems, soft systems approaches are conceptually compatible with complex socioecological systems frameworks, and provide a useful research methodology for interacting with stakeholders and guiding researchers as they carefully seek to structure the problem situation. These methods assist researchers to elicit perceptions of a real world situation and then organize the results into mental models of key themes that provide starting points to explore the context of change within the system.

A soft systems approach first requires expression of concerns about the system in a non-systems manner. This is accomplished through informal "strategic dialogues" (individually or in groups) with stakeholders comprised of a broad range of interests in the system (van der Heijden 1996; van der Heijden et al. 2002). To begin these collaborations Quinn and Voyer suggest asking, "If there was one core question that underlies all the strategic challenges you face what would it be?" (1996). van der Heijden (1996) suggests the following questions:

- What concerns you most about the future?
- What would you ask an 'Oracle'?
- What would be a good/bad scenario?
- What would lead to a good/bad scenario?
- What critical decisions have to be made soon?
- What was learned from past surprises?

The strategic dialogues that begin a soft systems inquiry into a problem situation differentiate the soft approach from traditional hard approaches which seek to narrow and define problem statements early on in a research process. A soft systems approach purposefully avoids narrowing the problem definition too soon, instead seeking to gather the many views, values, perceptions, and expectations that characterize a complex issue. Not only do these methods distill various interests, but they also reveal the multiple scales at which an issue can be framed. Churchman suggests that researchers "sweep in" a wide variety of stakeholders, both friends and enemies, in order to reveal the many assumptions about the nature of the problem and what would constitute improvement (1979).

Interview results along with appropriate literature review findings are mapped in an ordered database that provides an overview of the key themes in stakeholder frameworks clustered according to their qualities in the situation. In the first stage of mapping, emergent issues are unrestrictedly clustered according to all of their potential interactions. Next, clusters are refined according to common and divergent world views and assumptions. The issues should also be clustered in terms of their properties of internal or external influence. The resulting thematic database can also be represented as a *rich picture*, a graphical conceptualization of the situation. Transformations of key issues that would improve the problem situation are identified from the *rich picture*. A TWOACE analysis (described in detail in chapter four) is applied in order to specify the world views that give this transformation meaning, the actors involved, and the environmental constraints.

QnD Modeling System

The *Questions and Decisions*, QnD, modeling system is a problem exploration object oriented tool that increases understanding of potential behaviors and management options of a particular socioecological system (Kiker et al., 2006; Kiker and Linkov, 2006). Through a user-friendly graphical interface stakeholders can “play” their system by manipulating institutional and ecological components of interest. Results differ from the combinations of various environmental and economic drivers and the player’s response to them via management options implemented in different spatial areas and over different time periods. As various scenarios are played, the interactions between institutional and ecological parameters are exposed and future possibilities of the system can be envisioned.

The QnD system not only helps stakeholders deepen their understanding of a particular system’s components and dynamics but also acts as a device to bring cohesion to a stakeholder community. Throughout its iterative design process, a QnD system engages stakeholders to accomplish multiple tasks: facilitating initial agreement on key forces and themes, broadening understandings of others’ interests, developing scenarios and analyzing various policy options. QnD was created as a technical tool that is complemented by and works in tandem with an iterative exploration process. The system’s design process was intended to be compatible with several social science methodologies, such as the Soft Systems Methodolgy (SSM), scenario planning, or cognitive mapping. In order to apply the QnD modeling system to Jamaica’s food security issues, quantifiable components, processes, and drivers were revealed through soft systems methods.

Eight of the simulation processes available in the QnD modeling system were used in this research project. Table 3-2 describes the operations performed by these processes.

Table 3-2 QnD processes.

Process name	Operation performed
PAddValue	Input one is added to input two
PSubtractValue	Input two is subtracted from input one
PMultiplyValue	Input one is multiplied by input two
PDivideValue	Input one is divided by input two
PSetValue	Output is set to input
PRelationship	A two column table of values relates any

	number of pairs of points as independent and dependent variables. All points between defined pairs fall on a linear relationship.
PIfGreaterThan	If input two is greater than input one than perform following subprocess. If not greater jump to next main process.
PTemporalRunningAverageValue	The values for the input from the time step prior to any number of consecutive previous periods are averaged.

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The QnD modeling system was applied to the Jamaican food system by translating the results of a soft systems analysis into a conceptual object format (described in detail in chapter four). This structure forms the backbone of QnD:Jamaica, a functioning food system simulation model. The next section describes the specific methods employed during field work to build a *rich picture* that could inform model design.

Informing Decision Support Tool Development

An initial list of potential collaborators identified general stakeholder groups according to their structural location within the system. A review of Jamaican food system literature suggested that tourism, small scale agriculture, international trade, government and environmental interests are major subsystems influencing food security. A general list of participants included small farming communities, tourist industry actors (traditional and eco-based), informal and formal food distribution actors, agricultural, nutritional, and environmental NGOs, and Ministries involved in food system management. To this general list were added specific individuals that had proactively explored and/or participated directly in management issues related to Jamaican food security as evidenced in academic papers and governmental reports as well the leadership lists for organizations involved in food security. Where feasible, potential participants were contacted via email to ascertain their availability in Jamaica during

July 2006. As it was not possible to identify by name or contact many stakeholders from outside of the country, they were solicited in person once field work began.

The first interviewees included three professors from the University of West Indies (UWI-Mona) and a researcher at the Caribbean Food and Nutrition Institute. During the first interviews specific individuals from the above general stakeholder categories were suggested as additional participants in a "snowball sampling" manner. These included a divisional director within the Ministry of Agriculture, a rural development field officer, an ecotourism outfit owner, members of a parish-level farming cooperative, a livestock farmer, and a manager of a local supermarket.

During the interviews, the problem situation as understood by the stakeholders was investigated through the scenario planning approach (van der Heijden, 1996) and the Soft Systems Methodology (Checkland, 1979, 1999). First, concerns about the system were expressed in a general manner. The collaborations began with one general question similar to the one suggested by Quinn and Voyer (1996): "What do you believe are the biggest challenges to Jamaican food security?" The ensuing discussion loosely followed the question structure as proposed by van der Heijden (1996). The conversation was often supplemented by questions directly related to the interviewee's field of expertise. The interviews were recorded and reviewed later to determine what and why key issues were of concern and attributed to which stakeholders. In accordance with the scenario methods described above (van der Heijden, 1996) a thematic database was created that clustered the main issues affecting food security by their understood internal or external influence on the situation.

CHAPTER 4
JAMAICAN FOOD SYSTEM: AN ILLUSTRATIVE CASE

The pathways that couple production and consumption in small open economies were revealed in order to be represented in the food system model QnD:Jamaica. The actors and interactions involved in the Jamaican food system were reviewed within the qualitative framework provided from the results of soft methods research performed in the field, and organized into conceptual groups that loosely followed the framework suggested by the research group GECAFS. The qualities examined were socioeconomic populations, land uses, food pricing, distribution and marketing structures, and consumption issues as well as how each subject is embedded in the historical context. This systematic analysis structure provides an approach that can guide future meso scale explorations of other food systems and be used in distilling features the meso scale of food systems in general.

Within this framework, empirical data were reviewed for the period of 1986-2004 to develop quantitative descriptions for the objects that structure QnD:Jamaica. This period was chosen because data existed for occurrence of multiple political, economic, and climatic events. These include internal structural adjustments made in accordance with International Monetary Fund (IMF) agreements such as exchange rate deregulation and market liberalization, hurricanes Gilbert and Ivan, additional known drought and flood events, and the September 11th attacks on the US, which affected international socioeconomic conditions.

Historical Review

The 1970s in Jamaica were characterized by a strong national state that utilized extensive price controls, subsidies and nationalization of primary industries to solve poverty issues. Prime Minister Michael Manley's People's National Party (PNP) pursued a policy in the early 1970s of import substitution in efforts to strengthen the Jamaican economy. However, by the late 1970s the country was heavily indebted to international financial institutions and began a series of extreme economic reforms in the 1980s and 1990s such as devaluation of the Jamaican dollar, elimination of state marketing boards, trade liberalization, and privatization of state and public owned industries.

The Exchange Rate, Inflation and Food Imports

Between 1981 and 1985, government support for agriculture was heavily withdrawn. This was due to overall decreases in government spending as well as a decrease in the percentage of spending on agriculture from 19% in 1975 to less than 4 % by 1990 (Weiss, 2004a). In addition to reduced internal supports, increased input costs, and the overall rise in the cost of living, Jamaican agriculture also suffered from the reform policies of AGRO-21.

Designed with help from USAID, the policies of AGRO-21 aimed to free up labor from agriculture and make it available to sectors of the economy in which Jamaica was believed to have a comparative advantage: mass tourism and manufacturing. However, as labor was shed without increases in mechanization or other productivity supports, agricultural production volumes began to fall (Witter, 1989 in Weiss, 2004a). Additionally, the new industries proved unable to support the extra labor. During the late 1980s and early 1990s there was a mass outward migration of one in twelve Jamaicans (Anderson and Witter, 1994). This experience illustrates Weiss' conclusion that in contrast with free market theory, "the decline of one sector often produces serious dislocations without concurrent gains elsewhere" (2004, 474). Jamaica clearly exemplifies this with the trade deficit quadrupling between 1980 and 1990 and then almost tripling again between 1990 and 2004.

Between 1989 and 1992, monetary policy makers in Jamaica aimed to stabilize prices through macro economic tools (Robinson and Robinson, 1997; Planning Institute of Jamaica 1990-1994). Bound by IMF agreements made during the late 1980s, the Jamaican government followed a policy of currency devaluation that, in fact, actually increased the prices of consumer goods. Between 1990 and 1991 the Jamaican dollar depreciated against the American dollar by 60.9 % compared to 25.7% between 1989 and 1990 (Planning Institute of Jamaica, 1991). According to the financial transmission model put forth by Allen et al., the exchange rate exhibits the most significant effects on consumer prices in Jamaica and is linked to the importance imported goods in the economy (2002).

Currency devaluations were expected to increase domestic foods' competitiveness. The rising costs of imported production supplies, however, constrained the Jamaican farmer, and food prices rose (Planning Institute of Jamaica, 1992). As the purchasing power of the Jamaican dollar plummeted between 1989 and 1992, consumer prices steadily rose increasing 268% point to point. Of the eight regularly tracked household consumption groups, the food and drink category is weighted highest at 55.5% within the Jamaican CPI. Thus, food price increases generally have a large influence on the overall inflation rate.

An emergency Food Assistance Program was introduced in the early 1990s to prevent food riots over the high cost of food. This only served to strengthen the pattern of importation by subsidizing imported food staples rather than local ones. "The bias in consumption habits toward foreign foods" was fueled by making it "rational from the point of view of households maximizing nutrients per dollar to buy imported instead of local foods" (Witter, 1989 in Weiss, 2004a, 468).

The 1990s also saw reductions in trade barriers furthering the upward spiral in cheap imported food. Between 1991 and 2001 Jamaica's total food and beverage imports increased by two and a half times. The largest increases were in cereals, feeds, and meat products which account for half of the value of Jamaica's agro-imports (Weiss, 2004a). While domestic poultry production grew, it was fueled by US subsidized imported feedstuffs. Also, imported livestock amounts increased more than twice as fast during the 1990s. Per capita meat consumption increased by 55% between 1980 and 2000 moving to the center of the diet where it was previously relatively rare (Weiss, 2003).

Economic Development and Poverty Alleviation

Records indicate a decrease in poverty, from 30.5% in 1989 to 16.9% in 1999, while unemployment remained fairly constant around 15-17% (Osei, 2002; Le Franc and Downes, 2001; Salmon, 2002; King, 1998). This conundrum addresses the real drivers behind poverty reduction in the 1990s and supports the model that Jamaican consumption and production activities are highly affected by the external environment. While Salmon puts some faith in the success of the government's National Poverty Eradication Program at limiting poverty, Osei, King, and Le Franc and Downes are more skeptical about the government's role in increased consumption levels (Ibid.). Real price decreases and real wage increases, neither caused by governmental policy, played the largest role in increased consumption levels (Ibid.). The informal sector, in terms of domestic and international trade (both legal and illegal) and remittances from abroad, were the key factors to reducing the numbers of extreme poor.

Le Franc and Downes use the strong correlation between reduction in the poverty ratio as well as the inflation rate as evidence that falling prices have been the main driver of increased consumption (2001). They also make the important point that price changes not only affect income's purchasing power but also have substitution effects in which consumption patterns, and thus nutritional patterns, are changed.

These conclusions agree with earlier findings that absolute poverty was reduced by a recovery in real wages through informal activities, not economic reforms (King, 1998). The informal sector grew from 14% to 29% of the labor force between 1972 and 1997, and accounted for 30% of the labor force in 1999 (36% of total employment) (Osei, 2002). Decreases in unemployment have been shown to be the result of a decline in the number registered in the work force rather than an actual increase in employment (ECLAC, 2004). As Weiss describes, “Jamaica’s economy now rests on a precarious balance of external migration/remittances, tourism, drugs, and borrowing that is layered upon a notoriously high level of inequality” (2004, 483).

Climatic Shocks

The Jamaican population’s food security was also affected by climatic events. These natural disaster events affected food accessibility by increasing food costs as well as other consumption expenses in the form of household repairs and through the loss of jobs. If consumption expenditures return to pre-disaster levels before domestic production recovers, there can be a sharp increase in the relative importance of imported goods in the total consumption budget (Brown, 1994). For these reasons, the components and processes of the Jamaican food system must be evaluated within the dynamic context of climatic shocks.

Hurricane Gilbert

Hurricane Gilbert passed directly over the center of the island on September 12, 1988. Damage from this category five hurricane was estimated at $US 4 billion, with the agricultural sector accounting for 40% of this amount (PAHO, 1988). Gilbert affected 810,000 people and damage amounted to 65% of GDP (ECLAC, 2004).

Hurricanes have major economic effects on the balance of trade because of the increased expenditures on capital goods, most of which are imported, as well as the destruction of export goods that generate foreign exchange earnings (Brown, 1994; ECLAC, 2004). In 1988, an inflation rate of 7% was expected (Brown, 1994). Prior to Gilbert, the inflation rate was at 3.1%, on target to stay within the projected limit (Ibid.). However, the shortfalls in balance of trade caused by increased influx of food and rebuilding materials compounded with the decrease in exported agricultural goods from crop damage caused increased inflation in the post-hurricane months (Ibid.). In November, a rate of 14% was projected, however, by the end of the fiscal year the rates had recovered and final inflation for the year was 9.1% (Ibid.).

Hurricane Ivan

The rate of inflation in 2002 and 2003 was 7.3% and 14.1 % respectively, the highest in six years. This increase is believed to be caused by further depreciation in the exchange rate compounded by increased oil prices (ECLAC, 2004). At the beginning of 2004 a decrease in inflation was projected for the year from 14% to 9%. In the first half of the year domestic agriculture experienced a 6.5% gross decline due to dry conditions in the central and western parishes where the majority of domestic food is produced. This led to food shortages and the food and drink category drove 80% of the inflation in the second quarter of 2004 as opposed to 28% in the first quarter (Planning Institute of Jamaica, 2004).

Category 4 Hurricane Ivan passed from east to west, just south of Jamaica in September 2004. Most affected were the parishes of St. Catherine, Clarendon, Manchester, St. James, Hanover and St. Mary. A total of 102,000 people or 14% reported damage to households (ECLAC, 2004). Of those evaluated, 9% were completely destroyed, 75% severely damaged and 14% had only minor damage. Total damage was estimated at $J 11,163 million with $J 3,666 million of the total reconstruction costs coming from imported goods. An estimated $J 137, 235 (or $US 2,287 in 2004 dollars) reconstruction expenditure per house was estimated.

Two groups most significantly affected by Ivan were farmers and fishers, particularly those on the southern coasts (ECLAC, 2004). An estimated 11,100 hectares of domestic agricultural land was affected with 117,700 farmers sustaining losses. There was $J 2,632 million damage to the domestic sector with legumes sustaining $J 43.2 million, vegetables J$ 396.4 million, and root crops J$ 570.6 million in losses (2004 J$).

Banana production for the year was entirely destroyed. This sector's devastation put 8000 persons out of work for a period of six to nine months (Ibid.). Full recovery of tourism infrastructure occurred three months after the event (Ibid.). Efforts were made to employ workers in rehabilitation efforts, but temporary loss of employment was inevitable due to the decrease in tourists (Ibid.).

Road infrastructure was another of the significant areas to sustain damage. However, direct damage costs were much less than the indirect losses sustained because of the missing support that the infrastructure provides to other sectors (Ibid.). Floods and landslides cut off entire sections of roads, damaged retaining walls and bridge approaches, and deposited silt on roadways. Slippage of entire sections of roads occurred from the saturation of land and raging rivers scoured road edges. However, a single lane of traffic was ensured on all major roadways by the end of the month. Although an assessment of the indirect unit transport costs increases was not available, the increases were expected to be "very high in monetary terms-that will have a negative bearing on the population's well-being." (Ibid., 36).

Holistic Exploration

After a quarter century of pursuing a failing model of an export led economy, Jamaica has now become what Witter terms a 'consuming appendage' of the US economy (2000 in Wess, 2004). Propositions that consider a more balanced and diversified model of economic development are presently being put forth (MOA, 2005). However, changes to the current internal food system must proceed with caution. Policy designed to improve or adjust the current Jamaican food system is hemmed in by the large numbers of the Jamaican population who depend directly on informal food production and distribution for their livelihoods. The creation in 1963 of the Agricultural Marketing Corporation (AMC) to consolidate distribution, wholesaling, and retailing operations appeared to be a solution to the inefficiencies of the Jamaican food system. Instead, the corporation resulted in massive livelihood losses to sectors of the traditional system. Similarly, campaigns to “clean up Kingston” and remove informal traders were also unsuccessful (Espeut, 2003).

The current food production and distribution system persists because it functions as a last resort informal income source pursued by the large amounts of surplus labor in the country (Lewis, 1954). In other words it is a symptom of larger societal structure and cannot be superficially reformed. The internal mechanisms that transmit economic, social and environmental effects and feedbacks within the Jamaican food system must be explored in tandem so that the outcomes of complex interacting components can be weighed in a holistic context.

The next section describes the *rich picture* that resulted from the soft systems analysis which aims to provide a more holistic conceptualization of the issues involved in Jamaican food security. This is followed by a detailed empirical review of the five explicit conceptual categories revealed through the *rich picture* and chosen to be represented in QnD:Jamaica. These categories include population typology, land use, food distribution, food pricing, and nutritional consumption.

Rich Picture Reveals Conceptual Framework

Main areas of concern affecting food security revealed by stakeholders through the soft systems approach could be clustered by internal and external socioeconomic and ecological drivers. External issues included changes in tourism visits, changes in export markets (closing: bananas, opening: niche), prices of imported food, decreasing nutritional and cultural value of imported food, and hurricane effects on infrastructure, tourism and productivity and rainfall effects on productivity. Each of these external concerns also relates to key internal issue clusters. For instance, land use change decisions are internal drivers but are closely tied to external drivers such as closing banana markets. Changed utilization of this newly available land raises new concerns in terms of maintenance of ecological integrity and economic exploitation. If niche markets open, what institutional and infrastructural organization is necessary to take advantage? How can tourism be exploited without sacrificing ecological assets? What about the current production system reduces food security? What rural economic activities besides agriculture are options? These issues in addition to others are graphically represented in the *rich picture* (Figure 4-1).

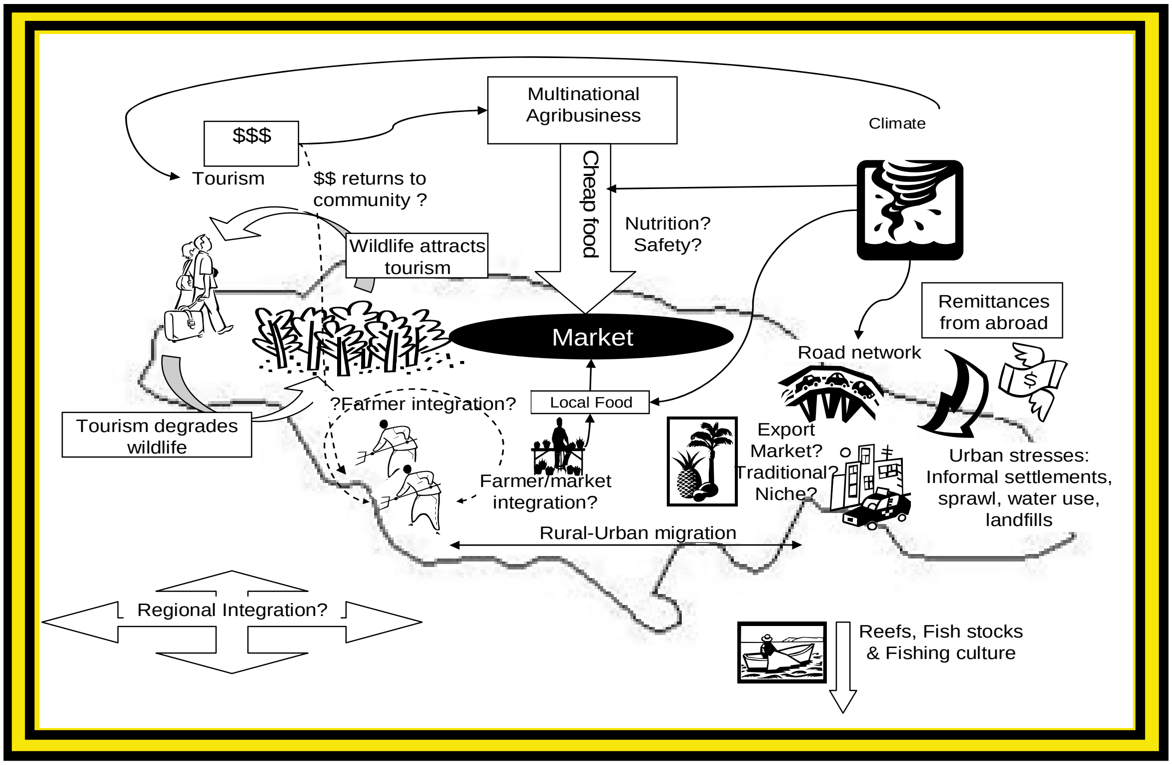

Figure 4-1 *Rich picture* of the key themes of Jamaican food security.

One of the above key issues that lends itself to a potential transformation for decreasing food system vulnerability is the farmer/market integration concern cluster. This cluster includes concern over small farmers' returns from crop sales. The TWOACE conceptualization of the farmer remuneration system is shown in Table 4-1.

Table 4-1 TWOACE characteristics of farmer remuneration system.

Farmer remuneration system	
T ransformation: What input transformed into output?	Farmers receive little share of market price →Farmers greater share of market price
W orldview: What world view makes transformation meaningful?	Domestic agriculture strengthens food security.
O wners: Who could abolish system?	International institutions, Jamaican government, higglers/middlemen
A ctors: Who will perform activities to make transformation happen?	Non-governmental rural development advocacy groups, farmers cooperatives
C ustomers: Who will benefit/suffer from system?	Farmers, citizens of Jamaica
E nvironmental constraints: What constrains the system performing the transformation?	Minimal tariffs on imported food, farmers have little clout, opportunities for farmers to sell directly are limited

Other themes for transformation where the TWOACE analysis method was applied include: tourism returns to community, hurricane destruction on agriculture, value added processing in agriculture, regulation of distribution, coordination of production decisions, improved foreign marketing system.

Often during a TWOACE analysis of a potential transformation, underlying influences surface to an extent where examination must stop so the issue could be deconstructed further. For instance while "improving returns to farmers" was the initial issue distilled from the farmer/market integration cluster, when the contextual environment that constrained this transformation was made explicit, new transformations that would need to occur prior to or in tandem with the examined transformation were revealed. In this case, the lack of remuneration is constrained externally by WTO trade agreements that limit the amount of protect ional tariffs Jamaica can levy on imported goods (often produced by multinational organizations under economies of scale or agricultural subsidization). Increases to remunerations are constrained internally by the low incentive for distributors to pay farmers more. Related to this is lack of clout farmers wield in order to demand more. However farmers are often reluctant to organize. These new concerns now become new key areas for potential transformation to be examined.

The qualitative descriptions were conceptualized by a formal framework to identify a limited number of quantifiable parameters and drivers of interest for the scenario model. The formal framework chosen to organize the scenarios and parameters of interest was developed by the international research group Global Climate Change and Food Systems (GECAFS). This group studies new policy formulation and management methods that could increase food and livelihood security around the world in the face of changing environmental conditions. By studying multiple national and regional food systems, they hope to uncover general trends in how certain structural features of food systems benefit or harm aspects of food security. Inspired by the underlying assumptions of nested systems' emergent properties, the GECAFS framework aims to create food system descriptions that account for the interactions between components at multiple spatial and temporal scales (Ericksen 2006a, 2006b).

This framework assumes that by analyzing the variation that occurs in a specific system's internal interactions and outcomes as it is exposed to different drivers and driver strengths key features that provide systemic strength or weakness under given scenarios can be revealed. This framework divides the areas of interest into activities, drivers, and outcomes and explores interactions between them. Activities refer the tangible structures and actors involved in producing, processing, distributing and consuming of food. Outcomes refer not only to food security but also to effects on social welfare and environmental security and the interactions between these qualities. Interactions between socioecological contextual drivers and activities produce varying conditions of food security in terms of availability, access and utilization.

Patterns in these interactions are revealed by evaluating each food security component: utilization, access, and availability.

Having identified key actors in the Jamaican food system through the soft systems approach it was simple to apply the GECAFS conceptual model and make explicit the activities that affect food security outcomes. The large degree to which these activities occur external to Jamaica is evident (Figure 4-2).

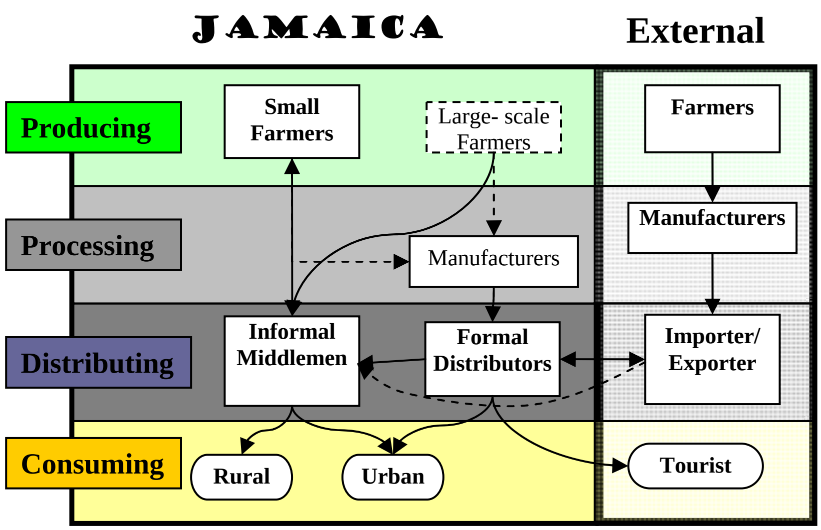

Figure 4-2 Food system activities and actors.

The GECAFS framework builds upon some of the soft system results to bring new insights to the situation. When assessing the interactions of areas of key concern on availability conditions in terms of production, distribution and exchange, key features of the Jamaican system that directly influenced model development were revealed (Table 4-2). It became evident that in Jamaica availability is influenced differently in terms of food type, domestic/imported and population type, rural/urban. This indicates that the food system activities-driver interactions should be explored separately for their effects on the two food and population types in the decision support tool.

Table 4-2 Jamaican food system interactions that affect availability conditions.

Food type	Location of interactions	Rural population	Urban population
Domestic	Production	Water Land Climate shocks Production decisions	Water Land Climate shocks Production decisions
	Distribution	Few	Road Infrastructure Higgler infrastructure
	Exchange	Few	Relative import/domestic prices
Imported	Production	External changes	External changes
	Distribution	Road infrastructure Market infrastructure	Road infrastructure Market infrastructure
	Exchange	Domestic production	Domestic production (to a lesser extent than in rural)

Empirical Review of Conceptual Categories for Model Parameterization

The elements of interaction that were revealed during Phase one were organized following the object oriented approach in which anything that can be conceptualized can be viewed as an object. The concepts in object oriented approaches are nested in hierarchies that capture the multi-scalar nature of reality. QnD:Jamaica was structured by arranging the drivers, activities, and outcomes as descriptive data objects in a hierarchy that reflects five conceptual categories of concern: population typology, land use, food distribution, food pricing, and nutritional consumption (Figures 4-3 and 4-4). The sections that follow discuss these five categories' detailed empirical backgrounds which were used to parameterize QnD:Jamaica.

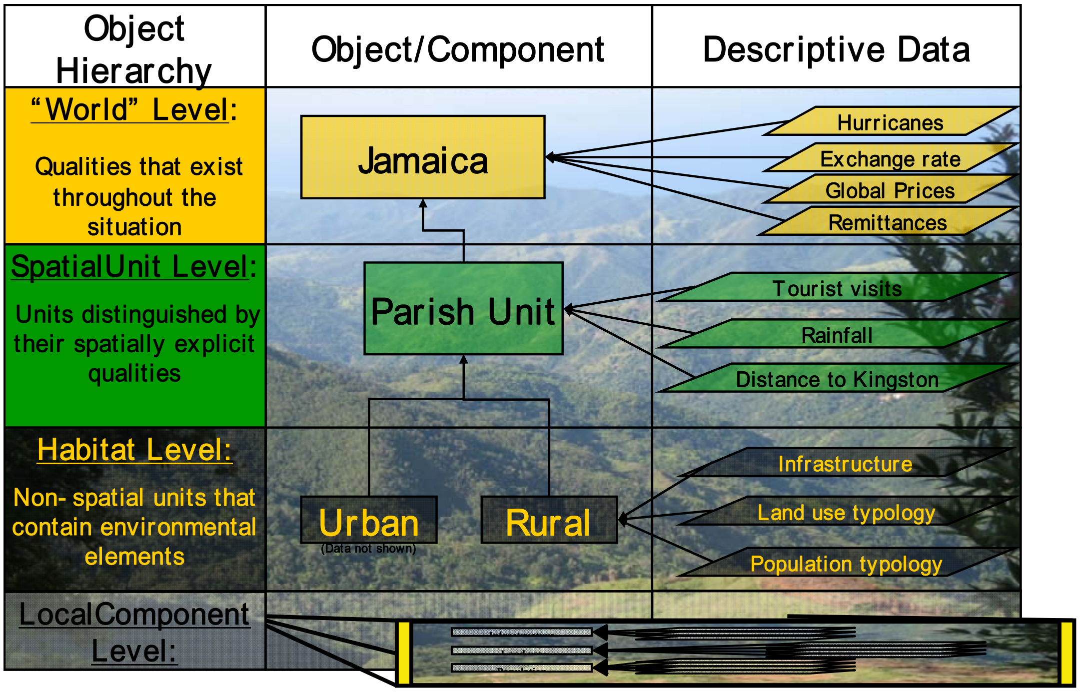

Figure 4-3 Depiction of QnD:Jamaica's hierarchical object oriented structure.

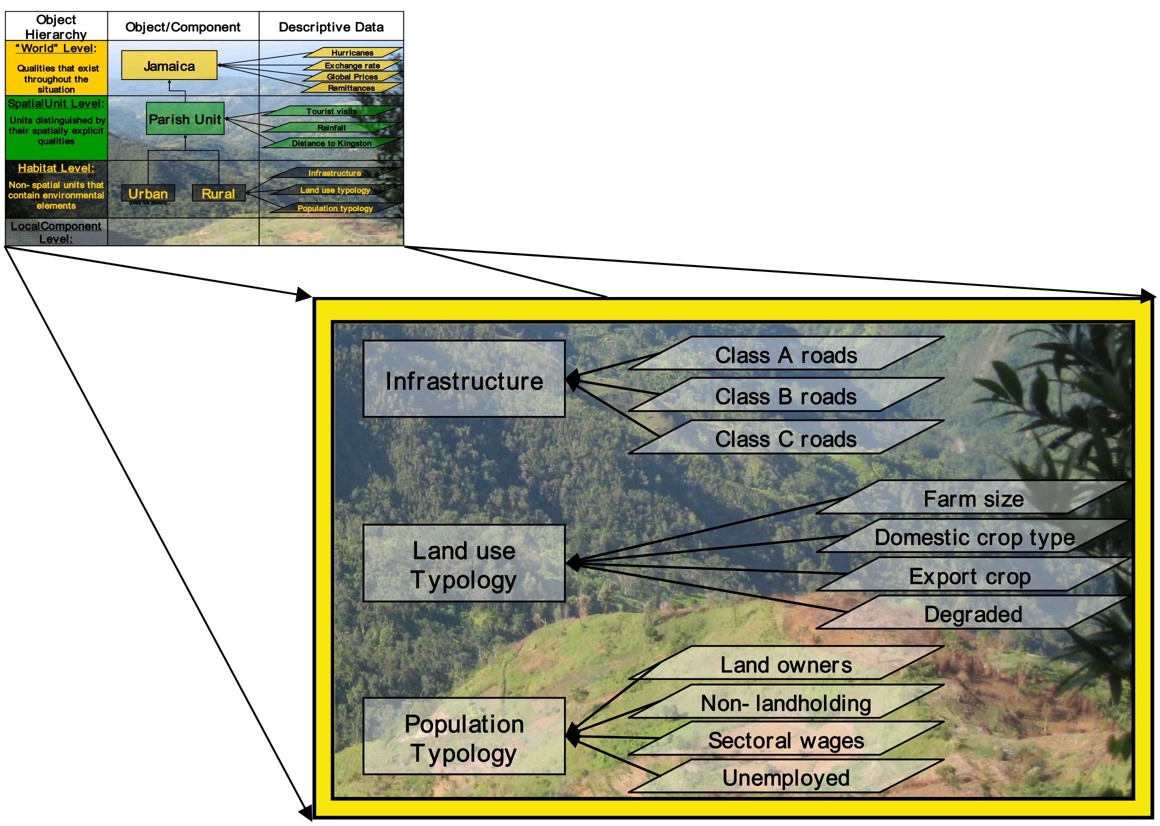

Figure 4-4 Depiction of Local Components descriptive data.

Population Typology

The small farmer communities in Jamaica (and the whole of the Caribbean) possess a unique set of qualities that distinguish them from other small scale agriculturalists around the world. The Caribbean "peasantry" should be understood as a "reconstituted" peasantry (Mintz, 1974) that emerged from an industrial form of production: the plantation. This agricultural structure which was "capitalist and commercial in its economic relations and urban in its value orientations" (Le Franc, 1981, 1) has had a number of implications for the present structure of the Caribbean agriculturalist and rural society as a whole.

Subsistence farming as conventionally defined does not exist in Jamaica. While the small farm often provides direct sustenance to its cultivator, there is always a market orientation even for the smallest farm producing the smallest bit of crops (Spence, 1996). This current production situation is built upon the remnants of the provisional gardens and trade network that originated during the colonial period. While the small scale farming sector supplies a majority of domestic food, the large scale export sector continues to benefit from higher quality land and infrastructure access, fueling an antagonistic tension between the dualistic agricultural sectors (Beckford, 1972; Edwards, 1961).

80% of Jamaican farmers (800,000) work less than 25% of the land (400,000 hectares) on farms less than 5 hectares each. These farmers provide the vast majority of domestically grown food (STATINJA, 1996; Goldsmith, 1981). Additionally, Spence has shown the impressive extent to which small farmers engage not only in domestic market production but also in export orientation (1996, 1999). Not only do small farmers diversify between domestic and export production, but they also expand their income to include a variety of non-farming sources.

Data from the most recent Census of Agriculture corroborates the qualitative expressions of the existence of "baskets" of livelihood strategies employed by small farmers (1996). Figure 4-5 shows the diversification of small farms' primary income sources across parishes.[3]

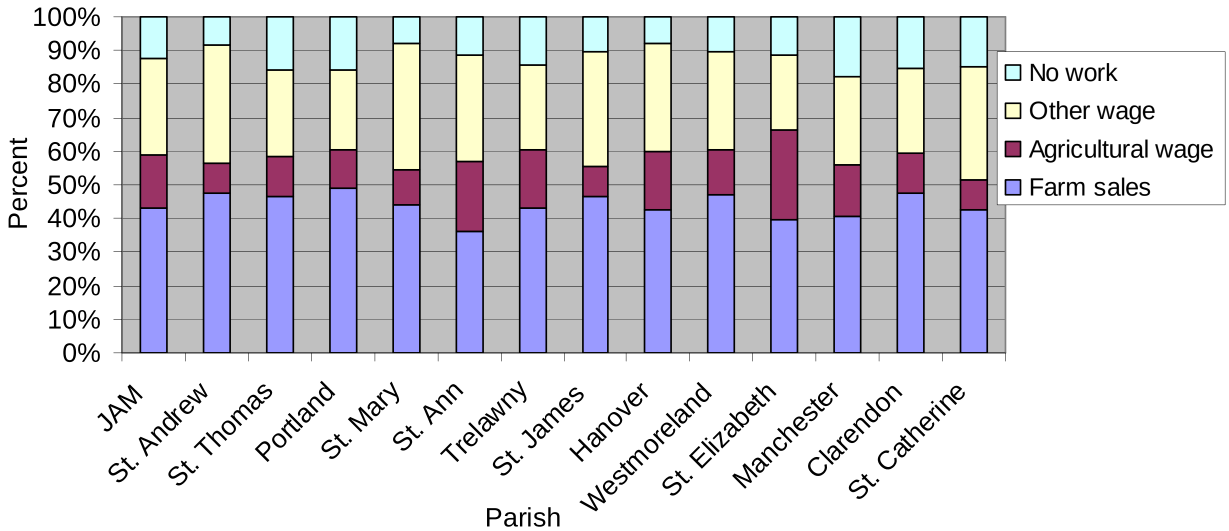

Figure 4-5 Primary income source of small farms by parish. (STATINJA, 1996)

However, this diversification of income strategies appears to be a means to finance the main intended activity of farming (Ishemo et al. 2006). Le Franc explains that this variety of diversification strategies serves as the key starting point for developing a typology for examination of the socioeconomic system:

> "Off farm employment provides much-needed work capital and funds for domestic consumption, particularly during slack periods…because of the need to earn income from a variety of sources, it makes little sense to try to understand the social and economic divisions simply in terms of land ownership. Instead it is only a guide and it is necessary to describe the socio-economic strata and the hierarchy they form in terms of particular combinations of economic pursuits" (1981)

The key reason behind these diversifications is the inability of agricultural sales alone to generate enough income to support a family within the increasingly cash dominated environment

[3] There are also significant differences between income strategies employed by female versus male headed households, i.e. service wage earning females vs. agricultural wage earning males. Only combined sex averages are shown in Figure 4-1.

(LeFranc, 1981). Historically, the free exchange of labor between households was a common practice in Jamaica and bolstered agricultural profit margins. However, the extent that exchange can be utilized has been changing over time and differs across parishes exemplifying the dynamic pressures of the cash economy (Ishemo et al., 2006). Presently, the use of wage labor by small farmers even when sufficient family labor exists on farm is common (LeFranc, 1981; Ishemo et al., 2006). While 76% of surveyed migrant farmers moving from other parishes into the Rio Grande Valley (an area in north eastern Jamaica dominated by both small and large scale export banana production) claimed the use exchange labor prior to their move, 71% explained that they currently relied instead on wage labor (Ishemo et al., 2006). Many farms, however, do not possess the means to transition from exchange labor to wage labor resulting in labor shortages while unemployment persists (Ibid.).

There are differences not only in the types of income diversification available across the island but also in the levels of land ownership within rural populations. Figure 4-6 displays the distribution of rural economic units by their landownership status at the time of the last census (STATINJA, 1996).

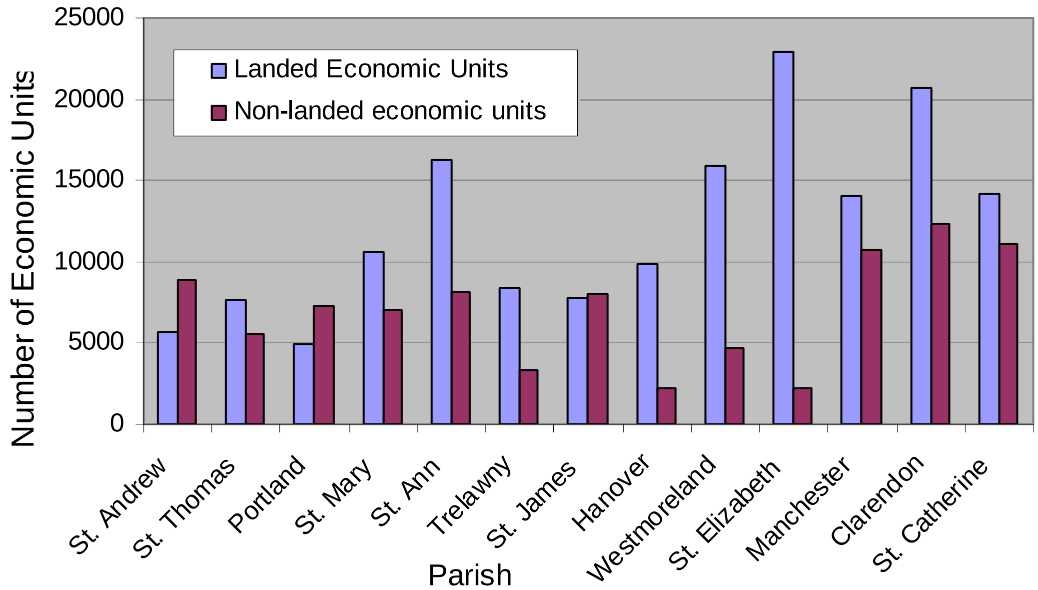

Figure 4-6 Landownership of rural economic units by parish. (STATINJA, 1996)

Land use and Agricultural Productivity

There are a number of grey areas with regard to interpreting survey data on how small farmers utilize their land (Spence, 1996). In particular, the area of land in ruinate or pasture must be interpreted flexibly as farmers often use the term pasture for any areas of grass whether used for livestock or not, and land in ruinate can either be truly in fallow or might be brought into use at any point when needed (Ibid.). An equally slippery slope is the very line drawn between export and domestic crop areas as intercropped food forests are common.

Despite these grey areas, attempts to quantify the export/domestic split on small farms exist (Spence, 1996, 1999; Davis-Morrison and Barker, 1997; STATINJA, 1996). Spence documents an export oriented bias of land allocation among small scale farmers in the parish of Clarendon which he describes as "being representative of the island as a whole" (1996, 133). This corroborates previous descriptions of this bias despite the small scale sector's role in supplying the majority of domestic food (Goldsmith, 1981). Spence attributes the bias, to not only a more favorable export infrastructure but also to the social factors related to the "structural dynamics of small farming" (1996, 133). The first factor includes access to better credit and ensured markets but even more reliable and timely transport and payment aspects. The second influential factor relates to the crop types' labor intensity, environmental needs and level of long term investment/commitment. He cites farmers' age as the single most important factor contributing to land use decisions because of its influence on land accumulation, physical capabilities and level of commitment (1996).

The 1996 Agricultural Census data show that the export bias on small farms does not hold for all parishes (Figure 4-7). St. Elizabeth, St. Ann, Manchester and Trelawny all show a greater proportion of land uses in domestic crop production.

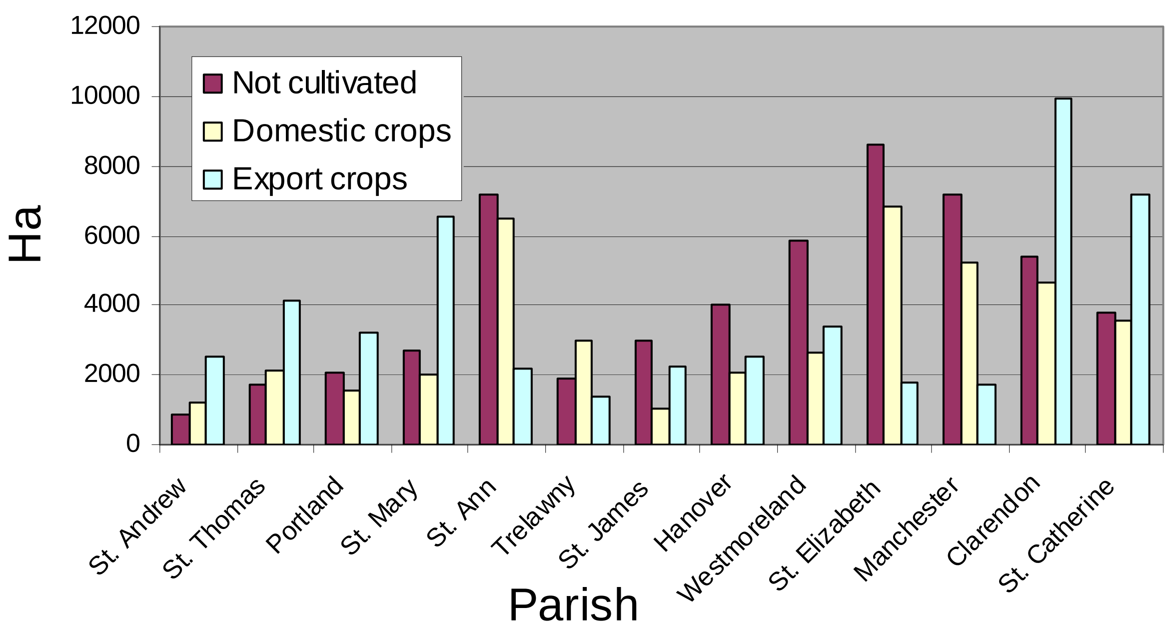

Figure 4-7 Small farm land use in terms of crop type. (STATINJA, 1996)

The extent to which farmers respond to market changes and alter the types or amounts of crops in production varies throughout the literature. A microeconomic modeling study in Mexico showed small scale farmers modifying production in "perverse ways" (Dyer et al. 2006,

279) in response to market price shocks because of interactions with previously unaccounted for social factors.

In Jamaica, opinions about how and why farmers make decisions are diverse. Spence concludes his studies discussed above by explaining that Jamaican farmer's generally respond little to price changes. However, Davis-Morrison and Barker document the dynamic patterns of production shifts on small farms in Portland parish since the 1970s (1997). They describe how the collapse of the export banana market in combination with increased support for domestic crops in the late 1970s and early 1980s led to the dominance of yam cultivation on small farms. However, the heavy destruction of this crop (as well as the bamboo needed to stake the yam vines) during Hurricane Gilbert in combination with an increasing export market for fresh produce caused farmers to turn to dasheen farming in the late 1980s. Alas, an extreme market glut in 1993 caused this market to fall out and farmers switched back to bananas.

Ballayram and Davis suggest that Jamaica's export supply responds to price incentives albeit slowly and at varying rates by crop (2003). They point out that price variability has been high during their study period and that while nominal value has increased significantly, real crop prices have remained stable or declined, likely do to movements in the exchange rate and the general price level. An important insight they provide into the Jamaican producer's logic is their low ability to mitigate risk. Vulnerability encourages non-movement in times of high variability. The newly competitive, and risky, market environment likely served to dampen producers' price responsiveness as compared to guaranteed markets and price the security that existed during the protectionist 1960s and 1970s.

Domestic Food Distribution

Approximately 80% of domestic produce is distributed and marketed by the informal higglering system (LeFranc, 1981). The use of the term 'higglering' for petty trading activity has a uniquely Jamaican origin (Mintz, 1974). Higglers purchase excess supply from small farmers and transport and sell the food staples in various market establishments. There are three types of domestic produce higglers: 1) Higglers who sell only their own produce; 2) Higglers who sell their own as well as others' produce; and 3) Higglers who only buy and sell (FAO, 2003). Most higglers live in rural areas and are located at the lower end of the income spectrum earning an average of less than $J 50 per week in 1977 (Witter, 1988). Today's higglering situation is very similar to the colonial marketing network that developed when Jamaican slaves were required to produce a portion of their food in provisional gardens and allowed to sell any surplus crops[4]. By 1735 the Sunday markets were formally recognized as places where slaves could sell "fresh fish, milk, poultry, and other small stock of all kind" (Mintz and Hall, 1960).

Jamaican producers are generally at the mercy of the higglers in terms of how much they sell, and at what price. Ruijs et al. explain that developing countries' domestic food supply is often price inelastic (at least in the short run) because farmers or traders cannot respond quickly enough due to low storage abilities among other factors (2004). These features challenge traditional economic theory that expects reductions in transport and marketing costs to decrease consumer prices and increase farmer prices leading to increased trade. Similarly, Wong implies that in Jamaica, and other developing countries, the "'laws of supply and demand' might not hold" (1996, 518) due to the inherent nature of the higgler as a petty trader. Like a subsistence farmer, the higgler is trying to maximize highly limited resources.

Estimates range between 25-50% for regular post harvest losses and up to 100% for semi-regular losses (FAO, 2003). Hundreds of kilograms of food rot in the fields during seasonal

[4] The ruling English maintained their tastes for European food and imported the majority of their foodstuffs at high costs. The plantation owners had a large aversion towards putting potential cash crop land into foodstuff production for on island consumption. Thus provisional slave gardens were a way to reduce operating costs. This cultural phenomenon was the original source of the 'consuming appendage' situation that exists today. Since, the islands inception there has been little effort to promote import substitution, excluding M. Manley's early terms.

gluts when prices in nearby urban markets are unrepresentatively high (JSDNP). It is unclear if these situations result from logistical collection obstacles, real lack of market and/or intentionally maintained low supply levels by higglers to earn a greater profit at the expense of farmer's earnings.

The potential of the first explanatory factor is clear upon observation of the egg carton-like cockpit country of the Jamaican interior. Jamaica's parishes are linked by a higher quality, Class A, outer ring road that loops the island and by lesser quality, Class B, roads that link north to south through the hilly interior. Class C roads with limited paving connect isolated communities throughout the rugged countryside to the greater road network. Although the Jamaican road network is extensive, it is in very poor condition. Road quality deteriorates as one progresses further from the main arteries often turning to dirt paths that become impassable in heavy rains. Higglers often charge more to transport crops from areas with poor roads and some exporters will not travel to certain regions due to bad road conditions.

The high dispersal of the small farming sector across this rugged landscape with each farm producing just a small amount for sale has been blamed often for the obvious challenge it poses for would be food distributors (Mintz, 1974; Norton and Symanski, 1975). Katzin relays a typical historical scenario with a higgler traversing across paths accessible only by foot or donkey for a daily collection of nineteen bunches of carrots, twelve scallions, five of beets and five of turnips (1959 in Norton and Symanski, 1975).

Over the past decade the price differentials between domestic goods and subsidized industrially produced foreign foods have driven certain sectors of Jamaican agriculture out of business particularly onions, Irish potatoes, and the dairy industry (FAOSTATS). At present, certain vegetables such as tomatoes, cabbage, and carrots are facing similar price competition.

However, the majority of Jamaica's vegetables are traditional crops such as calalloo and choo choo, which do not face this direct competition. Although, even in these sectors, there is evidence that the prices of traditional crops are being driven down as consumers substitute for cheaper non-traditional vegetables and as preferences shift. Many farmers complain that the low prices of imported foods relative to domestic crops make it less desirable for higglers to collect their produce. Farmers go further to explain that the strength of the underground import market lures farmers out of agriculture and into illegal food importing. Youth express concern explicitly about the troubled marketing system when they explain why they will not pursue farming (JSDNP).

Especially since 2001, when the cell phone market was deregulated,[5] higglers know what the consumer market prices for both domestic and imported foods are and will set their buy prices for farmers accordingly. A MOA official related that higglers will often limit the amount of produce they take to market in order to drive prices up. The fixed handling costs charged by higglers are on a per container basis even though there is no uniform container size and include transport and stall fees but are assumed to be low (Wong, 1996). Additionally, farmers are reluctant to sign contracts with distributors because the farmers expect them to buy outside of the contract in order to force the farmer's price down (FAO, 2003).

Food Marketing

The Jamaican marketing infrastructure consists of modern retail outlets as well as government maintained parochial markets and informal street vendors (Norton and Symanski, 1975). Although modern grocery stores are transforming the retail sector in larger urban areas

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[5] The cell phone has revolutionized both farmers and higglers information access and networking ability (Hourst, Martin 2006). Approximately 2 million Jamaicans have cell phones, that is three per household.

such as Kingston, Mandeville, May Pen, and Montego Bay, traditional markets are still the major source of local foodstuff trade outside of these areas.

Norton and Symanski categorize the traditional parochial markets by the number of higglers present (1975). Small markets usually have less than twenty higglers, while upwards of sixty will be present in a large market. They also show a strong correlation between the size of a community and the extent of its market. They showed that only four of Jamaica's twenty-nine large markets occur in communities with less than two thousand inhabitants. In the same way, only three of the thirty-five small markets are held in places with more than three thousand residents (Ibid.). The markets are often weekly but occur more often in some places depending on supply and demand (Ibid.).

Each parish has one or more centralized markets in its major urban areas in addition to smaller markets throughout. The central markets are more likely to serve as retail and wholesale centers where country higglers bring in food from rural areas and sell to town higglers who will sell in peripheral suburban markets. This is particularly true of the biggest single market, Coronation Market in Kingston, which serves as a hub for distribution to other parishes as well as at least eight other daily urban and suburban markets in Kingston (Norton and Symanski, 1975). Witter estimates that 15,000 higglers serve the Kingston area alone (1988).

Norton and Symanski illustrate Coronation's significance with a survey showing that only fifteen of sixty-four markets nationwide have no higglers with supplies from Kingston's central market (1975). They also list factors that serve to guide development of a nationwide market typology: distance to Coronation market, size and nature of local market, regional specialization and seasonal supply and demand factors. Other parishes also have central wholesale markets that serve the wider countryside, though not on the scale of Coronation. These include Savanna-la-Mar in St. Elizabeth, and Montego Bay in Saint James (Ibid).

Most Jamaican markets occur around the same time usually towards the end of the week making it difficult for higglers to work the national circuit and efficiently disperse supply to spots of higher demand. This often leads to a wide range of prices throughout the country (FAO, 2003). The price differences even between Coronation Market and Kingston's secondary markets such as Papine and Constant Spring are high and there is a thriving town higgler system of buying from one market (even modern supermarkets!) and selling in secondary suburban markets. Coronation Market's size often ensures lower prices, certainly in Kingston and often compared to other parish markets as well.

Imported Food Distribution and Marketing

Many retailers have increased the share of imported to domestically produced foods because of ensured supplies, reduced tariffs and a stable exchange rate (USDA, 2003). Some additional conditions that give US products an advantage in Jamaica include massive product advertisement exposure through increased cable and internet access, and increased demand for ready to eat products which are not manufactured domestically. Both traditional Jamaican food outlets and supermarkets use a middle man distributor to acquire the majority of their imported foods. However, Jamaican grocers are increasingly aligning with international chain stores and product lines to consolidate the distribution and marketing sector both vertically and horizontally, although direct importing by large retailers still contributes only 5% to their total imports (Ibid.). A challenge to realizing the benefits of direct importation is limited storage space therefore retailers are still largely supplied by local distributors.

Recently, grocers have been unable to meet operational costs through sales earnings because prices are so low in part from the highly competitive market (Gordan 2006). Not surprisingly, the Jamaican consumer is highly price responsive and the extreme price competition between retail and wholesale outlets is causing the line between their roles to blur (USDA, 2003). The competition from supermarket chains like HiLo and SuperPlus are leading independent retailers to form alliances and also expand into rural towns to tap new markets (Gordan, 2006).

Wholesalers and informal commercial importers also supply the traditional outlets such as the parochial markets and small grocers with imported foodstuffs. These operate mostly in rural and lower class urban areas but face increased competition from the encroaching larger retailers. This sector is expected to be displaced by chain and independent large scale retailers in the medium to long term (USDA, 2003).

The Jamaican Consumer

Calorie intake is not a complete measure of nutrition. The amount of energy supplied by each macronutrient: carbohydrates, protein, fat etc., has important implications for a population's food security. Dietary choices are not a cold function of cost per calorie. Rather cultural and innate human preferences for variety as well as sugars and fats play a large role in a consumer's food buying strategy. Popkin coined the term 'nutrition transition' to describe the dietary shifts that usually occur along with typical demographic and epidemiological changes in a country's development process (2003). The two main features of the nutrition transition are the reduced role of carbohydrates and the increased role of animal fats in providing caloric energy supply. This increased role of animal fats has important implications for international grain markets and ecological resources world wide. These transitions occur due to a number of factors including urbanization, technological changes, economic growth and cultural shifts.

National caloric availability data does provide insight into present macroeconomic self-sufficiency issues in Jamaica indicating that the amount of imports in the country alone are enough to satisfy annual per capita caloric needs (Ballayram and Henry, 2004). However, it is important to 'unpack' the imported supply as well as domestic foods in terms of what they provide nutritionally and how they are distributed geographically, demographically and temporally throughout Jamaica.

Current data records in Jamaica account for national availability of calories, or Dietary Energy Supply (DES), by food group and imported vs. domestic sourcing, as well as income level food expenditure amounts by food group (FAO, 2003; FAOSTAT; Ballayram and Henry, 2004; Survey of Living Conditions, 2002, 2003). Much Jamaican developmental literature suggests that between 1989 and 1998 the Jamaican diet was comprised mainly of domestic products (MOA, 2001). These documents suggest that only in 1999 did consumption of domestic foods fall below that of imported foods with 269.3kg to 307.3 kg/yr/capita respectively (Ibid.). This data is actually describing only <u>potential</u> intake of domestic foods (availability) and, as described in the 'Transport and Marketing' section, a lot of domestic produce during this period wasted in the fields (JSDNP).

The Survey of Living Conditions (JSLC) household expenditure data provide insight into financial aspects of consumption but because detailed quality and volumes are not surveyed, actual intake changes can be examined. For example the 2003 JSLC reveals that the lower income quintile spent 16.9% of its household food budget on cereals as opposed to 10.3% spent by the upper quintile. Average food expenditures as a percent of total consumption in 2003 are documented at KMA[6]=35%, other towns =40%, and rural=45%. Between 1990 and 1992 the average food expenditures were KMA=50%, other towns =55% and rural=60%. Yet, the qualitative differences such a calorie/J$ or fiber content are hidden and real dietary distribution is

[6] Kingston metropolitan area

masked. The decrease in relative amount spent on food suggests increased food accessibility, but evidence suggests that the types of food purchased have been changing which might have implications for the utilization component of food security.

In 1998 the Caribbean Food and Nutrition Institute (CFNI) revealed that 31.8% of the Jamaican population possesses pre-obesity conditions with 19.7% already obese (1999). In a 1991 survey in Spanish town, Wilks found 30.7% of men and 64.7% of the women to be overweight (1998). Between 1964 and 2000 the share of fat in the total DES increased from 19.9% to 25.9% (FAO, 2003). Carbohydrate percentages dropped from 69% to 62.8% over the same period. This evidence agrees with the expected characteristic of a nutrition transition in developing countries (Popkin, 2003). Likewise, the share of calorie availability from meat products and vegetable oils has greatly increased since 1964 from 175 and 190 to 250 and 400 kcal/capita/day respectively. Prior to 1984 sweeteners did not compose a significant proportion of imported food, in the 1996-1998 period imported sweeteners supplied approximately 18% of DES.

The top five dishes in Jamaica are plain rice, fried chicken, boiled yellow yam, rice and peas and boiled dumplings. In 1989 the contributions to calorie intake by food category were: 45% carbohydrates, 22% animal products, 14% fats and oils, 12% sugar, and 7% legumes. In a Spanish Town study nutrients contribution to DES for males was 57.7% carbohydrates, 13.05% protein, and 30.6% fats. For females it was 59.6% carbohydrates, 13.1& protein, and 30.6% fat (FAO, 2003).

Poor households in many developing countries exercise similar strategies to cope with resource shocks and maintain consumption (Handa and King, 2003). These include informal credit markets and extended sharing networks (international remittances as well as rural to urban links and neighbor to neighbor sharing). In times of strife, traditions of communities reaching out to the least fortunate are varied. Some practice ‘len han’ or lending a hand to those in need (ECLAC, 2004). Handa and King studied the different coping mechanisms between urban and rural households through one of the most common food security indicators: child wasting. Clarke and Howard, indicate increasing investment in Kingston’s slum buildings as a factor that has lessened differences in resilience between in rural and urban communities (2006).

Household consumption surveys are the major source of permanent income data for Jamaica and many countries around the world. In developing countries these surveys often suggest that food expenditures (purchased and home grown) account for over half of the household’s budget. The survey data also indicate a positive relationship between increased income and calorie intake, but at a declining rate as income increases (Alderman, 1986). The calorie-income elasticity for lower income groups was traditionally believed to be high, ranging from .4-.8 indicating a high amount of responsiveness to lower prices or increased income (Ibid.). These findings validate intuitive notions that when one has little of something, and if more of that item becomes accessible, either through decreased price or increased income, one will choose to acquire that item. This led policy makers to adopt poverty reduction strategies of increasing income or regulating prices. However, those approaches failed to view the situation with a wide enough lens. That view is based on the traditional and cursory definitions of food security, that calories are the primary nutrient limiting improved nutrition in developing countries rather than other deficiencies or surpluses that occur from intake of non-staple foods (Levin et al., 1993; Behrman, 1995).

In a study of the reliability of survey data for predicting food expenditures in Kenya and the Philippines, it was shown that the causal relationship between increased income and increased calorie intake is much weaker with elasticity ranging from .2 to even less than .01 (Bouis and Haddad, 1992). They attributed the weak relationship to the nature of the surveying methods which measured availability much more than actual intake.[7] However, Bouis went further to establish a behavioral explanation for the low responsiveness of calorie intake amongst the poor (1996). One would expect a poor person to spend every bit of additional purchasing power (due to price falls or income increases) on staples. However, this assumes away the humanity of that person. Humans are not completely rational and will likely spend a "surprise" windfall on pleasure rather than security. He attributes this to one's inherent humanity. As Timmer has stated, an appropriate food policy model must approach demand behavior of lower income people in terms of their resignation to a state of chronic need (2000). In other words, the utility derived from a certain food over another, or the combined utility of all food consumed is derived from a <u>combination</u> of energy, variety and taste. It appears irrational to purchase a more expensive starch because it tastes better than the cheaper even though there might be a sacrifice in energy intake but this behavior is common in households that have a brief gain in financial resources (Ibid.).

This concept agrees with evidence from Indonesia that a marginal increase in a staple's price will produce a shift to another staple or just an over all decline in consumption. If the relative prices between nutritionally different but similarly taste valued products fall, a consumer will spend any extra income on the item with greater taste value thus sacrificing nutrition. Once

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[7] Bouis also points to a possible phenomenon that could serve to dampen the apparent elasticity of higher income groups while simultaneously over exaggerate the elasticity observed by the lower classes. This phenomenon is the nature of cultural relations during times of strife. During these periods, rich households might actually be purchasing more and transferring these amounts to the poor who are purchasing less. In this case actual calorie intake would be maintained, but it would go unmeasured by traditional methods. This type of informal transfers and sharing are likely common in Jamaica. This also agrees with a common phenomenon, that counter the capitalistic model whereby in times of scarcity, price is actually cheapest as the good is ultimately shared freely rather than profited upon.

a base level of calories is supplied, tastes play a more significant role. In general, in low income households, the marginal utility that can be derived from energy trumps taste, or variety, whereby at middle incomes, variety has the greatest value, and for the highest income brackets taste is the highest priority when making decisions between foods.

This chapter provided a historical context for the Jamaican food system and described the rich picture that was developed from soft systems methods in the field. This was followed by a discussion of how the rich picture was used to reveal five conceptual categories that framed the object oriented structure of QnD:Jamaica. These categories were then reviewed in terms of their available empirical background in order to parameterize the model. The next chapter describes how these categories are explicitly represented in QnD:Jamaica.

CHAPTER 5
JAMAICAN FOOD SYSTEM MODEL DESIGN AND TESTING

Approach

As the simulated food system involves transmission mechanisms that channel shocks through the market, a number of economic models that aim to give insight into consumer demand, producer supply response, and price transfers in developing countries were reviewed (Robinson and Robinson, 1997; Alderman, 1986; Timmer, 1980, 2000; Bouis et al., 1992; Skoufias, 2003; Handa and King, 2003; Rouijs et al., 2004). A general conclusion of critics of the financial strategies pursued by Jamaica and other developing countries during the past three decades has been the persistence of "black box" models to shape developmental policy (Bernanke, 1995). These macroeconomic models often fail to explain why people participate in foreign trade under adverse conditions. A. Walker, in response, presents microeconomic models that claim to look "at the way in which the market is organized, the resulting interaction of participants and the impact that they have on price movements" (2002, 4) in an effort to more thoroughly explain production and consumption behavior in developing countries.

However, as one of the main goals of this type of modeling exercise is to bridge cross-disciplinary and sector communication divides, the level of disciplinary jargon in most of the reviewed models fails to meet QnD:Jamaica's needs. Additionally, neither a wholly macro- nor micro- approach will fit this project's lens of discovery. Finally, there is limited agreement even within the economic development community on the efficacy of these models (Berhrman, 1995; Bouis, 1994; World Bank, 2003).

Empirical, theoretical and qualitative data informed the design of QnD:Jamaica's simulation structures. In designing the processes that simulate the dynamic transfers of food volumes and values, simple mathematical functions were employed to capture the unique production and consumption mechanisms in Jamaica but also highlight generalizable features of these mechanisms across developing countries. In this manner the QnD modeling system could be applied to other national, regional or international socioecological situations/food systems. Therefore the submodels' dynamics are limited to simplified and intuitive understandings of the reviewed theoretical models in the interest of convenient collaborations with stakeholders from varied expertise levels.

QnD:Jamaica is concerned with three flows: food, money and people. The data that describe the representations of these flows is organized in an object oriented hierarchical structure. Simulation occurs on a monthly timestep. The subprocesses of QnD:Jamaica are presented below along with the associated structural assumptions that relate to the empirical review presented in the previous chapter. Additionally, the simulation results of three comparative index categories, productivity, pricing and consumption, are shown against historical data to build confidence in QnD:Jamaica's simulation representations.

Population Typology Representation

The population characteristics as described in chapter four made it difficult to distill a rural typology by only land ownership or income source. Therefore in QnD:Jamaica, each parish's rural population is distinguished by both landownership and major income source. Capturing this level of heterogeneity of the rural demographic landscape is vital for food security and other developmental studies (Dyer et al., 2006). The rural population typology in QnD:Jamaica consists of ten CLocalComponents shown in Table 5-1.

Table 5-1 Rural population typology.

Landowners	NonLandowners
CFarmer	CRuralAgWageEarner
CAgWageEarnerWithLand	CRuralTouristWorker
CRuralTouristWorkerWithLand	CRuralOtherWorker
CRuralOtherWorkerWithLand	CRuralUnemployed
CRuralUnemployedWithLand	CRuralFisher

As the major income source distribution does not vary significantly across small farms of 0-5 hectares, it was assumed that all small farm land owning units in a parish own the same amount of land (STATINJA, 1996).

The urban population typology is simpler than the rural because food security is often closely linked to agricultural activities and land ownership. The urban population consists of two types of wage earners: CUrbanTouristWorkers, CUrbanOtherWorkers. Also included in the urban typology are urban fishers, and urban unemployed. Both rural and urban unemployed have monthly earnings (from the informal sector) these are assumed to be less than the minimum wage.

Urban tourist workers wage is calculated from a PRelationship process with number of tourist per month acting as the independent variable in a negatively sloping linear relationship. This independent variable value is represented as a timeseries driver in the simulation. However, a hurricane occurrence will reduce this value. Urban other workers' wages are calculated by a linear relationship driven by GDP values. The average weekly earnings for a general laborer were J$895 and $J1600 for a tourist worker in 1992 (Planning Institute of Jamaica, 1992).

The understanding of interactions between wages and prices in Jamaica is somewhat muddled (Craigwell, 1991). It is unclear whether a cost-push relationship exists whereby rising wages drive price increases in an inflationary spiral (Bourne, 1977) or if prices are so exogenously determined and labor unions so powerless that workers seek to "catch up" with price inflation (Craigwell, 1991; Downes and McClean, 1982). Craigwell's study of Jamaica's wages and export prices over the period of 1957-1984 revealed the possibility of a positive feedback between wages and prices supporting the inflationary spiral theory (1991). However, similar tests on Barbados and Trinindad and Tobago suggest only uni-directional flow from price to wage (Ibid.). Additionally that study period was largely comprised of a peculiar time in Jamaican history when governmental regulation of wages was high.

In Portland parish, rates as high as 79% of small farmers receive remittances from abroad with 74% of recipients receiving cash on a monthly basis (Ishemo et al., 2006). Some 67% of recipients received less than $J5000 (~$US83) per month and 90% less than $J10000 ($US 166) per month (Ibid.). The ratio or remittances to total income increased throughout the 1990s (World Bank, 2003). All population groups in QnD:Jamaica receive equal remittance amounts. The total remittance value entering Jamaica is a driver inputted as a linearly increasing timeseries file.

Land Use Representation

Land use in QnD:Jamaica is divided first by rural and urban uses (Figure 5-1). Rural land is further distinguished as non-agricultural lands, estate lands: farms >100ha producing mainly permanent export crops, and small farm lands: farms <5ha. Middle size farms between 5-100ha are not included in this model version. Estate lands are further categorized as cultivated and non-cultivated. Major estate crops include bananas, sugar cane and coffee, however, the model groups these types into the one category described as export crops. While small farms are described by the amount under cultivation in four main crop types: root crops, legumes, vegetables and permanent crops, as well as by the amount that is uncultivated. These crop type categories were chosen because they have environmental, economic, nutritional and cultural significance as evidenced by their use in the Agricultural Census, the Jamaican Survey of Living Conditions and the Economic and Social Survey of Jamaica.

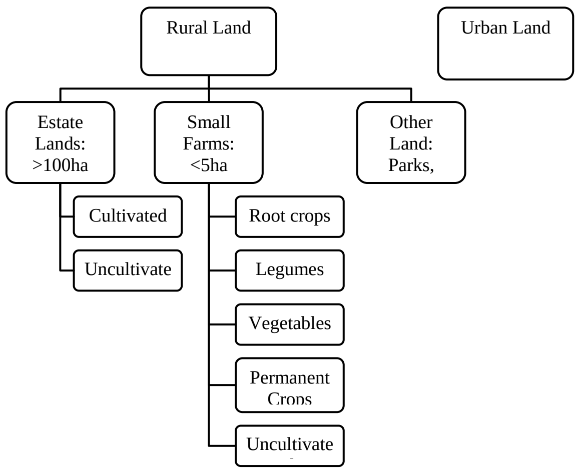

Figure 5-1 Land use structure in QnD:Jamaica.

Despite the various accounts of Jamaican producers' price responsiveness described in the previous chapter, for the short time periods simulated by this model (5-20 years), it is assumed that land uses are not substitutable. That is, land does not switch between cultivation of export crops, food crops, livestock and ruinate. This is in accord with producer response models used for similar market types in other regions (Ruijs et al., 2004). Instead the amount of land in each land use is driven by a timeseries file of trended known changes in area cultivated.[8]

The FAO and MOA estimate slightly different but similarly trended land areas under cultivation in the crop types of concern for 1995-2004 (Figures 5-2 and 5-3).

[8] A supply response function driven by price elasticity could be included in future scenario simulations whereby the total amount of land in production as well as the spread of crop types (domestic v. traditional export, domestic v. non-traditional export) varies. This could also include a degradation factor if land in ruinate is cultivated.

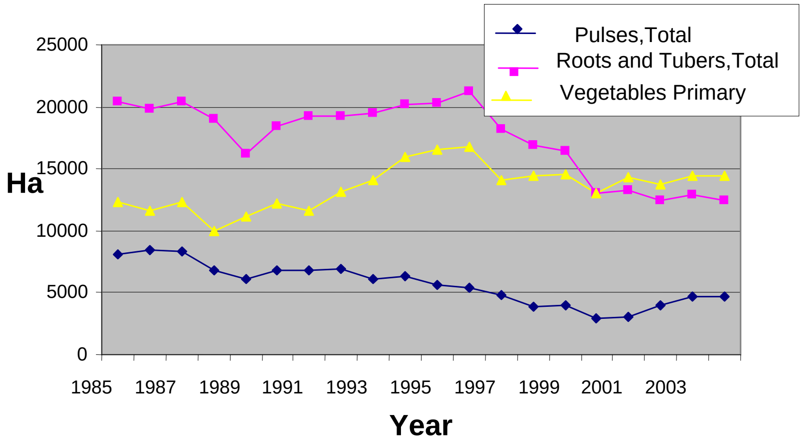

Figure 5-2 FAO cultivated area by crop group. (FAOSTATS)

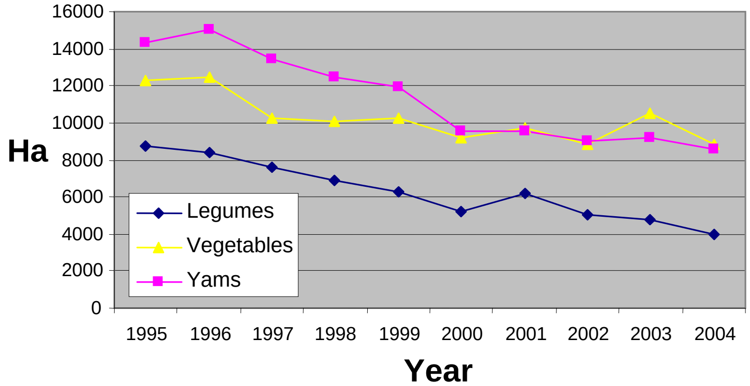

Figure 5-3 MOA cultivated area by crop group. (MOA, 2001)

Each of the three crop types exhibit distinctive trends. Legume area decreased steadily throughout 1986-2001 with a slight increase in recent years. Root crop land exhibited a fairly constant level until 1996, except for sharp decreases in 1988 and 1989 due to Hurricane Gilbert. After 1996, root crop land declined sharply again for two years. It held constant in 1999 and declined again in 2000. Since then it has been fairly steady. Vegetable area was fairly constant until 1991 excluding a decrease in 1988. Like root crop land, vegetable area increased steadily until 1996. Following a sharp decrease in 1997, area has been fairly constant except for a slight decrease in 2000.

The 1996 Agricultural Census facilitated the distillation of national agricultural land areas into proper divisions by crop type on small farms at the parish level. It was assumed that as national areas changed the relative crop type distributions within parishes held constant over the years (i.e. the small farms of St. Ann and Trelawny still produce the majority of the nation's yams). These percentages are shown in Table 5-2.

Table 5-2 Percent of Jamaica's land uses by parish.

	Percent of all cultivated land in Jamaica	Percent of all permanent crop land in Jamaica	Percent of all legume land in Jamaica	Percent of all vegetable land in Jamaica	Percent of all root crop land in Jamaica	Percent of all uncultivated land in Jamaica
St. Andrew	4%	5%	5%	4%	2%	2%
St. Thomas	7%	8%	9%	11%	2%	3%
Portland	5%	7%	1%	2%	3%	4%
St. Mary	9%	13%	2%	7%	4%	5%
St. Ann	9%	4%	10%	19%	16%	13%
Trelawny	5%	3%	2%	2%	16%	4%
St. James	4%	5%	1%	2%	3%	5%
Hanover	5%	5%	3%	3%	7%	7%
Westmoreland	7%	7%	6%	5%	6%	11%
St. Elizabeth	9%	4%	34%	14%	5%	16%
Manchester	8%	4%	12%	11%	13%	13%
Clarendon	16%	20%	10%	11%	14%	10%
St. Catherine	12%	15%	6%	8%	9%	7%

It was originally thought that these distribution percentages could be multiplied by the national total land areas reported by the FAO and MOA to simulate proper parish level distributions while also accounting for the annual changes. However, the areas reported by the FAO and MOA needed to be modified before this distribution could be calculated. The land area data reported by the FAO and the MOA, lowered production in 1988, 1997, 2000, and 2004 appears to be a function of the amount of area harvested-not planted. In fact, each of these years correlates to a major environmental event that decreased production (Hurricane Gilbert, Tropical Storm Marco, drought and Hurricane Ivan respectively). Thus, while productivity appears constant in these years, it, in fact, decreased when the amount of actually harvested land was different than the amount originally planted. Thus, it is unknown how much of the decreased production is due to producers' land use choices prior to planting versus uncontrollable environmental factors post planting. This difference is critical for this study because of the interest in hurricane and flooding damage estimation.

In order to overcome what is believed to be an underestimation of land put into cultivation at the beginning of the season, trend lines were estimated for each crop type's national area.[9] Using this trend line as a driver represents producers' decisions but controls for the highly unknown feedbacks that drive those decisions. The land area values under contention were removed, and the trends for apparent periods were estimated separately (Figure 5-4).

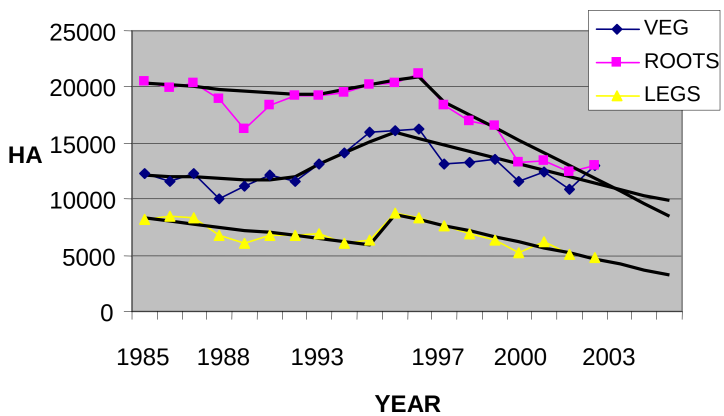

Figure 5-4 Estimated land areas that act as drivers in QnD:Jamaica.

Land use changes on the large plantations occupying the majority of Jamaica's agricultural land would have large economic implications in terms of wage earnings (or small farm earnings if land were distributed as such) (Weiss 1999, 2004b). Changes in these land uses would also have vast effects on the ecology of the island. Like small farms, cultivated land area on estates

[9] In the future, rather than a trend line, land use changes will be tied to market demand and price so that the dynamics could be internalized to the model.

simulated in QnD:Jamaica change through a driver file. This driver file was estimated using known decreases in sugar and banana land areas on large plantations.

Productivity Representation

The crop yield subprocesses in QnD:Jamaica are based on three PRelationship processes with the simulated month and rainfall amount serving as the driving independent variables. The following equation describes domestic crops' monthly yield (tons/ha) calculation and includes maximum yield, productivity, and flood damage coefficients in described in detail below.

Yield=Max monthly yield coefficient X Productivity coefficient X Flood damage factor

Each month is related to a maximum productivity due to seasonal variability. Coefficients for each month's maximum yield (tons/ha) were calculated from known typical annual yields for each crop type. Generally maximum productivity occurs in the early spring months (Table 5-3).

Table 5-3 Maximum monthly yield coefficients (tons/ha)

Month	Vegetables	Root crops	Legumes
J	0.9	1.5	0.15
F	1.0	1.45	0.15
M	1.0	1.45	0.15
A	0.9	1.4	0.15
M	0.9	1.4	0.15
J	0.9	1.35	0.15
J	0.9	1.2	0.15
A	0.9	1.2	0.15
S	0.9	1.25	0.15
O	0.9	1.35	0.15
N	0.9	1.45	0.15
D	0.9	1.5	0.15
Annual Yield	11	16.5	1.8

The Jamaican Meteorological Service possesses 30 year average parish level rainfall records as well as monthly parish level records for 1992-2002. This range of records served to define the time scale of QnD:Jamaica's base scenario. The crop productivity and flood effect generator was calibrated using known rainfall amounts from 1992-1997 including historical drought and flood events, crop yields and welfare effects. Initially the crop productivity coefficient was calculated with a relative rainfall index based on a month's real rainfall amount (mm) divided by that month's thirty year average amount (mm). However, because Jamaica's weather has distinct dry and wet seasons, this method failed to capture decreased productivity caused by abnormal rainfall in previous months of the growing season.

The use of a relative rainfall index based on a four month running rainfall average (as opposed to one) divided by the current month's thirty year rainfall average to determine productivity coefficients proved more appropriate. These productivity coefficients are shown in Table 5-4.

Table 5-4 Productivity coefficients

Vegetables		Roots		Legumes	
Relative rainfall index	Productivity coefficient	Relative rainfall index	Productivity coefficient	Relative rainfall index	Productivity coefficient
<0.5	0.75	<0.5	0.25	<0.5	0.75
0.6	0.9	1.25	1.0	0.6	0.9
0.699999	0.95	1.5	1.5	0.699999	0.95
0.7	1.0	1.75	1.0	0.7	1.0
0.85	1.0	1.75	0.25	0.85	1.0
1.0	1.1			1.0	1.1
1.39999	1.2			1.39999	1.2
1.4	1.5			1.4	1.5
1.74999	1.5			1.74999	1.5
1.75	0.8			1.75	0.8
1.89999	0.8			1.89999	0.8
1.9	1.0			1.9	1.0
10.0	1.0			10.0	1.0

Figure 5-5 graphically depicts vegetables' productivity coefficient PRelationship process shown in Table 5-4 above.

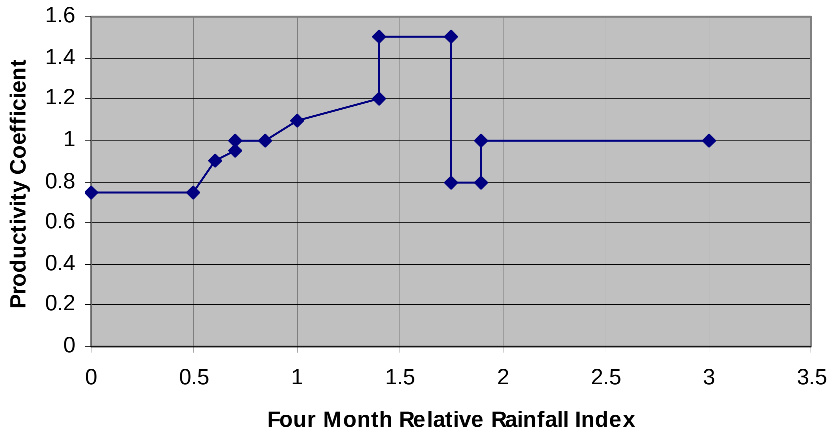

Figure 5-5 Vegetables productivity coefficient relationship

The four month running relative rainfall subprocess captures productivity decreases due to drought. However, in order to simulate sudden shocks such as a massive flood or hurricane, a separate subprocess also tracks one month relative rainfall. Floods in Jamaica are common because of high runoff coefficients across the island, excluding the porous Cockpit country (Nkemdirim, 1979). High runoff levels are principally correlated with: Annual rainfall amounts and seasonality and to a lesser extent slope, drainage density and elevation (Ibid). In mapping flooding hazards, Jamaica's Office of Disaster Preparedness and Emergency Management first mapped landslide risk with three geological and slope characteristics and then associated high flood risk with these areas that were less than 40 m high (CDERA, 2003). Presently, QnD:Jamaica simulates floods based only on rainfall amounts.

If the one month relative rainfall is greater than 3.25, indicating that the month's rainfall was 325% above normal, crop yields are reduced by a flood damage factor of 20%. As mentioned above, topography plays a strong role in flood occurrences. However, in QnD:Jamaica the flood damage trigger (a relative rainfall greater than 3.25) is ubiquitous across all parishes. In reality this trigger would be lower in places prone to flood (low lying areas, poor drainage etc.) and higher in landscapes that can withstand heavier rainfall. This uncaptured variation is likely one reason for the following calibration issue. 1993 and 1996 experienced similarly high monthly rainfall events, yet greater productivity damage was reported in1993. In order to maintain high levels of productivity during 1996 (the year of highest recorded productivities) the flood trigger was set above both 1993 and 1996 monthly relative rainfall.

Productivity Calibration

The food production sub models were calibrated using data from the six year period between 1992 and 1997. The calibration period was chosen because it contained data for drought, floods and normal rains. Monthly parish level rainfall data was only available for the years between 1992 and 2002.

Vegetables

Vegetable productivity between 1992 and 1996 experienced a gradual increase from 9.49 to 12.50 tons/ha. In 1997 there was a sharp decline due to a major drought. The productivity in 1995 was only slightly greater than 1994 but 1996 experienced a large increase due to ideal rainfall conditions. There were two reported tropical storms during this period, Gordan (1994) and Marco (1996). Additionally, floods from heavy rainfall were reported during 1993. .

Only annual historical productivity values were available. Thus, only inter annual productivity could be calibrated. The model's monthly outputs were summed and divided by the respective year's cultivated land area as simulated.

1992 and 1993 produce unrealistically high productivity levels. This is possibly due to increased maximum productivities throughout the time period from other advances made in production techniques such as fertilizers and pest controls. In order to account for the changes in maximum attainable productivity, additional parameters would need to be included in the model. Unrealistically high production levels in 1992 could also be due to lingering drought effects from 1991. Additionally, to reiterate 1993 experienced heavy floods which were not captured in the flood simulator so that the damage from1996 floods could also go unregistered. Productivity in 1994 and 1997 was slightly over estimated, while, productivity in 1996 was slightly underestimated. Simulated production volumes reflect similar levels of accuracy (Figures 5-6, 5-7, 5-8 and 5-9).

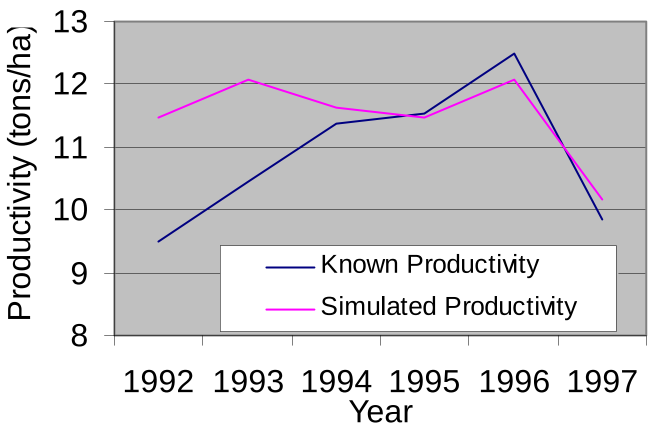

Figure 5-6 Vegetables productivity calibration by date.

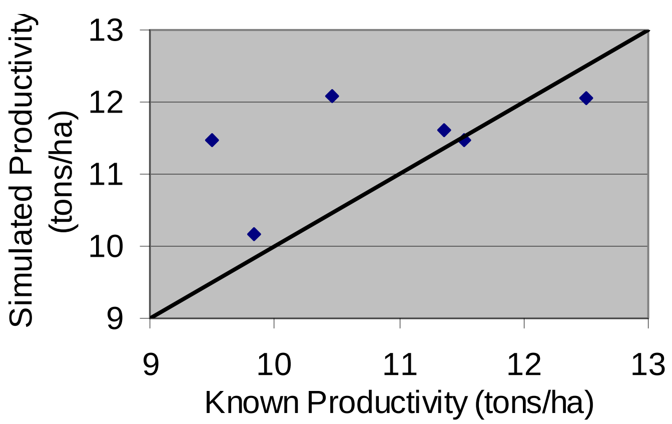

Figure 5-7 Vegetables productivity calibration difference from known.

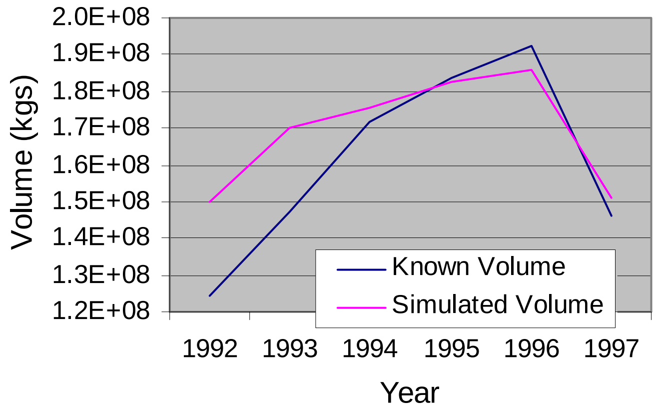

Figure 5-8 Vegetables volume calibration by date.

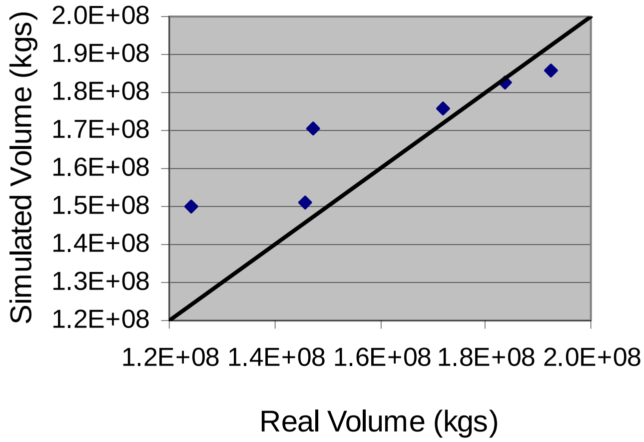

Figure 5-9 Vegetables volume calibration difference from known.

Root crops

Root crops productivity could not be calibrated to as high a level of accuracy as vegetables'. The productivities in 1996 and 1997 were underestimated (Figures 5-10 and 5-11). Despite imprecision in productivity simulation, the root crop volumes reflect a reasonable degree of accuracy (Figures 5-12 and 5-13).

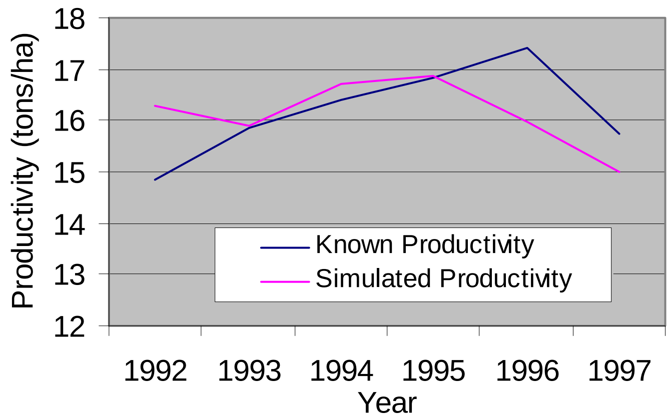

Figure 5-10 Root crops productivity calibration by date.

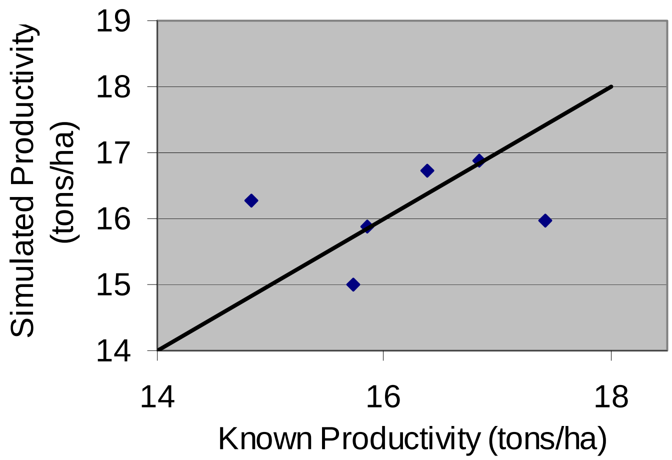

Figure 5-11 Root crops productivity calibration difference from known.

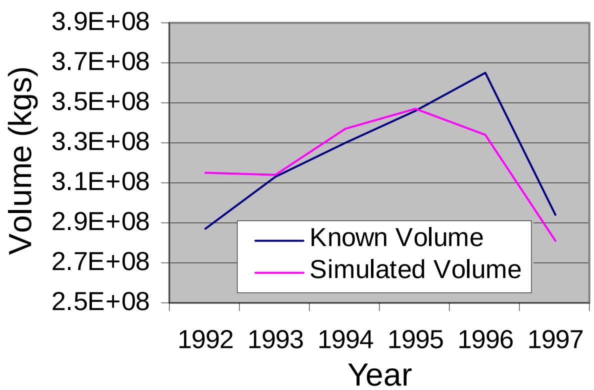

Figure 5-12 Root crops volume calibration by date.

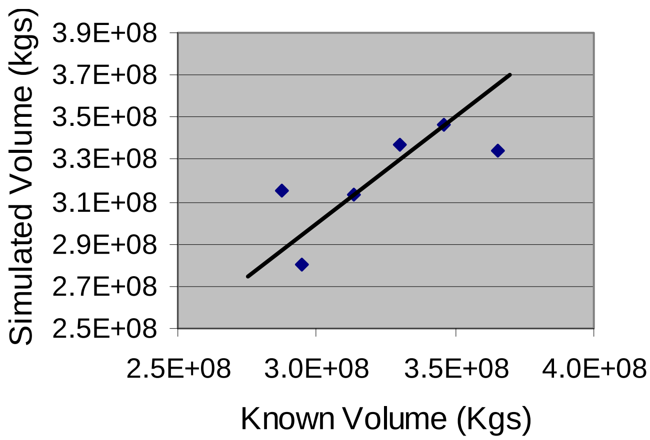

Figure 5-13 Root crops volume calibration difference from known.

Legumes

Legumes productivity values experienced the highest degree of error. Values in 1992-1994 are greatly over estimated, while values in 1996, and to a greater extent 1997, are underestimated. However, the inter-annual changes do show reasonably similar patterns as known changes. Despite productivity in 1997 being grossly underestimated, simulated volume reflects greater precision. (Figures 5-14, 5-15, 5-16, and 5-17).

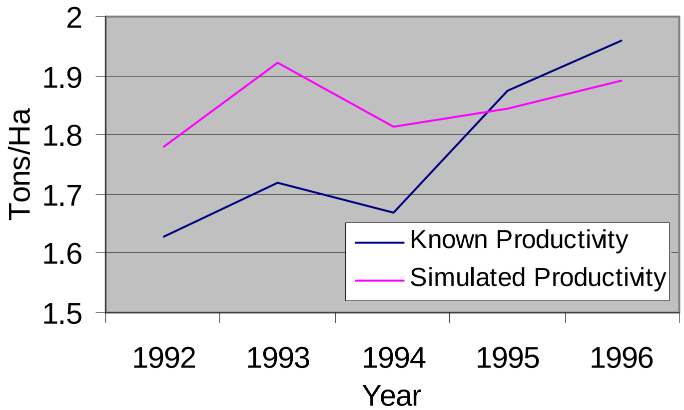

Figure 5-14 Legumes productivity calibration by date.

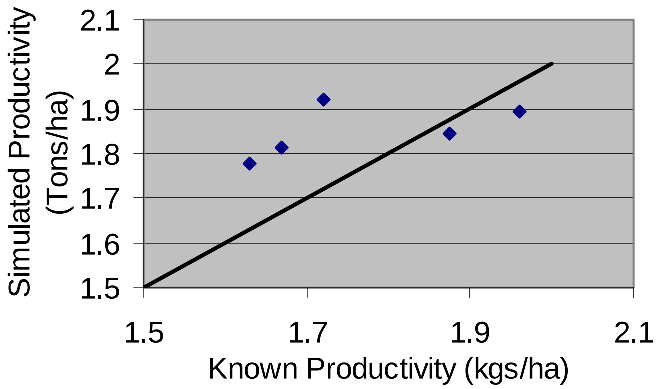

Figure 5-15 Legumes productivity calibration difference from known.

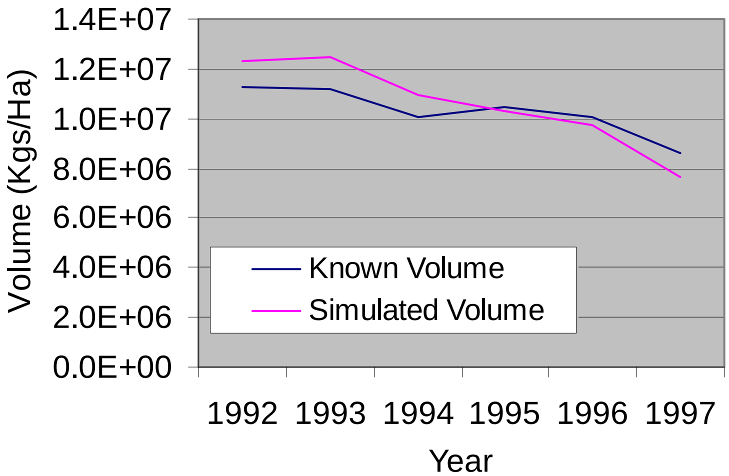

Figure 5-16 Legumes volume calibration by date.

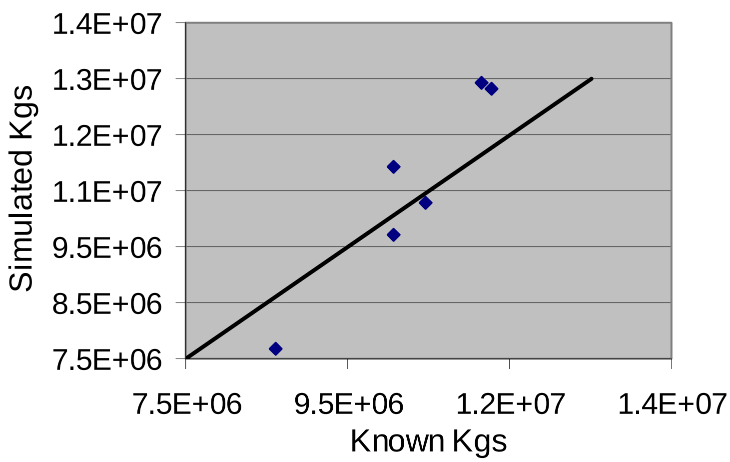

Figure 5-17 Legumes volume calibration difference from known.

Livestock

Although small farmers produce a fair amount of the national livestock, QnD:Jamaica simulates livestock production as a large scale industrialized process. This is a fair representation of the poultry industry in particular. As the vast majority of animal feed is imported, the border price of feedstuffs directly influences domestic livestock production quantities and can be used as a model driver. The strongest relationship between feedstuff price and production volumes was found between real Jamaican dollar values and total volumes. In order to calculate values in real Jamaican dollars, the external feedstuff price is multiplied by the exchange rate and divided by the Consumer Price Index, CPI, both of which are also included are timeseries driver files.

The real J$ value serves as the independent variable in a PRelationship process to generate livestock production volumes (Figure 5-18). Livestock production was calibrated within 10% of real known volumes (Figures 5-19 and 5-20).

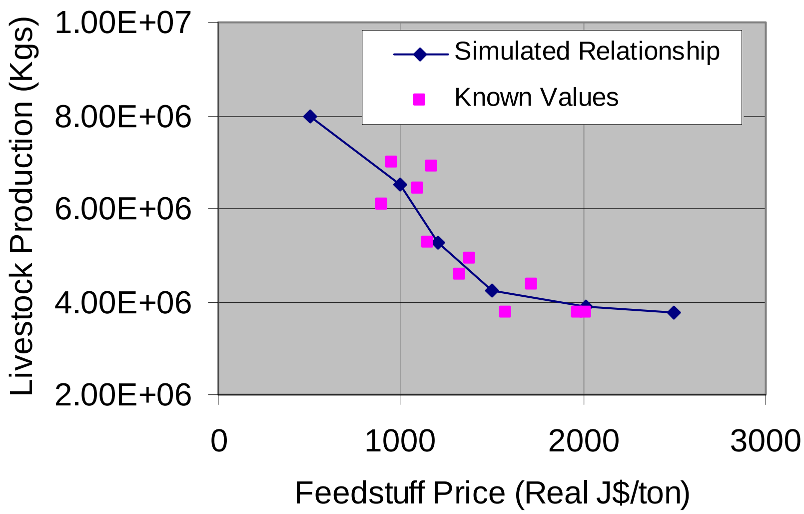

Figure 5-18 Livestock production relationship.

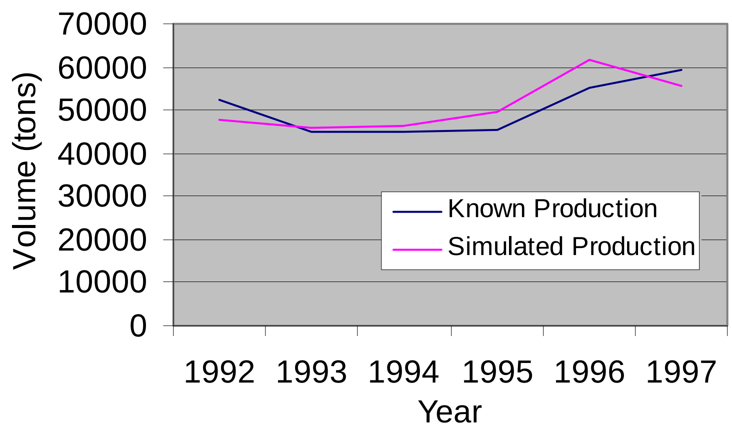

Figure 5-19 Livestock production calibration by date.

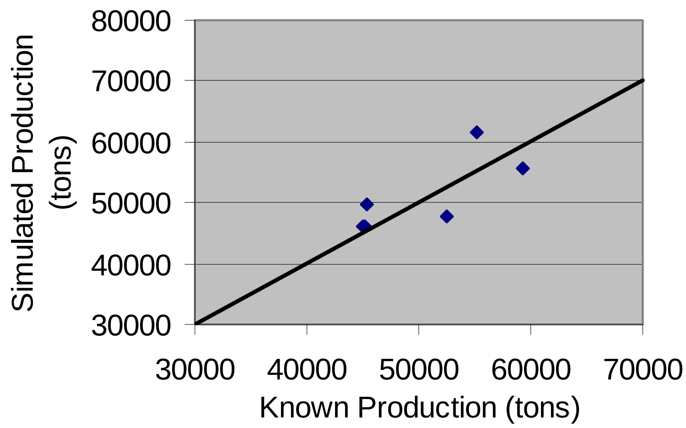

Figure 5-20 Livestock production calibration difference from known.

Testing Productivity Simulations

Vegetables productivity

As in the simulation of vegetable production in 1996, the model was not sensitive enough to produce high levels of productivity in 2001. Productivity was also underestimated in 2000. However, this was likely due to the model being overly sensitive to drought occurrences during that year. In the years 1998 and 1999, poor and good years of productivity respectively, were simulated near historical values. Volume levels reflected similar trends as productivity indicating no strong errors in land area estimation. The inter-annual shifts are also similar to known trends (Figures 5-21, 5-22, 5-23, and 5-24).

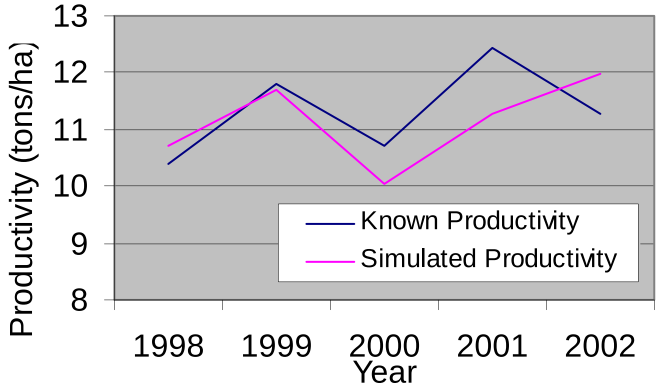

Figure 5-21 Vegetables productivity testing by date.

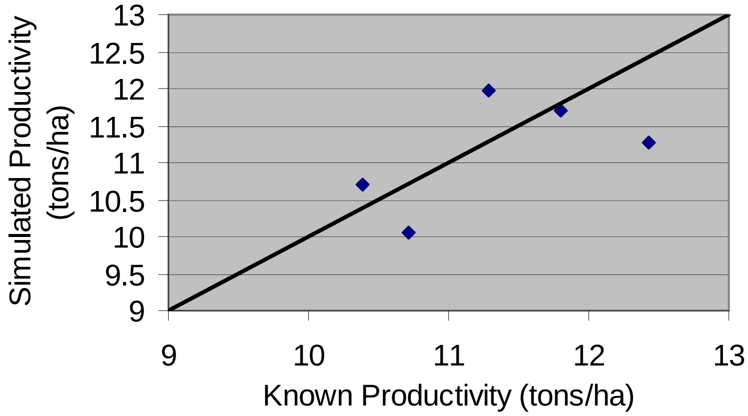

Figure 5-22 Vegetables productivity testing difference from known.

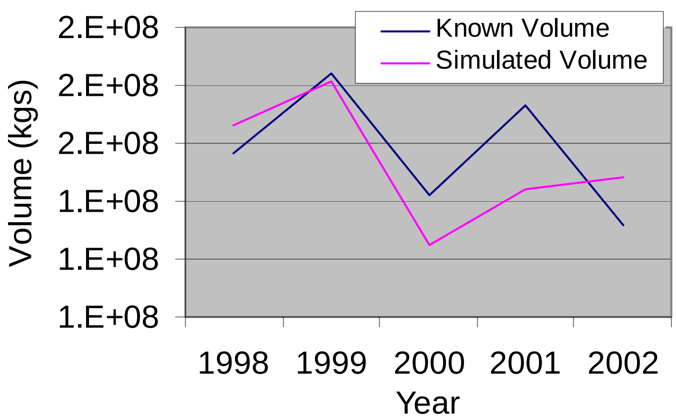

Figure 5-23 Vegetables volume testing by date.

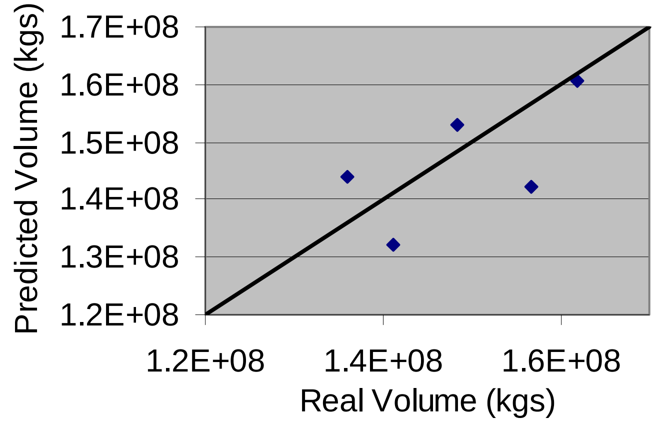

Figure 5-24 Vegetables volume testing difference from known.

Root crops productivity

Root crops productivity was tested with the greatest degree of accuracy out of the crop types. The year 2000 was the only year where productivity was greatly over estimated. Root crop production levels lend themselves more readily to course productivity simulation. This could be due to the nature of root crop production or to the fact that there is less variation within the root crop category as opposed to vegetables which contain a wider variety of species and cultivation techniques (Figures 5-25, 5-26, 5-27, and 5-28).

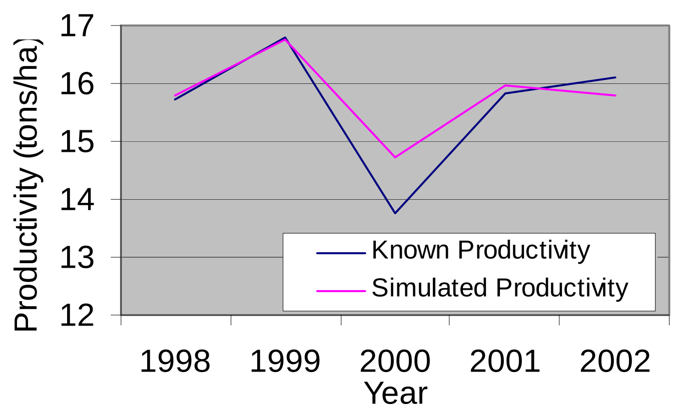

Figure 5-25 Root crops productivity testing by date.

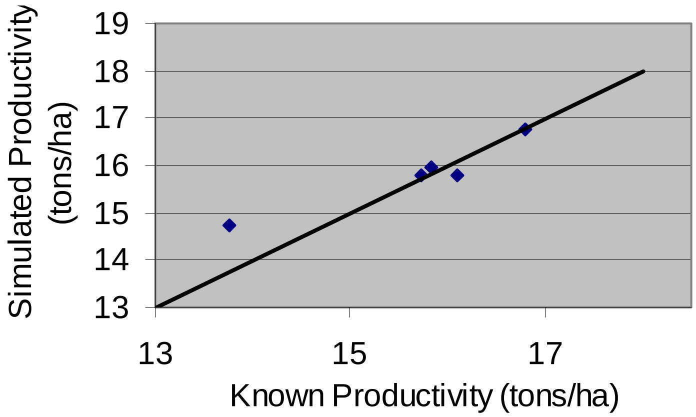

Figure 5-26 Root crops productivity testing difference from known.

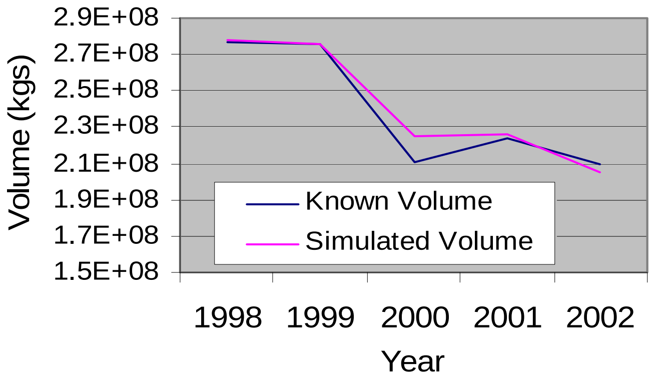

Figure 5-27 Root crops volume testing by date.

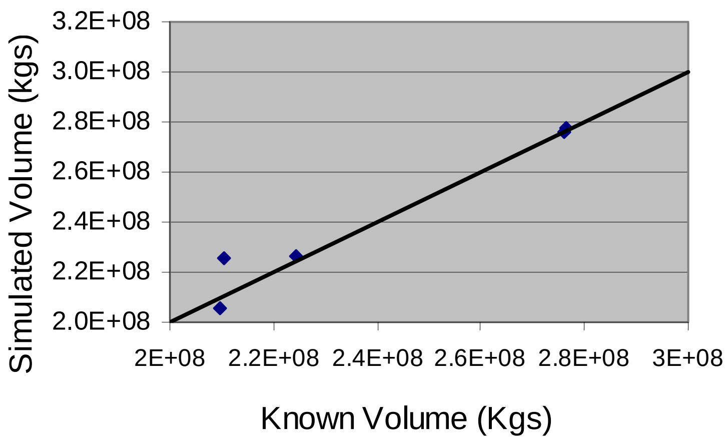

Figure 5-28 Root crops volume testing difference from known.

Legumes productivity

The legumes productivity simulator generated reasonably accurate inter-annual dynamics. Productivity in 2001 was underestimated and in 2002, overestimated. The increase in error between 2002 productivity calculation and volume calculation indicates error in the amount of estimated land in legume cultivation (Figures 5-29, 5-30, and 5-31).

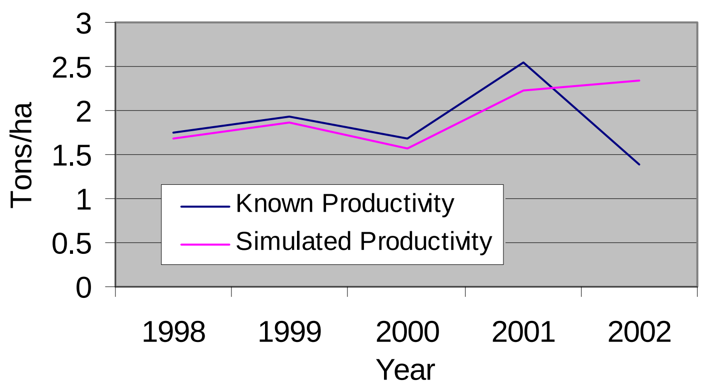

Figure 5-29 Legumes productivity testing by date.

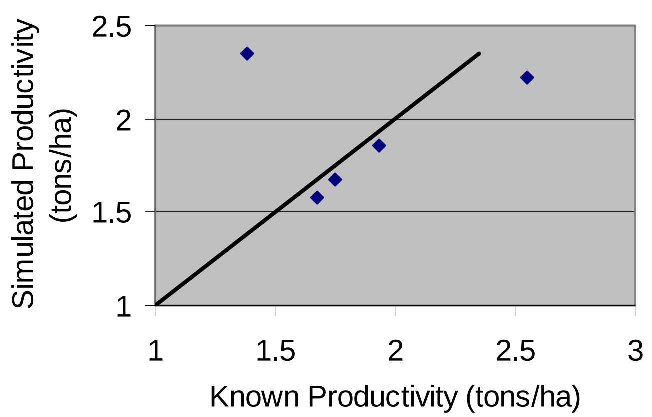

Figure 5-30 Legumes productivity testing difference from known.

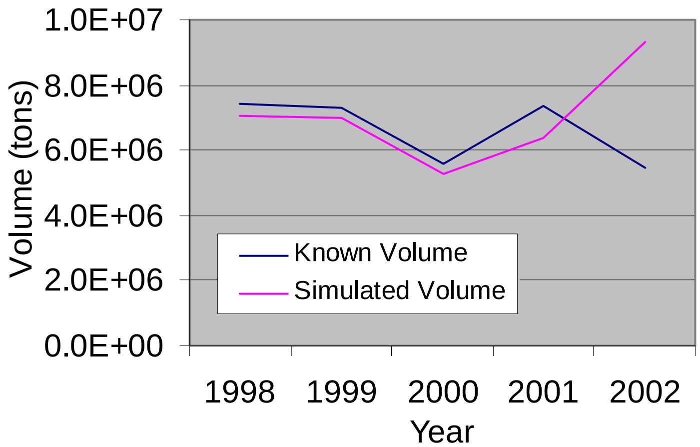

Figure 5-31 Legumes volume testing by date.

Livestock production

The livestock production process greatly underestimated production volume for 2000-2002. This is due to historically high production despite high feed prices (Figures 5-32 and 5-33).

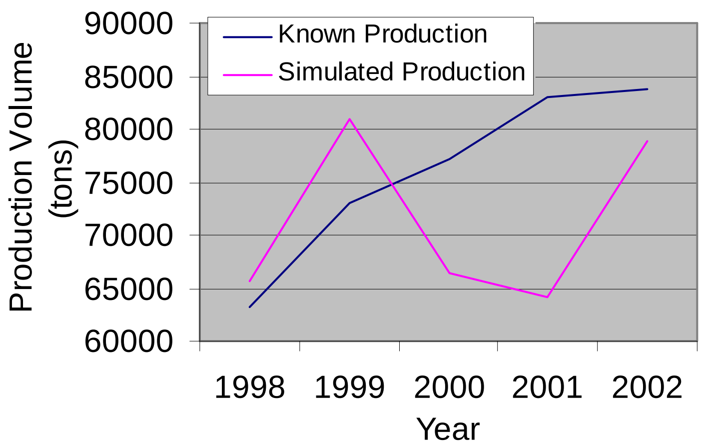

Figure 5-32 Livestock production testing by date.

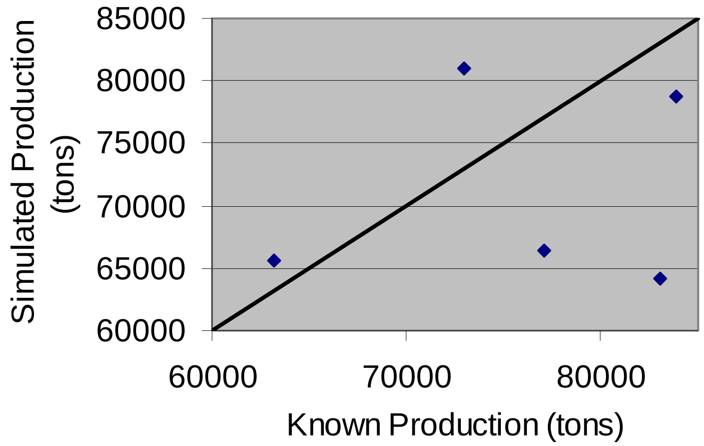

Figure 5-33 Livestock production testing difference from known.

Food Importation

Ideally the amount of food imported would be a result of feed back loops. The driving influences could be the amount of imported product purchased in previous time periods, either the immediately prior period or a running average of demand. Or, the imported food amounts could be driven by the supply present in the current time period. Each method would generate different degrees of responsiveness.

In this version of the model, however, imported food is represented as an unlimited supply. The amount actually purchased is limited by income restraints and imported food's prices relative to substitutable domestic foods (described in greater detail in 'Consumption' section below). In fact, the notion of inexhaustible imported food is fairly representative of the historical simulated period. It will be most important to develop feedback loops for additional scenario simulations beyond this historical period.

Food Distribution and Marketing Representation

The Jamaican food distribution and marketing landscape is understood as a single national system due to the island's small size and the presence of an extensive road network that makes it possible to visit every parish in a single day. However despite these features, Jamaica experiences moderate spatial and temporal price variation as a consequence of parish level supply, demand and infrastructural differences. Temporal shifts result from domestic seasonality and other climatic effects as well as external trade conditions. Spatial price variation is a function of transport and marketing infrastructure differences such as a parish's distance to ports, road conditions and rural population density. The expanding modern distribution and retail sector intertwined with the traditional higgler system present unique challenges to managing Jamaica's food distribution network. The following section discusses how the qualitative systemic structures described in chapter four are represented as specific sub models to simulate prices in QnD:Jamaica.

Representing National Farmgate Prices

Simple linear relationships were estimated using past known production volumes and their associated real farmgate prices within the study period to simulate the mechanisms acting on national real prices. The reviewed evidence in chapter four suggests that parish level prices should be increased above this base national level by factors representing higglers' transportation and marketing costs. The design logic of QnD:Jamaica's pricing processes is discussed below.

Crop pricing

It was assumed that the volumes reported by the MOA and FAO were the total production volumes rather than the actual volumes at market because the volume, productivity, and the amount of land in production agree.

Vegetable prices were simulated with a different process than root crops and legumes for the sake of exploration. While the real prices of vegetables were generated from a PRelationship process with production volume as the independent variable, the real prices of root crops and legumes were generated through a multiple step process in order to capture price elasticity. In those price generation processes, the percent change in the current month's production volume from the running twelve year average production volume served as the independent variable in a PRelationship process. These relationships are shown for the three main domestic crops modeled in QnD:Jamaica (Figures 5-34, 5-35, and 5-36). Nominal prices were calculated by multiplying the real price values by the CPI driver amount.

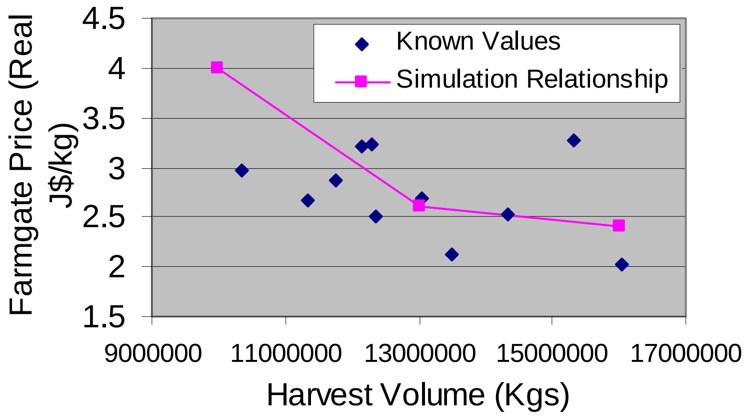

Figure 5-34 National vegetables farmgate price relationship.

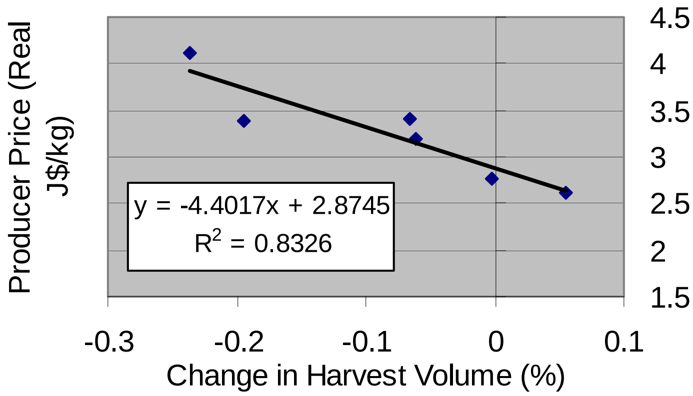

Figure 5-35 National root crops farmgate price relationship.

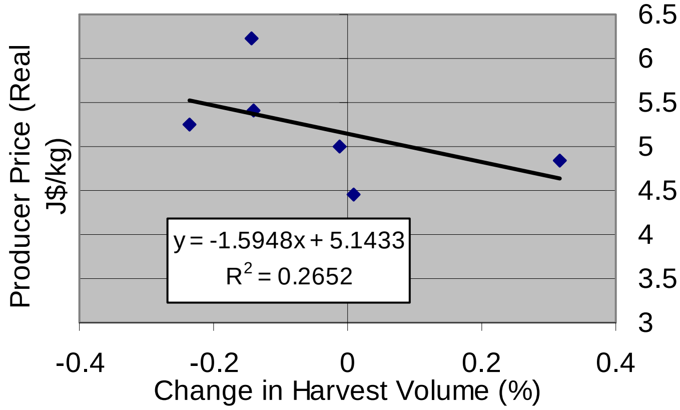

Figure 5-36 National legumes' farmgate price relationship.

Each price relationship function is bound by minimum and maximum values established just outside of the known historical values. The ranges are limited in real J$/kg to 2.5 – 4.2 for root crops, 1.75-3.3 for vegetables, and 4.4-6.3 for legumes.

Crop pricing calibration

Simulated vegetable prices in 1993 and 1995 were consistently lower than known values. As vegetable prices are calculated from a direct relationship with harvest volume, price error is a result of error in the production simulator. Figures 5-37 and 5-38.

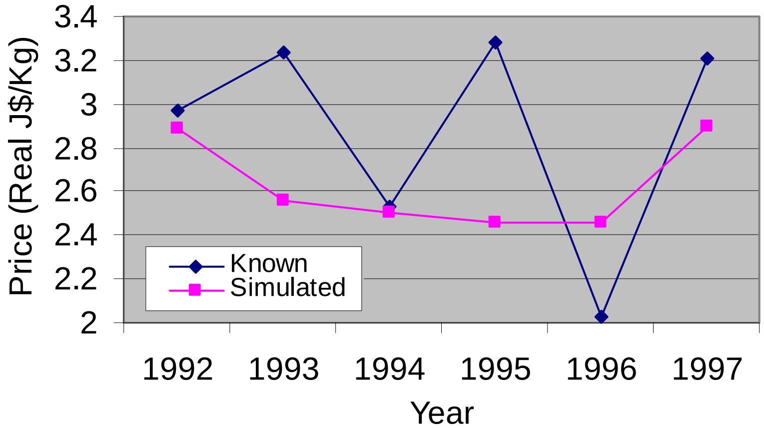

Figure 5-37 Vegetable price calibration by date.

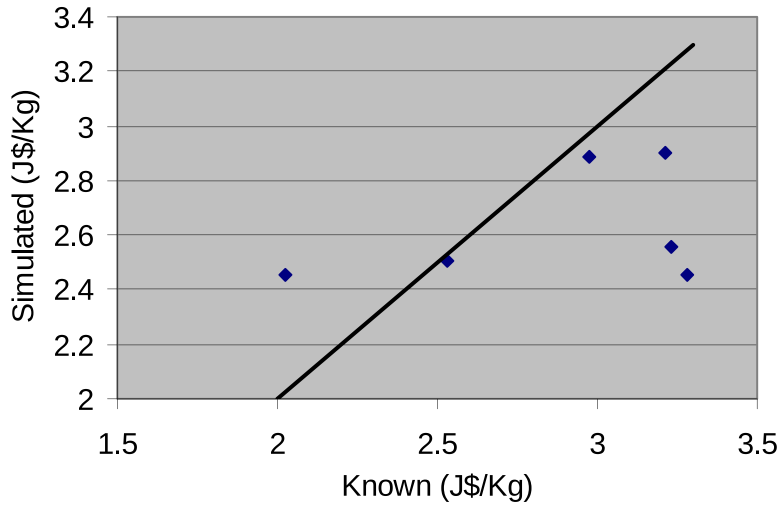

Figure 5-38 Vegetable price calibration difference from known.

Root crops' price simulation experienced a greater degree of error than vegetables price. Using the current subprocess design, high price levels could not be generated without over estimating prices in 1996 and 1997 (Figures 5-39 and 5-40). Simulated inter annual legumes prices were relatively stable (Figures 5-41 and 5-42).

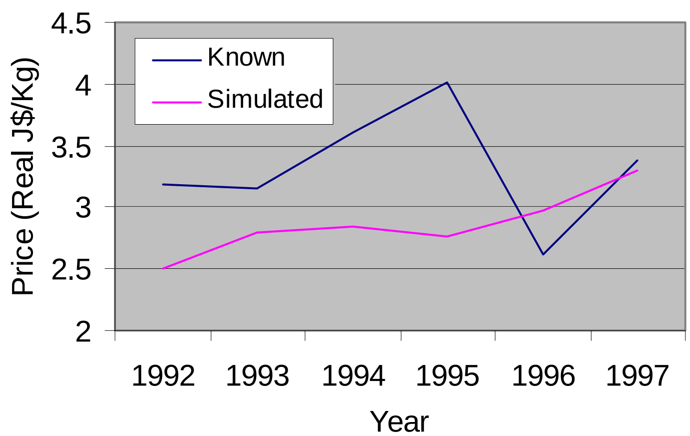

Figure 5-39 Root crops price calibration by date.

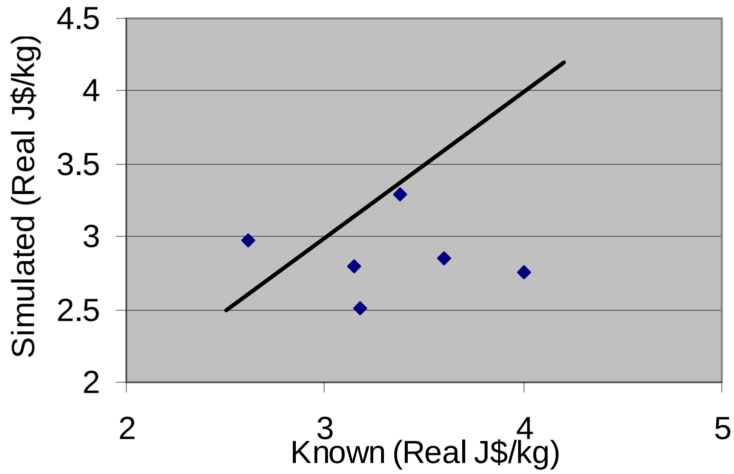

Figure 5-40 Root crops price calibration difference from known.

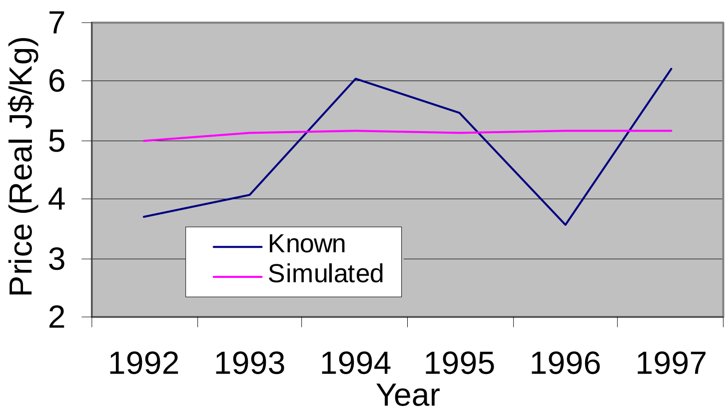

Figure 5-41 Legumes price calibration by date.

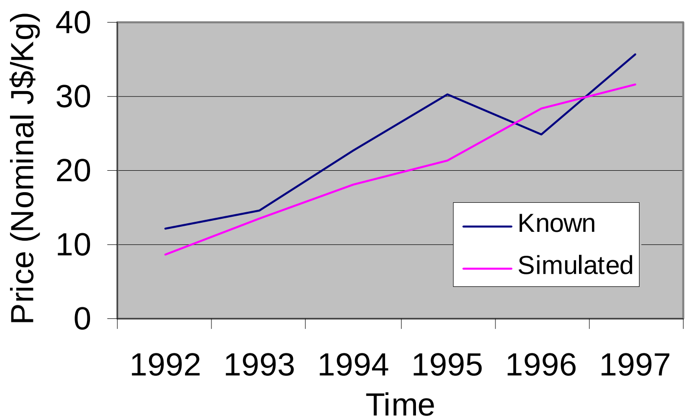

Figure 5-42 Legumes price calibration difference from known.

Livestock pricing

It is easy to distinguish external feedstuff prices as a clear driver for domestic livestock prices. After production volumes are simulated using external feedstuff prices as the independent driver, domestic poultry prices are calculated using a PRelationship process similar to the one employed for vegetables' prices that relates gross volumes to real prices (Figure 5-43). Livestock prices are also bound by limits just beyond the historical range: 4.6-7.3 real J$.

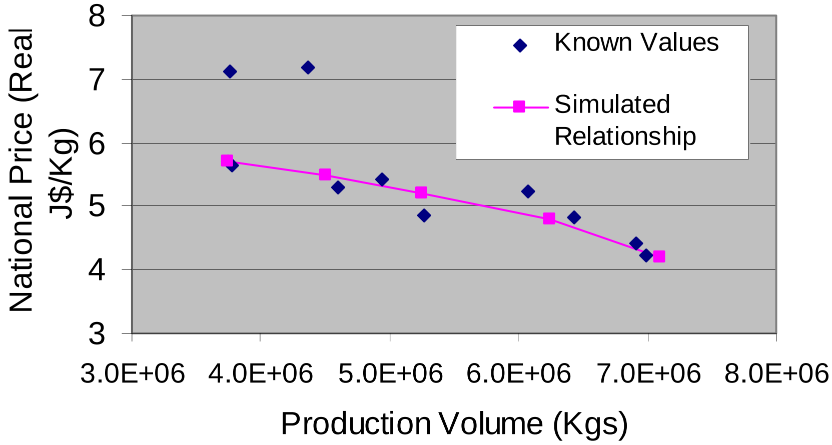

Figure 5-43 National livestock price relationship.

Livestock prices were calibrated within adequate levels for all years except 1992 and 1993. In those first years, prices were much higher than any for the rest of the period, but production levels did not reflect the expected decrease (Figures 5-44 and 5-45).

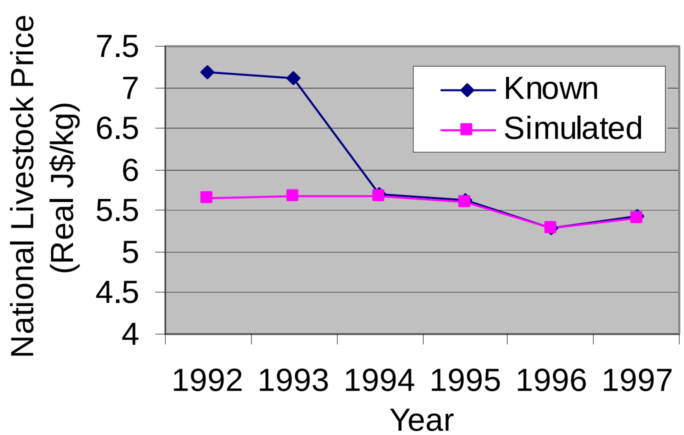

Figure 5-44 Livestock price calibration by date.

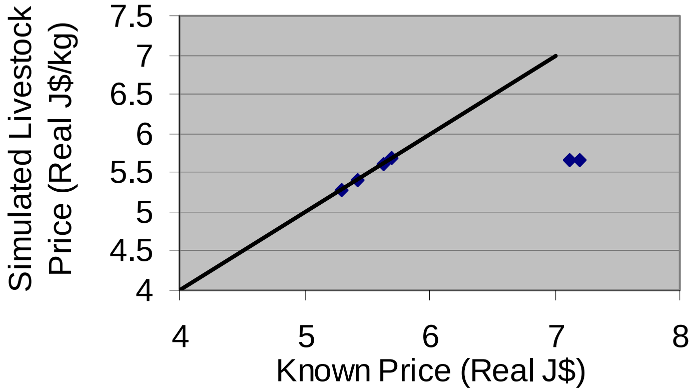

Figure 5-45 Livestock price calibration difference from known.

Price Testing

Average annual vegetable prices were consistently over estimated in the testing period simulations. However, inter-annual simulated dynamics are nearly similar to known changes (Figures 5-46 and 5-47).

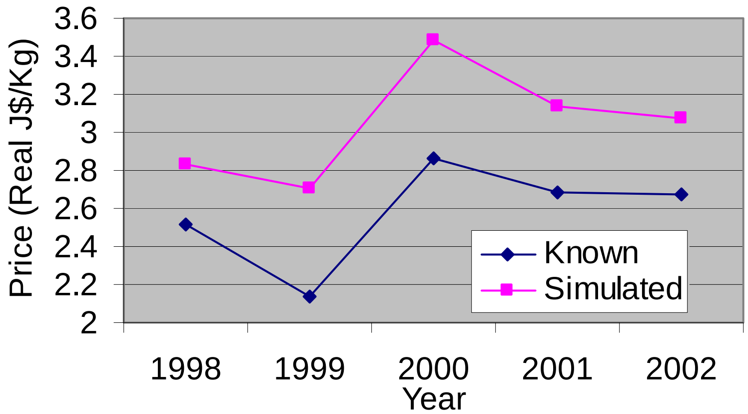

Figure 5-46 Vegetable price testing by date.

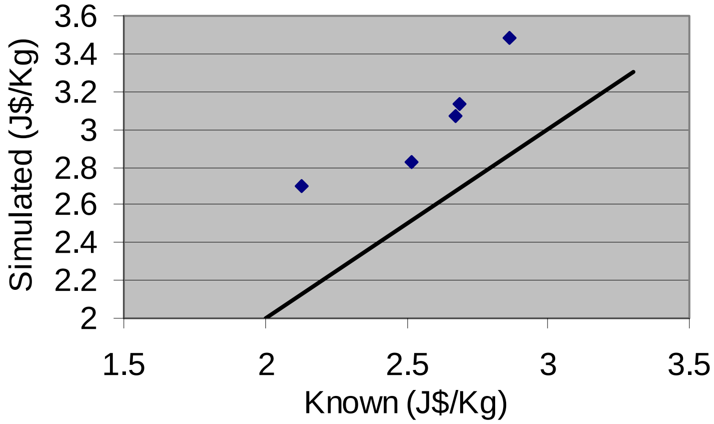

Figure 5-47 Vegetable price testing difference from known.

Figure 5-48 shows the monthly change in simulated nominal prices against the change in the known vegetable consumer price index. Simulated price changes were within reasonable levels; however, they did not display significant similarity to known prices changes. There is some evidence that the monthly price subprocess is moving closer to simulating reasonable prices. For example, QnD:Jamaica captures the large price jump in early 1993 even though it is simulated earlier than it occurred in reality. Also the simulation of the known large decline towards the end of 1993 followed by a degree of stability throughout early 1994 builds confidence in the model. Finally in late 1994, the simulated and known inter-monthly dynamics are similar.

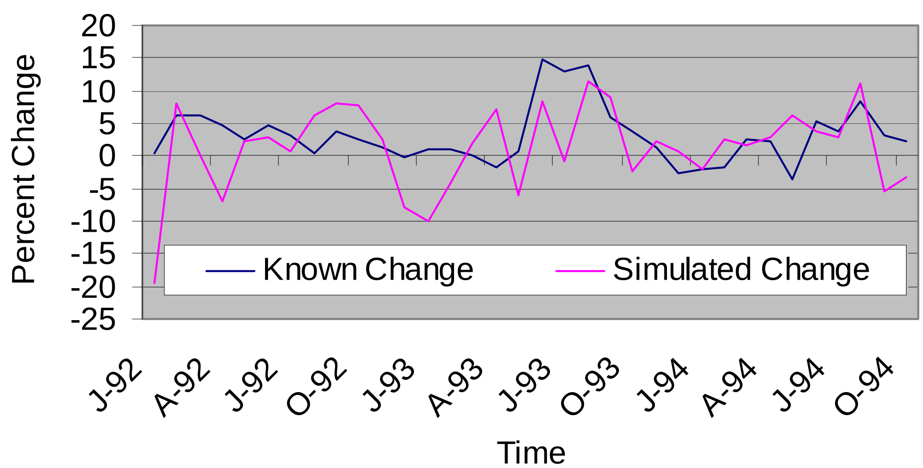

Figure 5-48 Change in known vegetables price index vs. change in simulated nominal vegetables price.

The testing simulation of root crops' prices reflects the model's inability to generate dynamic inter-annual changes for this crop which was revealed during calibration (Figures 5-49 and 5-50). Figure 5-51, however, shows that the model is generating dynamic intra-annual prices in accordance with monthly volume changes.

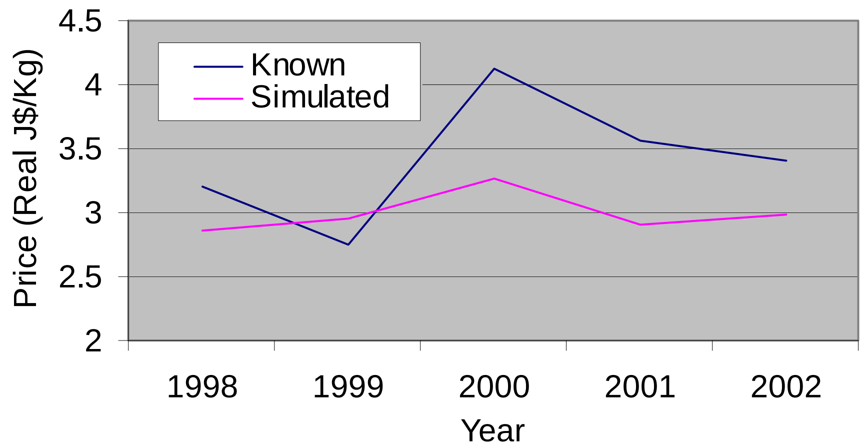

Figure 5-49 Root crops price testing by date.

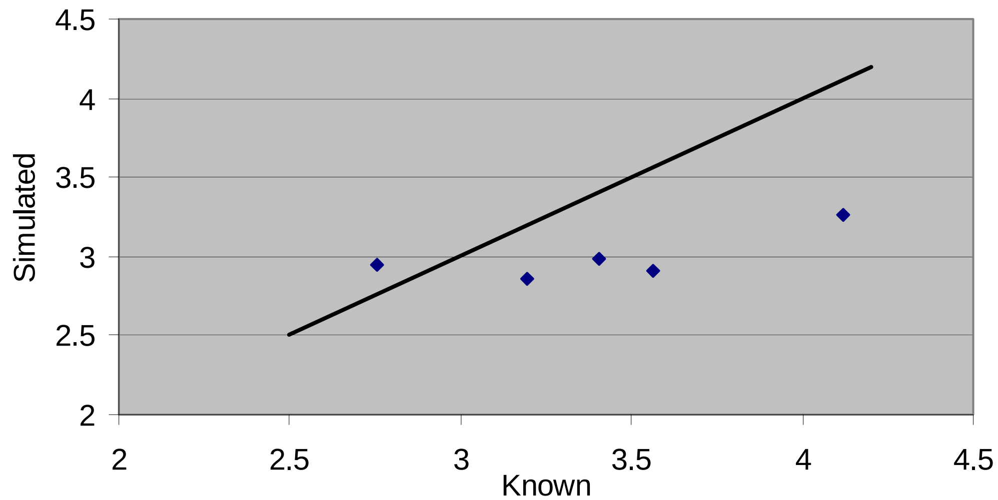

Figure 5-50 Root crops price testing difference from known.

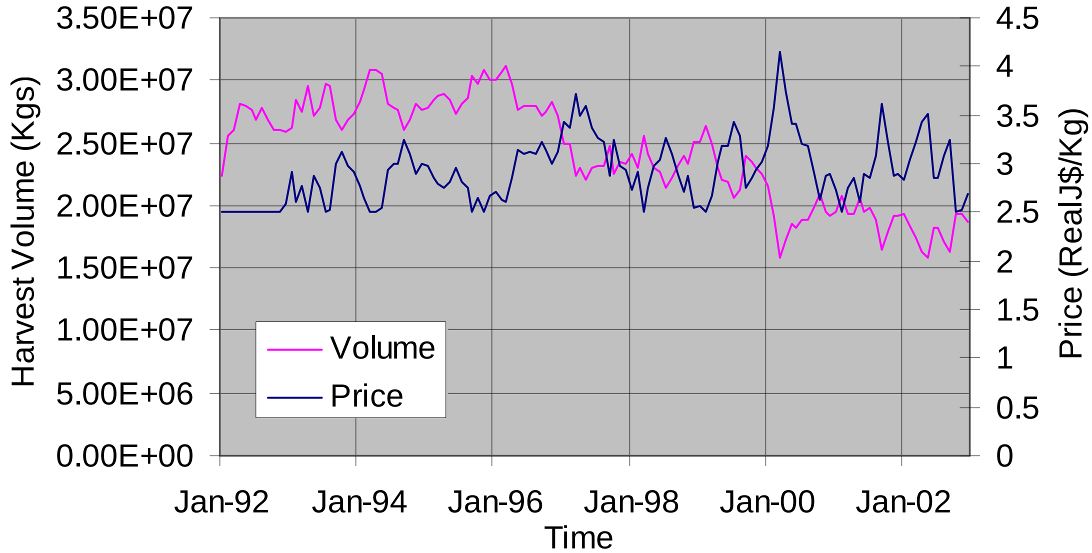

Figure 5-51 Root crops simulated volume and real prices.

Inter-annual legumes prices lack strong inter-annual dynamics as expected from the calibration period simulation (Figure 5-52). Livestock price simulation is generally similar to historic amounts (Figures 5-53 and 5-54).

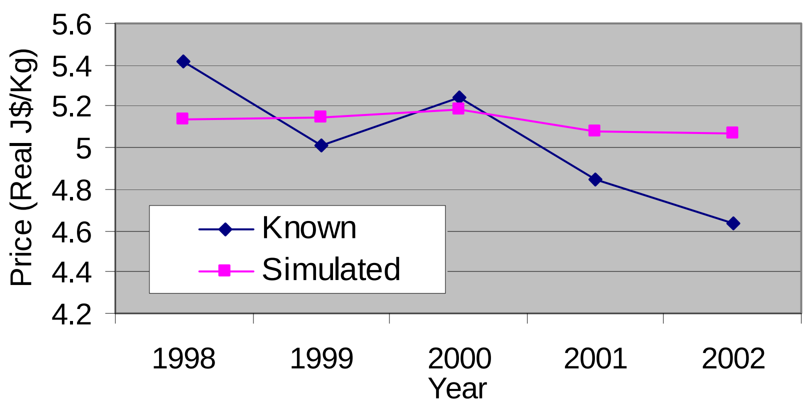

Figure 5-52 Legumes price testing by date.

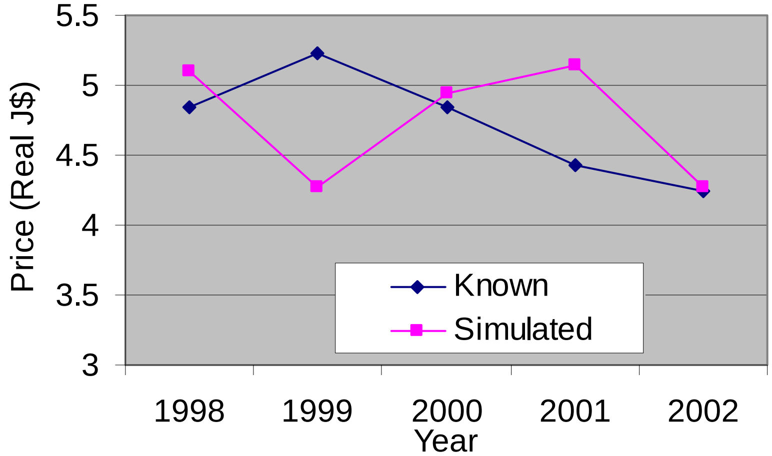

Figure 5-53 Livestock price testing by date.

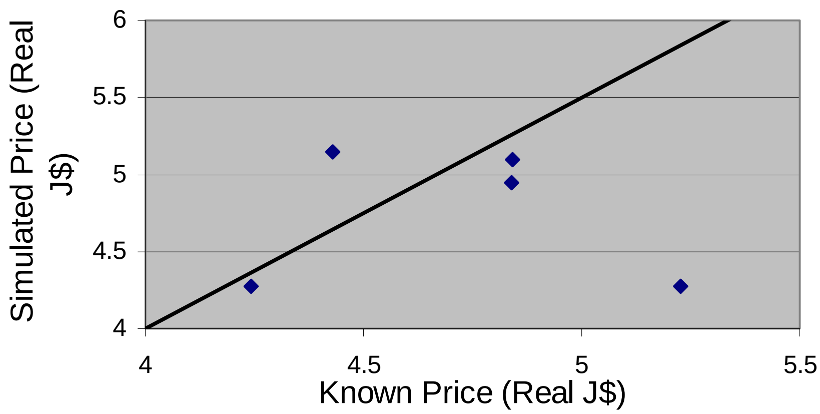

Figure 5-54 Livestock price testing difference from known.

Representing Producer-Higgler Food Transfer Volumes

All land owning population groups harvest their entire available crop of each food type (Root crops, Vegetables, Legumes and Permanent Crops). The total amount, DHarvested*Crop* is added to their D*Crop*Store by the process PMonthlyHarvest. Next the farmer will transfer a certain amount of this store to the DNational*Crop*Quantity. The process simulating the transfer of food into the market is guided by a producer propulation's production level relative to both other producer population's production levels across Jamaica and to the producer population's household consumption demands for the crop under question.

The features that establish the producer populations' food selling relationship process are based on the per capita monthly production amounts within each population group of each parish. The key points of interest are: 1) the average per capita production amount in the parish population with the least production amount, 2) the average national production amount, 3) the midpoint between the average smallest and national average, 4) the average production amount from the population group producing the most per capita, and 5) the largest production amount overall on a per capita basis (Figure 5-55).

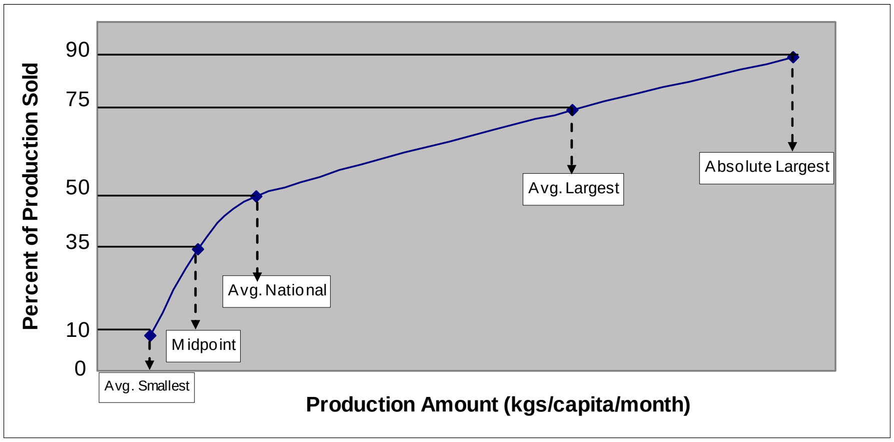

Figure 5-55 Percent of production sold.

It is assumed that producer populations' with the smallest production levels would only sell 10% of their crop because they are producing much less than the consumption demands for that crop. That is to say, they are producing so little it is assumed to be largely for subsistence rather than market. The average national production amount was equated with a 50% sell rate. Along the same lines, those producers growing the largest amount would on average sell 75% of their crop, but never more than 90%.

QnD:Jamaica's crop production simulation outputs were used to determine the values for each of the five points of interest above. The amounts for each crop are shown in Table 5-5.

Table 5-5 Crop sell amount factors (kg/capita/month).

	Average smallest (sell 10%)	Midpoint (sell 35%)	Average national (sell 50%)	Average largest (sell 75%)	Absolute largest (sell 90%)
Root crops	9.0	19.0	28.0	90.0	132.0
Vegetables	6.0	10.5	15.0	27.0	40.0
Legumes	0.18	0.54	0.9	2.19	3.6

Representing Consumer Prices

As discussed in chapter four, the Jamaican food distribution infrastructure often isolates rural communities. This is true not only in terms of collection of their produce, but also in terms of making imported food available to those populations. Thus, just as prices increase for domestic foods as distance from farm increases, so do imported food prices increase with distance from ports and urban centers. Transportation and marketing costs of a given population's food are captured in QnD:Jamaica through index factors that increase food prices above their base national price. Every parish has associated marketing and transport index factors for its rural and urban areas.

The base national price for domestic foods is the nominal farmgate price. The base national price for imported foods is set by a driver file containing external nominal prices in US$/kg. These prices are then multiplied by the exchange rate in that time period to establish the national base price in nominal J$. Tariffs on imported foods have been largely dismantled as required by WTO negotiations. However, higher customs duties are still employed for sixteen fresh vegetables, and certain processed fruits, meats and sugar products reflecting their domestic sensitivity. Under CARICOM agreements, agricultural imports from member countries face zero tariffs. It is assumed in QnD:Jamaica that imported vegetables and poultry are the only foods that experience a border duty. These tariffs are set at 200% and 86% respectively in the base scenario.

Marketing costs

As places with lower demand due to population or income have smaller and less diversified markets, it is safe to assume certain features of parish level marketing costs based on the surrounding demographic features (Norton and Symanski, 1975). The costs associated with rural marketing are based on rural population density while urban marketing costs are based on the existence and size of a central parish market. Likewise, domestic and imported foods are assumed to have different marketing costs because of the differing characteristics of their distribution systems. The DMarketingCostFactor for imported foods in rural areas is based on a linear relationship established by assuming a 50% price markup in areas with the highest rural population density (Saint Andrew/Kingston) and a 200% price markup in areas with the lowest rural population density (Trelawny). Urban imported foods' DMarketingCostFactors were estimated by associating the largest market, Coronation Market (easily accessed by both Saint Catherine and Saint Andrew/Kingston parishes) with a 50% price markup and other parishes containing large markets with 60% price markups. While imported foods' prices in parishes without large urban markets have 75% marketing mark ups. Domestic food in rural areas does not incur a marketing cost and in urban areas it experiences only 1/8 of that area's imported foods marketing cost. The DMarketingCostFactors are shown in Table 5-6.

Table 5-6 Marketing cost factors.

Parish	Rural population density (capita/km²)	Major market	Rural		Urban	
			Domestic foods	Imported foods	Domestic foods	Imported foods
St. Andrew	246.5	Coronation	1.0	1.5	1.06	1.5
St. Thomas	91.7		1.0	1.9	1.09	1.75
Portland	77.6	Port Antonio	1.0	1.9	1.075	1.6
St. Mary	150.2	Ocho Rios	1.0	1.8	1.075	1.6
St. Ann	103.7	Browns Town	1.0	1.9	1.075	1.6
Trelawny	68.1		1.0	2.0	1.09	1.75
St. James	146.1	Montego Bay	1.0	1.8	1.06	1.5
Hanover	138.5		1.0	1.8	1.09	1.75
Westmoreland	132.3	Negril	1.0	1.8	1.075	1.6
St. Elizabeth	104.4	Black River	1.0	1.9	1.08	1.65
Manchester	155.5	Mandeville	1.0	1.8	1.075	1.6
Clarendon	215.5	May Pen	1.0	1.6	1.075	1.6
St. Catherine	115.0	Coronation	1.0	1.9	1.06	1.5

Transport costs

The model developed by Ruijs et al. to examine food transport costs across different regions of Burkina Faso guided QnD:Jamaica's food transport pricing structure (2004). That model estimated graduated per ton per kilometer increases over main highway transport costs of 75% for less busy paved roads, 150% for unpaved roads, and 200% for dirt roads. During the rainy season a further 20% and 60% increase was levied on unpaved and dirt road transport costs respectively. In QnD:Jamaica, estimated food transport distances were established for each parish. Domestically produced foods were assumed to be transported 15 km for both rural and urban markets in all parishes. The distance that imported foods are transported varies by parish according to the average number of kilometers from its closest importing port (Kingston or Montego Bay). Each distance was then multiplied by the fuel cost per kilometer in that time period which is a function of world oil prices. The resulting fuel cost along with the marketing cost associated with each food type in each geographic region is then added to the national farmgate price.

In QnD:Jamaica the quality of road was quantified for each parish by calculating the proportion of Class C road length to total road length.[10] This factor, DTransportInfrastructureIndex, was set to 1.0 for all urban areas as well as the rural Saint Andrew/Kingston area which has the lowest percentage of Class C roads at 52%. A linear relationship was established by associating the parish with the lowest proportion with an index of 1.0 and the highest with 1.1. This index represents a range of zero to ten percent increase in food prices already containing marketing and fuel costs due only to the quality of road in a given parish (Table 5-7). The base index is increased by five to one hundred percent when road quality is temporarily reduced by hurricanes or floods depending on the strength of the natural hazard.

Table 5-7 Transport infrastructure index.

			DTransportInfrastructureIndex	
Parish	Proportion of Class C to total roads	Average distance to import port	Rural	Urban
St. Andrew	0.52	0	1	1.0
St. Thomas	0.82	50	1.1	1.0
Portland	0.61	98	1.03	1.0
St. Mary	0.58	35	1.02	1.0
St. Ann	0.53	60 (Either Port)	1	1.0
Trelawny	0.61	40 (Montego Bay)	1.03	1.0
St. James	0.83	0 (Montego Bay)	1.1	1.0
Hanover	0.60	30 (Montego Bay)	1.03	1.0
Westmoreland	0.64	45	1.04	1.0
St. Elizabeth	0.79	80	1.09	1.0
Manchester	0.72	98	1.07	1.0
Clarendon	0.61	74	1.03	1.0
St. Catherine	0.75	15	1.07	1.0

[10] The Ministry of Transport characterizes 80% of Class C roads as in poor condition. Rural areas are mostly comprised of Class C roads.

The DRoadFloodDamage index is determined with a relationship function that uses the DMonthlyRainfallRatio as the independent variable. The relative rainfall in a given parish is the ratio of that month's total rainfall to the thirty year average rainfall in that month. A ratio of less than 1.3 (30% above average rainfall) does not incur a damage factor. A ratio of 1.3 sets the road damage index at 1.05. The index increases linearly until the relative rainfall is 3.0 (300% above average rainfall, indicating a major flood) at which point the damage index is 1.1. If the relative rainfall is 4.0 the associated damage index is 1.5. The flood damage index is multiplied by the infrastructure index. In this way floods in areas where the roads are already of poor quality (as represented by a high transport infrastructure index) compound the already high transportation costs.

Jamaican Consumer Representation

Both economic and nutritional limitations guide the food purchase process logic in QnD:Jamaica. Nutritional demands are set by typical dietary intakes as represented in five major food groups. Budget limitations are guided by historical household expenditure data. Additionally, substitutability due to price or cultural preferences structures the food purchase process.

It is a fair assumption that perceived value, rather than brand recognition or domestic loyalty, is the most important decision in Jamaican consumers food buying decisions especially for the lower income groups (USDA, 2003; Timmer, 2000). Thus dietary outcomes in Jamaica are foremost a function of food prices relative to income. However, other preferences are important as well as the increasing role these preferences have in higher income echelons.

In the case of carbohydrates, the traditional domestic starch, the yam, is actually in competition with cereals, rice, and potatoes for the staple food "slot" in the Jamaican diet. Rice has long been a staple of Jamaican food culture although it has always been largely imported.

Imported cereals and potatoes, on the other hand, have only recently become staples in the Jamaican diet and their volume per capita has been on the rise.

These foods are usually imported as refined wheat and corn flours, and processed bread and pasta products for the cereal group and as frozen potatoes used largely for French fries. All of these imported products generally have much lower nutritional values than domestic yams. Thus, the competition that yams face from cereals and potatoes has major implications for the Jamaican diet in terms of nutritional characteristics and cultural value not to mention the Jamaican small farmer.

Because of these nutritional effects incurred from the price competition between different products in similar roles, all dietary choices were simplified into five food group categories: carbohydrates, vegetables, legumes, meat and fish. The average Jamaican diet is composed of a spread of the five categories, each of which can be satisfied by two different but substitutable food types distinguished by location of origin (domestic or imported) and nutritional qualities. By setting minimum required/desired amounts for each food category within the total food basket, it is ensured that the price line is not the only factor that influences consumer decisions.

At this stage in the simulation each population group has earned an income represented as their DPrePurchaseWealthStore and they are ready use this store to purchase food. The food types that can be purchased are:

- Carbohydrates: CRootCrops, CImportedStaples
- Vegetables: CVegetables, CImportedVegetables
- Legumes: CLegumes, CImportedLegumes
- Animal Meat: CLivestock, CImportedAnimalMeat
- Fish: CFish

The base preferential consumption basket in terms of number of servings per food group is shown in Table 5-8. The qualities of each serving are described in Table 5-9.

Table 5-8 Base preferential consumption basket.

Base preferential basket by food groups	Staple carbohydrates 7 servings	Vegetables 4 servings	Meat 2 servings	Legumes 1 serving
Calories/domestic daily serving	700	120	538	60
Calories/imported daily serving	1624	120	538	60

Table 5-9 Descriptions of one serving for each food type.

	Staple carbohydrates		Vegetables		Animal meat		Legumes
Size	100g		100g		100g		40g
Food type	Domestic (yam)	Imported (dumplings/ cereal flour) 100gserved =50g flour	Domestic (cabbage)	Imported (cabbage)	Domestic (fried chicken)	Import (fried chicken)	
Calories/ 100g	100	232	34	34	269	269	60
Fat g	0.0	0.7	0	0	15	15	
Fiber g	3.7	1.7	2	2	0	0	
Sugar g	1.0	10.2	3	3	0	0	
Protein g	2.0	5.3	1	1	29	29	

Unrealistic amounts of money could still be spent trying to fulfill the minimum of a certain category requirement in some situations. For instance the price of vegetables could increase above a threshold (and supply was still at a level where a significant amount could be purchased) where consumers in reality would not buy any. To account for these situations a maximum expenditure for each category was set. This is based off maximum historical expenditure percentiles by commodity group. These generally came from 1992 data, when both food expenditure as a percent of total budget as well as the annual percent increase in the food and drink CPI (77.30%) was at its highest for the study period (JSLCs 1990-2003).[11]

[11] Interesting exceptions include greater proportion spent on starches in 1990 compared to 1992. It appears that this was largely compensated by a decrease in cereal purchases in the lowest quintiles and by a cut back in meals away from home by the middle class. Fruit and vegetable expenditures in 2003 comprised greater shares of the budget than in 1992 for all regions.

The maximum food expenditures as a percentage of total consumption by region were rural=65%, urban=60% and Kingston/Saint Andrew (KSA)=55%. Table 5-10 shows the maximum expenditures by food category used in QnD:Jamaica.

Table 5-10 Maximum food group expenditures by geographic region.

	KSA	Towns	Rural
Meat & dairy	31%	30%	39%
Carbohydrates	16%	18%	24%
Fruits & vegetables	14%	10%	9%
Meals away	24%	26%	20%
Other	15%	16%	8%

The maximum all food expenditure is declared as the DFoodBudgetFactor for each population group based on their regional location (rural, urban or KSA). Likewise, the maximum percentage of food budget allotted to each food group is declared for each population group as DMax*FoodGroup*BudgetFactor.

These factors are used to constrain the desired purchase within reasonable expenditure limits. The DFoodBudgetFactor is multiplied by the population group's DPrePurchaseWealthStore to arrive at the DMaxFoodBudget. This budget is then appropriated to DMax*FoodGroup*Budgets. These are further divided into Max*FoodType*Budgets by multiplying the DMax*FoodGroup*Budget by the related food type's expenditure factor.

The different transportation and marketing factors present in rural and urban areas result in different regional/habitat level food prices in a given parish. Therefore, the regional price differentials, DRural*FoodGroup*PriceRatio and DUrban*FoodGroup*PriceRatio, between local and imported FoodTypes are calculated separately:

1) D*Habitat*Consumer*ImportedFoodType*Price / D*Habitat*Consumer*DomesticFoodType*Price = D*HabitatFoodGroup*PriceRatio

The resulting D*<u>HabitatFoodGroup</u>*PriceRatio is used in a simple linear PRelationship function to determine the percentage of a FoodGroup's demand that will be filled by its associated local FoodType (Table 5-11).

Table 5-11 Food type expenditure factor.

X D*HabitatFoodGroup*PriceRatio	Y D*DomesticFoodType*ExpenditureFactor	Notes
0	.25	ImportedFoodTypePrice is anything <50% of the DomesticFoodTypePrice in same FoodGroup
.5	.25	ImportedFoodTypePrice is half of the DomesticFoodTypePrice in same FoodGroup
1	.5	ImportedFoodTypePrice is equal to the DomesticFoodTypePrice in same FoodGroup
2	.75	ImportedFoodTypePrice is twice of the DomesticFoodTypePrice in same FoodGroup
>2	.75	ImportedFoodTypePrice is more than twice of the DomesticFoodTypePrice in same FoodGroup

The above relationship function assumes that the consumption amount of a particular FoodType is directly proportional to its price relative to substitutable FoodTypes within a given FoodGroup. These are the values currently in the ComponentDetails for all food groups except vegetables. The current relationship for vegetables describes a less elastic price responsiveness. No matter how much cheaper imported vegetables are than domestic ones, imported vegetables will never make up more than 55% of the vegetables' budget as opposed to a maximum of 75% for the other imported food types. The relationship could be modified to show either a preference for domestic or imported foods within a food group when the price ratio equals one or other "tipping points" of interest.

Having accounted for consumer price responsiveness with the above relationship, consumer dietary demands as captured in the five food groups are then calculated. Basic food group needs are declared in the "GLOBAL" section of ComponentDetails file as DMonthly*FoodGroup*Needs (kg/capita/mo). The total needs of each food group for a population group are calculated:

3) DTotalMonthly*FoodGroup*Needs = DMonthly*FoodGroup*Needs X DPopulation X DAverageFamilySize

The unsold homegrown food available to landowning population groups is then accounted for:

4a) D*FoodType*Store = DPrePurchase*FoodType*Store

4b) DTotalMonthly*FoodGroup*Needs – DPrePurchase*FoodType*Store = D*FoodGroup*PurchaseDemand

Next, the total demand for each FoodGroup is distributed into its associated local and imported FoodType demands using the above expenditure factor based on price differences between substitutable products:

5a) DDesired(Domestic)*FoodType*Purchase = D*FoodGroup*PurchaseDemand X D(*Habitat*)*FoodType* ExpenditureFactor

5b) DDesired(Imported)*FoodType*Purchase = D*FoodGroup*PurchaseDemand - DDesired(Domestic)*FoodType*Purchase

The cost of each desired amount of food is then calculated by multiplying it by its associated price.

6) DDesired*FoodType*PurchaseDemand X D*Habitat*Consumer*FoodType*Price = DDesired*FoodType*Cost

In order to constrain the amount of money spent on a food group, this cost is then compared to the maximum allowed expenditure (described above) for a particular food group[12]. If the DDesired*FoodType*Cost is more than the allowed expenditure than the amount to be spent on

[12] This accounts for intra FoodGroup substitutability while the ExpenditureFactor accounts for inter FoodGroup substitutability.

the food type is instead set to the D*FoodType*Budget. This expenditure, whether DDesired*FoodType*Cost or D*FoodType*Budget, is tracked as DMoneyPaidFor*FoodType*.

In case the DDesired*FoodType*Cost (and the associated DDesired*FoodType*Purchase) was unreasonably large and constrained by the maximum budget, the real amount to be purchased must be recalculated:

7) D*FoodType*Purchase = DMoneyPaidFor*FoodType* / D*Habitat*Consumer*FoodType*Price

This amount is then transferred from the DNational*FoodType*Store into that population's D*FoodType*Store and the DMoneyPaidFor*FoodType* is transferred from their DWealthStore into the CUrbanMiddleFolk's DWealthStore

Consumption Testing

Figure 5-56 shows the large geographical spread in the imported vs. domestic carbohydrates price ratios generated by the marginal marketing and transportation cost factors. Also shown is the decrease in this ratio over time, which agrees with historical evidence, indicating that imported food prices have decreased relative to domestic food. Figure 5-57 shows the simulated annual totals of imported vegetables purchased vs. the known imported levels. This food type shows more realistic simulation amounts than imported staples levels shown in Figure 5-58.

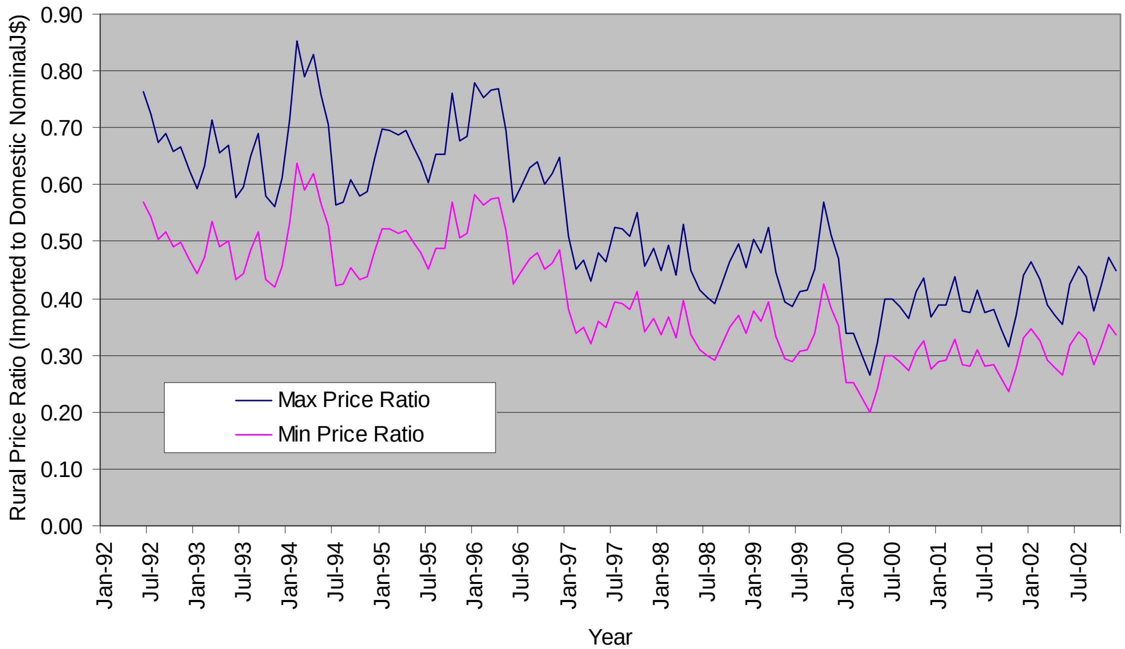

Figure 5-56 Maximum and minimum rural carbohydrate price ratios across parishes.

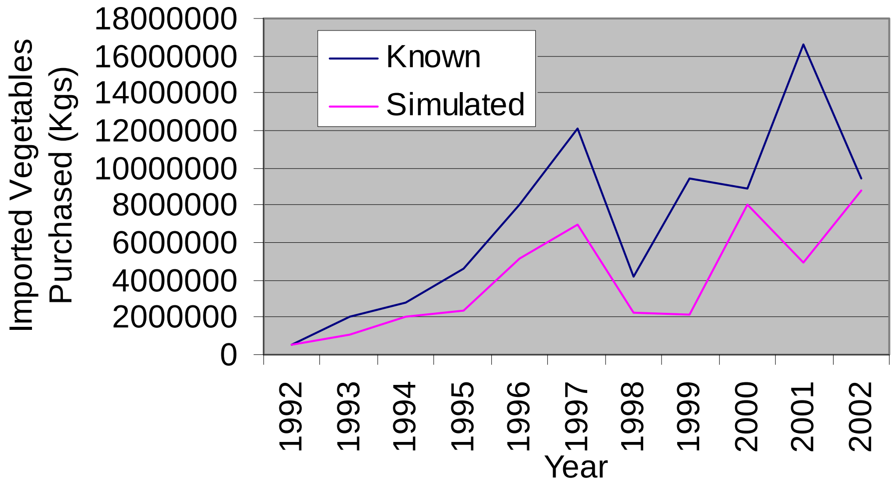

Figure 5-57 Simulated vegetable purchases.

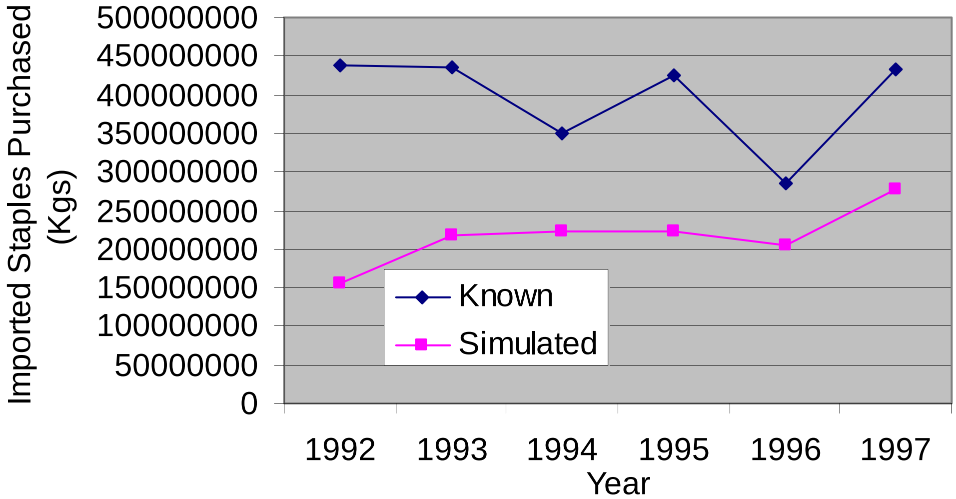

Figure 5-58 Imported staples purchased.

CHAPTER SIX
AN ILLUSTRATIVE SCENARIO SIMULATION

The following is a discussion of a simulation exercise completed with QnD:Jamaica. It serves as an illustration to guide and inspire future scenario simulations. In this exercise only one external parameter is manipulated while all other components are held constant. This approach is one traditional method in scenario modeling and can be understood as an overlay of one new quality against a known historical background. In this way, this simulation exercise is essentially asking, "What if one external change of concern had occurred during this known historical period?" To expand this exercise, one internal parameter was also manipulated for a total of four scenarios including the unmodified base historical one. Changing these two parameters only allows one to perform a coarse sensitivity analysis. As QnD:Jamaica is in its relatively early stages of development it is important to isolate influences to really examine the model's responsiveness. Future simulations using QnD:Jamaica will move beyond this approach and describe a variety changing parameters in complex scenario descriptions.

Biofuel Demand and Rising Corn Prices

There has been much recent discussion surrounding the ramifications of rising corn and soybean prices and the role of growing ethanol biofuel demand in these increases[13]. The recent rise in corn tortilla prices in Mexico and the resulting food security effects has been well documented (Roig-Franzia, 2007). In the US, there has been a 70% increase in poultry feed prices over the past six months resulting in a 14% increase in broiler prices over the same period (Sauser, 2007).

[13] It is important to note that rising corn prices are likely an emergent property of other feedbacks in the global system besides ethanol demand. Potential activities of influence include droughts on multiple continents and rising international wheat costs also.

In Jamaica, these price increases are also a major concern for the poultry industry, as much of the feed is imported corn (Edwards, 2007). The Jamaican consumer's chicken prices have steadily increased over the past year to compensate for the increased production costs (Thame, 2007). The higher costs of this important source of protein in the Jamaican diet will likely have important nutritional effects on the population. In addition to these most direct food security concerns, downturns in the large poultry industry would have ripple effects across the economy. It is important to note that these increases are occurring against a backdrop of historically low corn and feed stuff prices. While ethanol production is a new element in corn prices and its effects on value is a large concern, the diminished prices throughout the 1990s and early 2000s could arguably be considered unrealistically low.

Jamaican corn-based feed prices increased by 25% in 2006 and are expected to increase another 35% by the end of 2007 (Thame, 2007). These values were used to estimate an external feedstuff price driver file that was used in place of the original timeseries file containing known historical prices. This file describes a linear feed price increase of 25% per year from the base price in 1992. To expand upon this simulation, the internal parameter describing consumers' ideal poultry demand total was increased from 3kgs/capita/month to 4kgs/capita/month in two scenarios. This represents changing preference, or utilization, patterns.

- Historical Scenario: 1990s feedstuff prices and historical 3kgs/capita/month livestock desired utilization
- Scenario 1: 25% annual increase in feedstuff prices and historical 3kgs/capita/month livestock desired utilization
- Scenario 2: 25% annual increase in feedstuff prices and increase in desired livestock utilization to 4kgs/capita/month
- Scenario 3: Historical feedstuff prices and increase in desired livestock utilization to 4kgs/capita/month

Discussion of Scenario Simulations

National domestic livestock production volumes, purchase volumes and consumer desired purchase volumes are the three output parameters examined in this discussion of the four scenario runs. These subjects were chosen because they embody the key qualities of food security: availability, accessibility and utilization. Total production amounts are described by the "Available" curve in the figures below. In these scenarios, the maximum desired amounts never exceeded the maximum budgeted amounts, thus, the "Accessible" curve describes the demand for domestic livestock amount and is unlimited by budget constraints. The "Purchase" curve shows what was actually bought by consumers. Also shown in the figures is the known real annual domestic livestock production volume as a reference (Figures 6-1, 6-2, 6-3 and 6-4).

In the historical scenario, the available amount is similar to the historically known production level, especially in the first five years of simulation. This scenario is showing an available level that does not meet the national needs and purchasing ability in the first four years. After 1996, however, accessibility becomes the limiting factor with purchased amounts declining below available levels as well as earlier purchase levels. Scenario 1 clearly shows a lower level of available chicken than the historical scenario. This is expected do to the rising costs of production incurred by the increased feed costs. Accessibility is similar to the historical scenario during the early years of simulation, but is lower in later years because the rising costs of production are being passed on to the consumer. These increased domestic chicken prices are causing the relative price between domestic and imported chicken to be greater which is the model's mechanism to limit consumer's domestic purchasing power. This decreased accessibility is especially apparent in years 5, 7, 8, 9, 10, and 11 of Scenario 1. However, lowered domestic availability is still a greater limitation than accessibility in all months except a few in year 7 and most months in year 9.

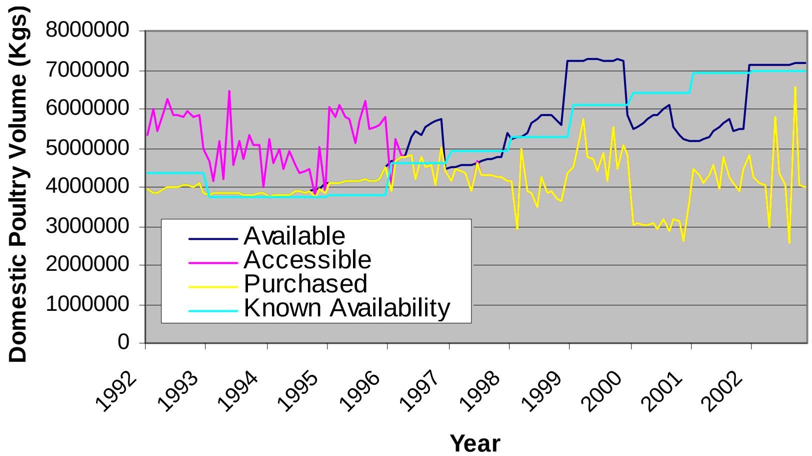

Figure 6-1 Historical scenario of domestic livestock production and demand.

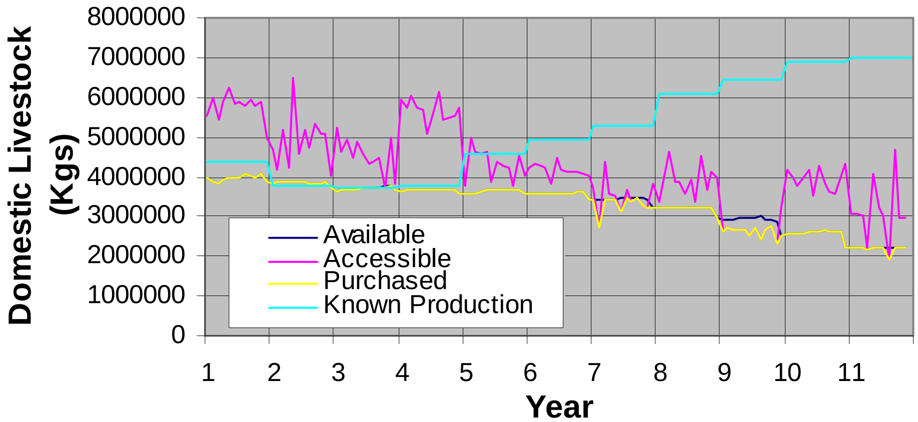

Figure 6-2 Scenario 1 of domestic livestock production and demand.

In Scenario 2, accessibility is always greater than the low amounts of available chicken. If poultry production decreased to levels simulated in this scenario, there would be a strong amount of unmet demand which would have strong implications for protein intake and shifts in diet composition. Scenario 3 shows purchasing levels most similar to known historical production amounts indicating that the Jamaican consumer's poultry demand is likely closer to 4kgs/capita/mo than 3kgs/capita/mo.

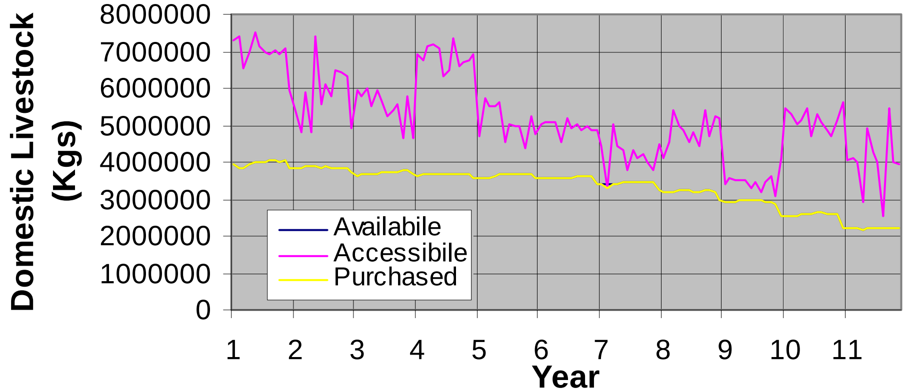

Figure 6-3 Scenario 2 of domestic livestock production and demand.

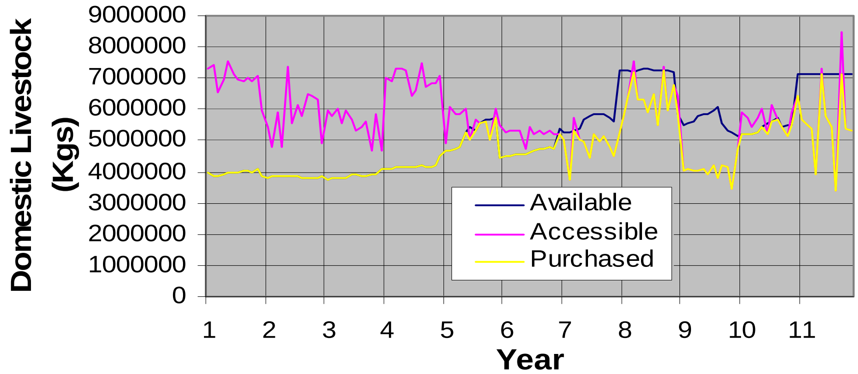

Figure 6-4 Scenario 3 of domestic livestock production and demand.

Figure 6-5 shows national base domestic livestock prices as well as the regional prices for rural and urban habitats in two parishes. It is not surprising that the urban area in Saint James generally shows the lowest prices as it has the lowest marketing coefficient being closest to a large market, Montego Bay. The sharp price increases throughout the scenario in all regions are due to transport infrastructure shocks caused by floods. It is interesting to note that there is never an event where one of these parish's habitat areas, either rural or urban, experiences a spike without the other habitat area.

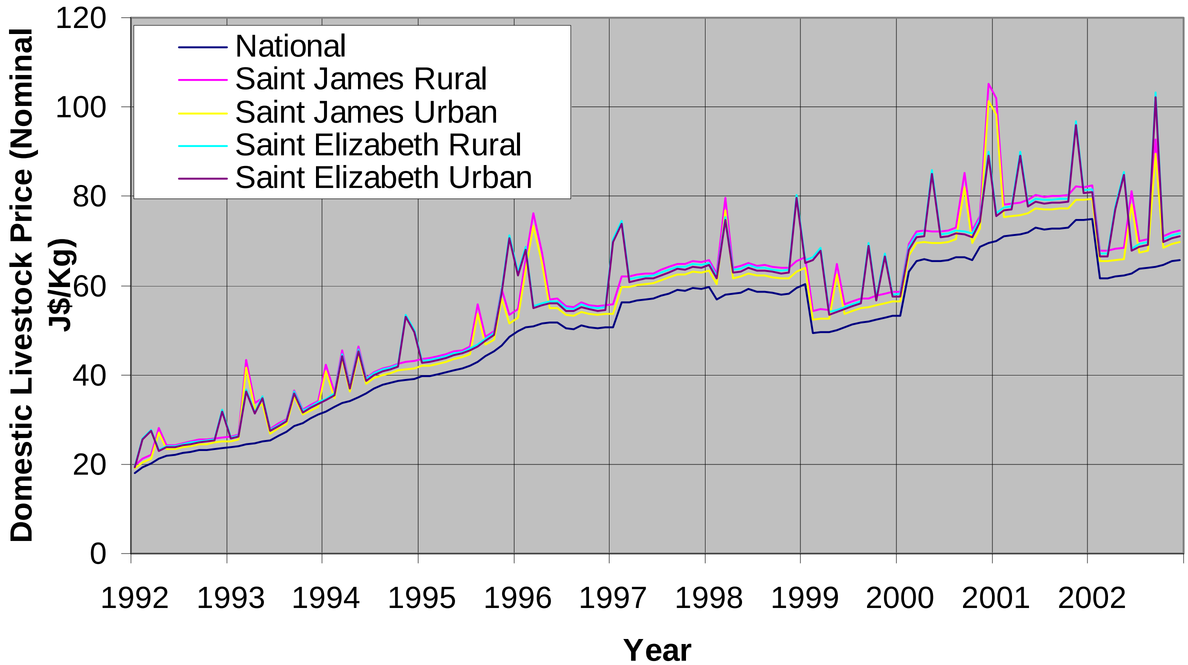

Figure 6-5 Regional price shocks to domestic livestock in historical scenario.

Figure 6-6 shows a technical error in QnD:Jamaica. The purchase amount process is using the budget data value from the previous month rather than the current month's data value as designed. This is resulting in what appears to be overly dynamic purchase output. Figure 6-7 also shows the Saint James farmer population's purchase amounts of imported and domestic chicken alongside their total poultry demand/needs. The output data shown in this graph has been modified to remove the noise errors that QnD:Jamaica produced. However, the most important results can be seen in both figures. The model is showing purchasing observed in the historical data records: decreasing domestic poultry purchases and increasing imported poultry purchases. This similarity to known trends is evidence that builds confidence in the mechanisms employed in QnD:Jamaica.

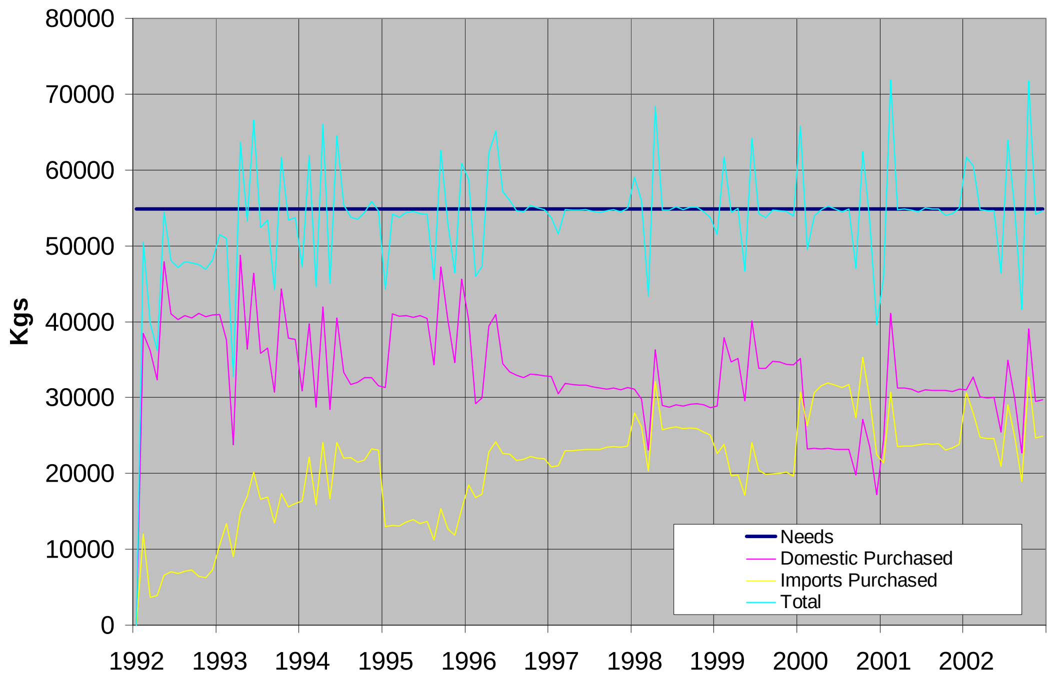

Figure 6-6 Internal structural design noise.

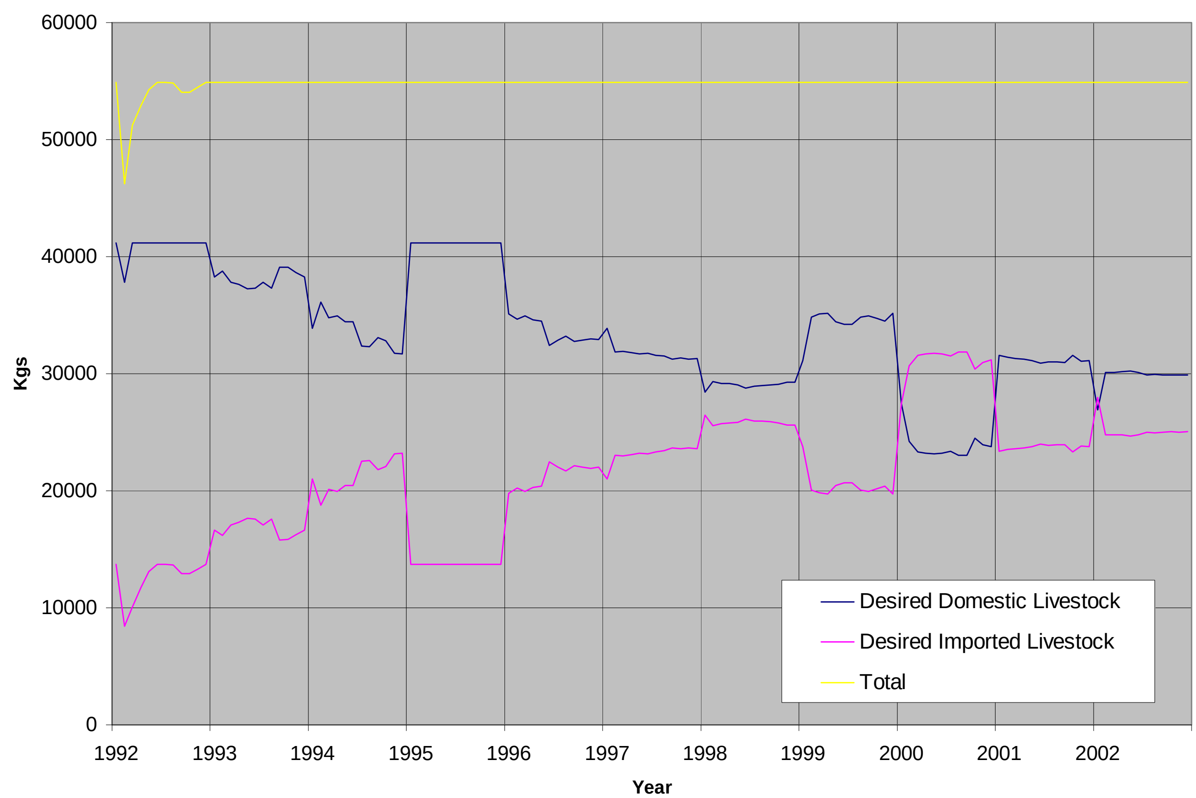

Figure 6-7 Domestic and imported livestock purchases of Saint James farmers in historical scenario.

Figure 6-8 describes the volume of imported animal meat purchased in the various scenarios. As expected, the purchased import amount is lowest in the historical scenario when domestic production was relatively high, prices relatively low and demand only 3kgs/capita/month. Similarly when the preference parameter is set at the lower value, imported livestock is still relatively low, but higher than in the historical scenario because domestic livestock prices were relatively higher compared to imported animal meat prices. Imported purchase quantities are generally highest in the second scenario when demand is high yet domestic production shows decreasing output due to higher feedstuff prices. In the first five years of the scenarios, imported purchased do not differ greatly from the amounts produced in the historical scenario. This is likely a result of the combination of domestic livestock prices' relative competitiveness to imported prices in the early years as well as relatively small value's in real internal feedstuff prices despite the great external increases.

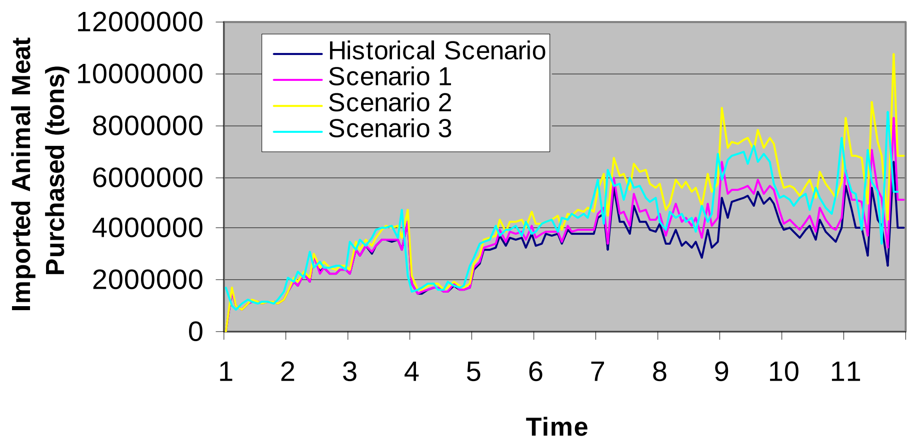

Figure 6-8 Total imported animal meat.

The changing demand for imported animal meat as domestic livestock prices and supply change as illustrated in the above scenarios indicates the need to consider the potential qualities of the imported animal meat in the event of a global feedstuff increase. As this situation is occurring in the global food system not just in the Jamaican context, at least one other immediate external parameter is important to this scenario exploration. Because Jamaica imports a fair share of its total poultry supply, around 25% annually throughout the 1990s, external poultry prices are important in the Jamaican food system. The rising cost of corn is also being passed onto US chicken prices (Sauser, 2007). The next step in this scenario exercise should be to examine the combined effects of rising imported poultry prices would have in combination with rising feedstuff prices.

CHAPTER 7
CONCLUSIONS

Modeling Jamaican Food Systems

This thesis represents the second developmental cycle in what hopes to be a chain of constructive model design and learning. The first iteration was completed during the summer of 2005 during multiple workshops led by GECAFS. During the phase of model development documented in this thesis, the structure of the base version was fleshed out into greater detail. Discussions in the field revealed a model structure that aims to depict the Jamaican food system in a manner most appropriate to those interests most involved in the situation. In depth empirical research guided parameterization of the model as many of the previously desired relationships and data were not well documented enough to support simulation.

There are many potential future applications of QnD:Jamaica. The most obvious is greater exploration of consumption activities in terms of the availability and accessibility of food. The assumptions and effects of the current expenditure factor and price ratio processes need to be explored further to determine their necessity and/or implications. Because changing food preferences is a key concern of Jamaica food security one of the user's management options could be to modify the proportions of desired foods within a consumer's food basket, i.e. increase daily vegetables demand from 400g to 500g. This represents desired effects of nutritional education policies or cultural changes. Additionally an ideal preference distribution based on the CFNI's recommended calorie source distribution by food category could be used to guide this parameter. Each month's consumption basket could measured against these proportions to show how simulated nutrition levels compare to desired levels.

Another obvious next direction for the model is the development of parameters based more directly on natural resources. These should include such indices as forest health (i.e. canopy cover, biodiversity), fisheries health (reef diversity, fish stocks), erosion indices, water quality (availability, stormwater and agricultural runoff), etc. Another necessary addition to the model is development of more internal feedback loops (rather than so many driver files) such as farmers' land use decisions, internal migration flows, and tying wages to economic sector indicators. These should also be tied into the ecological dynamics and indices.

Broader Lessons Learned

The most useful application of the knowledge gained during this research will be in discussions of more formal guidelines for conducting interdisciplinary meso scale research. One of the key struggles faced during this project was interpreting and manipulating available macro and micro level data in a manner that revealed a limited number of cross-scalar and cross-disciplinary linkages and systemic features in an effort to remain fairly transparent. The impact of this project has both practical and theoretical applications and advances multiple disciplines separately and the interdisciplinary cause itself. As development planners and the decision support community seek to apply the adaptive management paradigm, practical systematic methods that implement the proposed principles must be developed and tested. Traditionally these two fields have experienced tension due to communication and goal assessment difficulties, among others. This project serves as an example of one innovative method that aims to limit these difficulties. The knowledge gained during this research provides these disciplines with a case study demonstrating an explicitly collaborative, interdisciplinary and iterative framework for development and implementation of an adaptive management planning tool.

A future comparison of this project's site specific evidence with case studies from other food systems, will give insight into general structural patterns and "rules" in food systems. These patterns will help food system planners better maneuver through the many unpredictable variables as they formulate food security policy.

When a holistic definition is applied to food security, it becomes nearly impossible to ignore the previously hidden impacts that the current international food system has on all socioecological aspects of our global society. Traditionally underrepresented groups will be empowered when a rich definition of food security that necessitates a complex systems approach to food management is fostered. The food security evaluation framework that this project promotes has the broadest impact of raising awareness of the extensive and unseen ramifications of our global food system.

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