EX-ANTE IMPACT ASSESSMENT OF LIVESTOCK INTERVENTIONS IN CROP-LIVESTOCK SYSTEMS IN NORTHERN AFGHANISTAN

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ABSTRACT

Policy makers and practitioners in Afghanistan tend to favor interventions promoting high value agricultural activities, including dairy production. Given the lack of available research and data in the country, the impact of these interventions on traditional subsistence and semi-subsistence crop-livestock households is unclear. A system dynamics model was built to conduct an ex-ante impact assessment of livestock-based interventions in crop-livestock systems in northern Afghanistan. The dynamic simulation model draws on available data, including household level surveys and government price data to predict the outcome of the interventions. The analysis focuses on endogenously generated dynamics and the interaction between biophysical and economic outcomes. Simulation results show that the initial conditions of the households affect the outcome of the interventions. Forage yield improvements and donations of cows may succeed with higher endowment households, whereas interventions that lower transaction costs for milk sales may be more advantageous for households with fewer assets.

BIOGRAPHICAL SKETCH

Kurt Benson Waldman was born in Monkton, Maryland to Paul and Hurle Waldman in May of 1978. After surviving a fall from a second story window at the age of three into a particularly robust set of bushes, Kurt set off to understand the physical world better. Kurt graduated from Earlham College in May of 2000. He tried his hand at architecture and design in New York City until the firm folded. Kurt then explored some parts of the west coast and Hawaii, purchased a motorcycle, and worked at a winery until he shipped off for Peace Corps service in January of 2002. He completed a productive stint in a beautiful rural locale, in an upland valley of the Philippines as an agriculture extension agent. This flirtation with development led him back to Baltimore to work for Catholic Relief Services. After a year in Baltimore and a few courses in economics at the University of Maryland, he found himself in graduate school at Cornell. Kurt spent the summers of 2006 and 2007 in different parts of Afghanistan. Thesis research was conducted in Mazar-i-Sharif in July of 2006.

To Frank, long may you run.

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CHAPTER 1

INTRODUCTION

Problem Statement

Farm households in Afghanistan devote a large proportion of resources to staple production, specifically wheat, and less to higher value commercial crops (including forage for milk production), even though policy makers perceive that cash crops are more profitable. There is a wide variety of opinions about the profitability of land allocation to high-value agriculture in Afghanistan. These opinions are embodied in a range of development interventions that encourage various 'high value' or market-oriented enterprises in Afghanistan. One such enterprise is dairy production, and interventions include promoting land allocation for improved fodder germplasm, alternative fodder crop production, an emphasis on genetic improvement of animals, and construction of medium and large-scale dairy processing facilities. Participants in these projects are faced with decisions to adopt interventions and potentially reallocate scarce resources despite limited empirical evidence about the economic tradeoffs between various resource uses.

Thus, information on resource allocation strategy constraints, profitability, and transition dynamics will allow for more effectively formulated development interventions in Afghanistan. Beyond the immediate implications for development, this information may also illuminate the broader epistemological question of why farmers behave in a certain way in this context, making a step toward addressing other relevant land use questions for Afghanistan, such as the current rise in poppy production.

Background

A recent survey in northern Afghanistan indicated that, "under conditions of uncertainty, limited water, low wheat prices, and no summer cash crop compounded by a decline in livestock, opium was the only crop that would provide returns to scarce water" (Roe, 2006).[1] Water availability, often the most limiting factor of production in Afghanistan, is determined largely by access to irrigated areas. Rainfed cultivation and water availability are usually highly unpredictable and risky due to the infrequent rainfall in most areas of Afghanistan, particularly in the northern plains. Differences in land types and water access can lead to variation in patterns of crop production, livestock holdings, and cash income across households.

Rainfall and crop yields can be particularly important for households which maintain livestock and depend on crop production for livestock feed. Roe (2006) found that mean ownership of cows to be higher in rainfed cultivation areas that, "may reflect a generally greater involvement in livestock as an alternative to irrigated cultivation and a supplement to rainfed cultivation." Rainfed farms tend to be larger than irrigated farms although "returns from farming of this type are limited" and "do not translate in any discernable indicator of household well-being other than livestock ownership" (Roe, 2006, p.12).

In addition to production related constraints, Afghan farmers also face volatile prices for agricultural inputs and infrastructure is poor in Afghanistan (FAO, 1999). Farmers are forced to allocate scarce resources under considerable uncertainty in environmental and market conditions. As a result, Afghan subsistence farmers

[1] In many water basins (irrigated areas) ethnic power relations dictate access to water, which often coincides with the production of poppies. In rainfed areas, labor constraints and the need to grow grain outweigh the risks of poppy production.

encounter barriers to increasing their income through high value production, including high transactions costs, shallow local markets, and wide uncertainty in factor and output prices. Many of the current development interventions and evaluations of resource allocation in Afghanistan too often fail to account for these nuances (discussed below), which affect decision-making among subsistence farmers in other parts of the world (de Janvry, Fafchamps, and Sadoulet, 1991).

Mainstream development interventions in Afghanistan frame the question of resource allocation narrowly, focusing on market-oriented outcomes including higher value crop and livestock activities. Policies and interventions often do not draw upon relevant literature, including sub-optimal decision making and non-separability of production and consumption decisions. Policymakers in this context fail to fully consider the complex dynamics of subsistence farming and lack appropriate tools for ex-ante analysis of the systems in which they are implementing interventions.

Key Questions

A few important questions arise given the perceived problem of agricultural systems in northern Afghanistan. What are the likely outcomes of, and constraints for, higher-valued agricultural production, specifically dairy production, in northern Afghanistan given transactions costs, shallow local markets, uncertain water availability, and volatile market prices? What will happen if farmers adopt new strategies as a result of development interventions? Are there transition strategies, such as dairy production, that might improve development interventions supporting high-value crops and livestock activities?

Objectives

An exploration of the problem and questions related to high-value agricultural activities in northern Afghanistan necessitates an approach focused on practical applications and a problem-solving approach. The inquiry should be conducive to assessment of current crop-livestock farm systems in Afghanistan and evaluation of current proposed interventions and at the household level.

The objectives of this study are:

1) To construct and parameterize a model of representative households with mixed crop-livestock production in Afghanistan, in order to capture the biophysical and economic dynamics of the system.

2) To conduct an ex-ante evaluation of selected interventions in the livestock sector in northern Afghanistan, including the associated transition constraints, pathways, and effects of interventions on household welfare in a dynamic framework. Selected interventions to be examined include: dairy intensification through improved alfalfa germplasm, encouraging reallocation of land to forage production, gifting of lactating animals, and a reduction in transaction costs.

3) To assess the impact of shocks on high and low resource endowed mixed crop-livestock farmers given current strategies and under livestock interventions.

Thesis Organization

Chapter Two provides a summary of staple, forage, and livestock production in mixed-crop livestock systems in northern Afghanistan and a description of the major constraints on the system drawing from the available literature. Shocks that have affected the mixed crop-livestock system in past years are outlined and a brief description of current development interventions is included. The third chapter is a discussion of possible methods for evaluating the research question. The nature of the research problem is discussed along with ways in which similar models have been specified and the pros and cons of possible computational methods for ex-ante impact assessment. Constraints on high value production and a description of high value production in Afghanistan are included and placed in the context of Agricultural Household Models (AHM). A justification for the use of the system dynamics method of evaluation is offered based on characteristics of the research problem.

Chapter Four describes the structure of the dynamic model developed and applied to assess interventions. This section includes a description of the different components of the model, principal assumptions, and equation specifications. Chapter Four also introduces basic scenarios examined with the model. Chapter Five evaluates the model and discusses its limitations. Chapter Six describes the model scenarios and reports and discusses results. There is a brief comparative discussion of the model results for the interventions given the various shocks. Chapter Seven outlines conclusions drawn from the model results and conclusions based on the modeling process. Possible policy implications of the findings and future research are also suggested.

CHAPTER 2

MIXED-CROP LIVESTOCK SYSTEMS IN AFGHANISTAN

Description of Mixed Crop-Livestock System in Afghanistan

Household agricultural production in Northern Afghanistan operates as a highly integrated system, with mixed irrigated and rainfed cropping centered on wheat production and livestock husbandry. Wheat is grown mainly for household consumption (grain) and livestock consumption (straw), whereas a forage crop is often grown to complement livestock production, often roughly in accordance with the herd nutrient requirements. High value crops, such as melons or tomatoes, rarely are grown in areas where markets do not exist or function well and reliable irrigation is not feasible. Fruit crops used to provide about 40% of Afghanistan's exports although this has dwindled in recent years due to conflict and lack of irrigation (Thieme, 2004). In areas where irrigation exists, water sources are reliable, and markets are in relatively close proximity, there is higher crop diversity (Roe, 2006).

In integrated production systems, cattle traditionally provide draft power as well as household dairy products, consuming mostly crop by-products and occasionally leguminous fodder grown on irrigated land. The household directly consumes or markets the animal products. Small ruminants, most often sheep, are usually maintained only by households with access to larger amounts of rainfed or pastureland and by nomadic groups. Management of nutrient cycling and crop rotation is generally limited and there are competing uses for all resources at the household level, including manure. Feed purchases are uncommon but can comprise most of the producer expenditures in animal production. Households are often forced to sell animals when fodder resources and cash are limiting (Fitzherbert, 2006). The role of livestock in the mixed crop-livestock system in Afghanistan could generally be considered low input-low output and serve to manage high production risks.

Staple Crop Production in Afghanistan

Afghan Wheat and Wheat Production: Approximately 70% of the arable land in Afghanistan (about 2 million hectares) is cultivated with Afghanistan's staple crop wheat, of which 60% is irrigated and accounts for about 80% of the total yield (Chabot and Dorosh, 2007). Rice, maize, and barley are also produced in some regions although these crops are grown on a very small portion of cultivated land overall.[2] Average wheat yields vary dramatically depending on the source, ranging from 0.86 T per hectare per year (FAO/WFP, 1999) on rainfed land to 3.5 to 4 T per hectare per year (FAO, 2005) on irrigated land. Chabot and Dorosh (2007) estimate that half the total national wheat crop is produced in northern Afghanistan and the foothills of the region with 283 kg per capita, compared to a national average of 157 kg per capita. There are two main classifications of wheat: winter wheat, which takes 180 to 250 days to reach maturity and spring wheat, which takes 100 to 130 days. Irrigated wheat is harvested in April or May, and rainfed wheat is harvested from August to September.[3]

Factors of Production for Wheat (Seeds, Labor, and Capital)

Similar to yields, inputs for wheat production vary significantly among households and farming systems depending on the agro-ecozone and the management system. Storage of seeds for subsequent sowing is more common than purchasing of wheat seed. For many farmers, labor for wheat production often comes only from the

[2] About 350,000 tons of each in 2006 (compared to 5.5 million tons of wheat).
[3] See appendix for a detailed crop calendar.

household and wheat is not often produced for commercial purposes. Surplus grain is either maintained as a buffer until evidence of the next harvest or sold when cash is needed (Maletta, 2006). Oxen are used for cultivation and plowing when available, as are tractors in peri-urban communities.[4] When cash is available, di-ammonium phosphate (DAP) and urea are applied. Animal manure occasionally is applied also. Coke (2004) estimated an average application rate of 40 kg/jerib[5] of urea and 20 kg/jerib DAP across regions while estimates from Mercy Corps (2004) in northern Afghanistan were 75 kg/jerib of urea and 25 kg jerib/DAP.[6] Some small-holder producers practice crop rotation, use nitrogen-fixing leguminous crops and trees, animal manure, and chemical fertilizers to enhance production of higher value crops such as fruit, nuts, and vegetables (ICARDA, 2002).

Importance of Wheat Crop By-products

Wheat straw is a vital component of the mixed crop-livestock system. There is an active market in Afghanistan for straw, with highly variable regional prices. Although straw is used for dwelling construction, and cooking fuel, its most common use is to feed livestock. In many cases, it constitutes most of the animals' diets resulting in under-nutrition. Alternatively, households without animals sell excess straw. Straw is traditionally used in shelter construction (mud bricks) as well as for fuel cake production due to the local scarcity of fuelwood. Wheat stover is consumed by animals and is grazed in the weeks following harvest. Maletta (2006, p.1) stressed the importance of wheat by-products and believes "not considering crop residues (and weeds) as part of crop revenue would lead to a gross underestimation of the crop's

[4] Tractors may be more common in response to the shortage of labor and the recent availability of tractors imported from Pakistan and Russia.
[5] Jerib is an Afghan unit of measuremement approximately equal to 1/5 hectare. This application rate would be equivalent to about 200kg/hectare urea and 100kg/hectare DAP.
[6] Corresponding yields are presented in the appendix.

profitability...and may explain the prevalence of seemingly unprofitable wheat production."[7]

Consumption and Sales of Wheat

There are also wide discrepancies in nationwide wheat production estimates, ranging from 2.7 to 4.4 million tons per year.[8] Chabot and Dorosh (2007) used these data to estimate per capita annual consumption to be between 139.6 kg/person and 204.6 kg/person, depending on the region (and source of the estimate). The World Bank (2005) estimated the value of consumption expenditures per person per year in Afghanistan to be approximately $92 for a 2100 kcal diet (minimum level). This is approximately $0.25 per day, and one-fourth of this amount is not wheat. The NRVA household data on wheat sales suggest that in 2003 total marketed wheat was 683 thousand tons, equal to 25% of production (2.73 million tons).[9] However, the NRVA data (2003) and Grace and Paine (2004) show that many households had little or no marketed surpluses of wheat. Approximately 25% of Afghanistan's wheat supply is imported from neighboring countries, largely Pakistan (Chabot and Dorosh, 2007).

Forage and Livestock Production in Afghanistan

Forage Production

Approximately five to ten percent of the arable land in Afghanistan is allocated to forage production each year (ASA, 1994).[10] Four forages frequently are produced by northern Afghanistan smallholder farmers. Lucerne or alfalfa (*Medicago sativa*) is the

[7] Maletta (2005, p.2) also writes that, "in many locations, the cost of production is well above international standards, and the product seems to be easily outpriceable by foreign competition".
[8] Chabot and Dorosh use FAO and NRVA estimates published in the World Bank (2005).
[9] The northern region of the country accounted for about 90% of total marketed grain (620,000 tons), although most of this concentrated in the northeast provinces (Badakshan, etc not Balkh Province).
[10] Newer estimates of land in forage production are unpublished.

most important, providing up to five cuttings annually, but it has the highest water requirements. Shaftal, or Persian clover (*Trifolium resupinatum*) prefers heavy moist soils, but is grown where water is scarce, and can be harvested two to three times per season. Berseem, or Egyptian clover (*Trifolium alexandrinum*), is known for rapid growth and is higher yielding than Shaftal, but is less hardy and less tolerant to drought. Berseem is usually sown directly in early September and cut once before winter with as many as four or five cuts possible in spring. Grains, including sorghum and barley, and green maize are infrequently cultivated as fodder crops and constitute a small portion of overall crop area.[11]

<u>Afghan Cattle and Cattle Production</u>

The cattle native to Afghanistan collectively known as *watani*, comprise a range of *Bos taurus* breeds. The origins of the animals vary and they have adapted to the diverse ecological regions of Afghanistan, with wide variation in color, fertility, milk production, and mature body size. For example, in Badakhshan animals have adapted to extreme temperatures and high altitudes and generally weigh around 200 kg, whereas larger and more productive cattle are found in Herat and Kandahar and are thought to be related to Iranian breeds and can weigh about 400 kg. Calving typically takes place between March and May, although calving seasons are often correlated with the abundance of feed and weather patterns (Thieme, 2003). Fertility varies markedly due to inadequate nutrition and, in some cases, the calving period extends into July.[12] A wide range in the duration of lactation, ranging from 2 to 12 months was noted (AKF, 2004), with milk production of 500-1000 kg per lactation (Thieme,

[11] The most common is barley at 236,000 hectares cultivated in 2002 (which is the last year ASA data is reported). Maize and millet account for a very small fraction of cultivated land area (about 4% together).
[12] Thieme (2003) estimated that from 1994 to 2004, cows produced 0.64 offspring annually but without the high frequency of drought would give birth to 0.68 to 0.80 offspring annually.

2003). Daily milk production estimates range from one to two kilograms per day to as high as 20 kilograms per day.[13] The Aga Kahn Foundation (2004) reported that less than 10% of lactating animals produced in excess of 5 kg[14] per animal per day, although estimates from other sources range up to 20 kg per day.[15]

Livestock Feed Inputs

Most sedentary livestock holders in the north of Afghanistan depend on a combination of crop residues, locally grown forages, and homemade supplements to support one or two head of cattle. The basal diet of cattle in the north of Afghanistan is wheat straw, characterized by low crude protein content and a high neutral detergent fiber (NDF) content.[16] Cattle are also typically allowed to graze crop residues, such as maize stover. Small-holders who produce forage typically incorporate fresh forage (alfalfa is the most common) with the wheat straw during feeding, adding water to increase digestibility.[17] Winter (January to March) diets include wheat straw stored after the summer harvest as hay, any fodder that has been stored, and, when cash is available, added concentrate (usually cottonseed cake) to prepare animals for traction and lactation in the spring. Some farmers substitute sesame seed cake for cottonseed cake, although cottonseed meal is believed to be particularly effective in increasing milk production (Thomson, 2005). Winter is the time when feed stocks are generally lowest in Afghanistan. Grains, such as sorghum, millet, or barley and green maize

[13] The Food and Agriculture Organization has a series of milk projects and reports much higher milk yields as a result of their interventions. Many individual owners report much higher milk production, as high as 20 kg/day/animal.
[14] Aga Khan estimates did not clarify whether this was average production over the length of lactation or at a single point. Nonetheless this figure is low in comparison to other sources.
[15]FAO observed some cows producing up to 20 kg of milk daily in both Mazar-i-sharif and in the Kabul area. These estimates are unpublished, however.
[16] The average crude protein content of wheat straw in the US is only about five to six percent with NDF greater than ninety percent. Forage analysis values of collected samples are reported in the appendix.
[17] There is no data to show the degree to which digestibility is increased by soaking in water.

also factor into the diets but are not common. Buoy and Dasniere (1994) estimated average availability of feed, for a winter feeding period of 110 days, was 1000 kg of straw and 200 kg of legume hay per animal (with an estimated body weight of 300 kg) during non-drought years.[18]

Consumption and Sales of Livestock Products

Due to the low number of cows per capita, many households consume all of their milk production. The Aga Khan Foundation (2004) found that few farmers reported selling milk (for cultural and other reasons) and only 10 percent reported that cow's milk and milk products were important components of household cash income. Where a market for milk exists nearby, households might retain a fixed amount or portion relative to household size for consumption and sell the remainder. Levitt (forthcoming) found this to be approximately one kilogram of milk consumed per household per day while FAO data show an average ratio of 2:5 (consumed to sold milk). Milk is often given away or received by households as gifts depending on whether the household has milk available (Levitt, forthcoming). In addition, milk exchange and bartering often take place informally at the village or community level, while the exception to this is milk collection schemes supported by a range of non-governmental and government agencies.[19]

Resource Constraints for Crop Production in the Northern Plains

The main limiting factors for crop production in northern Afghanistan are water, labor and nitrogen. These are discussed in detail below:

[18] This is approximately 9 kg of wheat straw and 1.8 kg of forage as a winter diet.
[19] This is discussed in more detail below under interventions.

Water: Water is the major constraint to agricultural production in Afghanistan. More than 80 percent of the country's water resources come from snowmelt in the Hindu Kush (Ahmad and Wasiq, 2004). Currently only 12% to 14% of the land in Afghanistan is considered arable due to the scarcity of water (Alim and Shobair, 2003).[20] Crop production is highly dependent on irrigation, but the water supply is often inconsistent due to the frequency of drought and conflict over water access. Approximately 5% of the total land area produces 85% of the crops almost entirely on land irrigated from water basins via open canals and land fed by groundwater from snowmelt through underground *karezes* (tunnels) or shallow wells. Cultivation of rainfed farmland is risky because many areas in northern Afghanistan receive only 300-400 mm rainfall per year (Figure 2.1).[21]

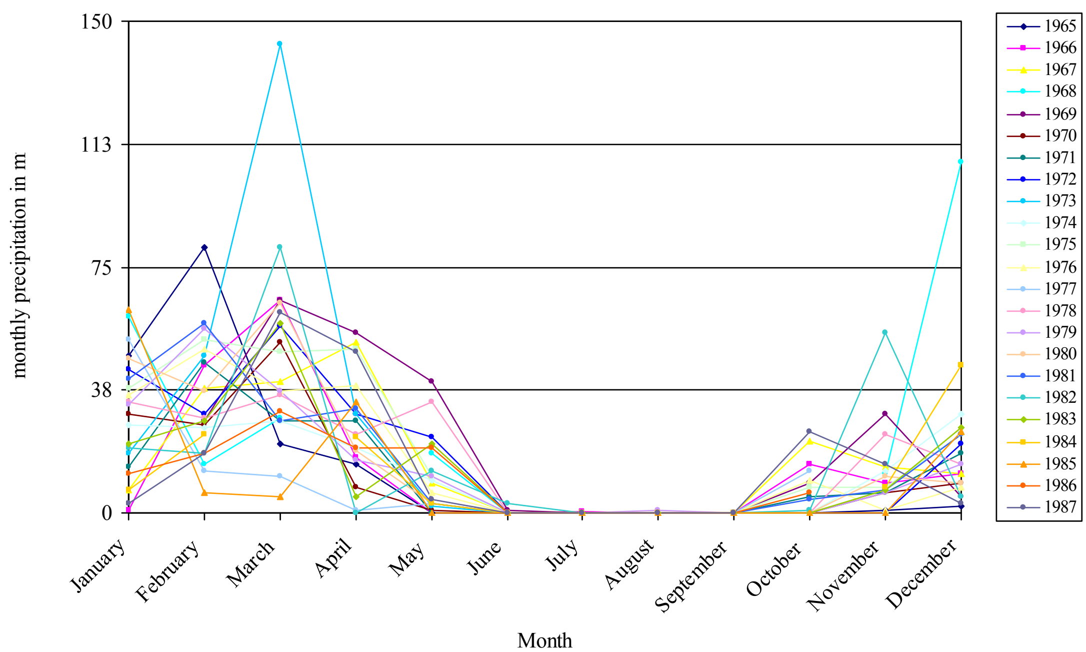

Figure 2.1 Monthly Rainfall in Mazar-i-Sharif from 1965 to 1985

(Source: Vulnerability Analysis and Mapping Unit, WFP)

[20] Other estimates of arable land differ slightly.

[21] In the northern valleys, annual precipitation averages 300 mm, most falling from December to May, whereas in the north overall, annual precipitation averages 400 mm per year.

The pattern of rainfall data collected in Mazar-i-Sharif (Figure 1) exhibits a unimodal pattern with almost no rainfall during summer months. In most communities, there is a complex social web governing the distribution of water arising related to social, political, and religious factors (Anderson 2006, Fitzherbert 2006). Where traditional social rules governing the distribution of water have broken down, and access to resources is dominated by power holders (Pain and Faryab, 2002).

Land: In Afghanistan, there is wide variation in topography, climate, soil, and rainfall leading to extremely different agricultural systems between regions and communities. Resource availability for agriculture also varies dramatically due to the distinctly different classifications of farmland based on water availability. The river valleys have the most reliable water supplies (Roe, 2006).[22] Land in river valleys is often irrigated by a system of open canals, which are dug by hand and provide a relatively permanent source of water (given seasonal oscillation in river flow). River valley land, usually is densely populated, and water distribution is often governed and regulated by multiple local institutional mechanisms. In theory, the *mirab* is responsible for water allocation, although there is often significant influence by the local *shura* and politicians.[23] Crop diversity is highest on irrigated land where water access is sufficient to meet multiple crop needs and lowest on rainfed sites (Roe, 2006). AREU also specified land on hillsides or in the foothills as a seperate type, irrigated by seasonal groundwater through a system of underground cisterns (known

[22] This is most obviously delineated by the typology of farm systems described by the Afghan Research and Evaluation Unit Water Opium Livestock baseline report.
[23] In the cultivated river valleys land appears to be constrained while elsewhere water seems to consistently be the limiting factor with other land types.

locally as a *karez*).[24] The third type of land is rainfed arable land. Rainfed land is the most abundant type of land, but also the most unreliable for cultivation because rainfall in the northern regions is sporadic. Rainfed land is not always farmed. It is often used either as supplemental land for wealthier households or marginal land farmed by poorer households who have no access to land with greater water access. Rainfall is closely related to crop diversity and cropping choices are more constrained on rainfed land due to greater variability in rainfall. In practice, this land is cultivated with wheat, barley, or other crops with low water requirements.

Labor: In northern Afghanistan, households provide most of their own farm labor even if they are not purely subsistence farmers. Poor farmers who often cannot cultivate their own rainfed land due to weather or capital constraints, frequently provide paid agricultural labor to those with irrigated land (AREU, 2002). Unskilled agricultural laborers make between 80 to 200 Afghanis per day ($1.60 to $4/day), with the lower bound in rural areas and upper bound in urban labor markets.[25] However, the cultivation of poppies may also partially inflate wages in areas of northern Afghanistan where there is minimal poppy production. Regardless, paid employment for households with mostly rainfed land guarantees at least some household income.

Sharecropping is also common among poorer households and the terms of agreements are determined by a number of factors including; inputs provided[26], amount and price of farm labor, crops cultivated, and land type (Coke, 2004). Given these factors, the landlord generally receives about 25% of the harvest for providing land only; 50% for

[24] Since most of the land in northern Afghanistan is flat plains, the *karez* system is not common around Mazar-i-Sharif.
[25] The afghani to dollar conversion is approximately 50afs:$1 in 2006.
[26] Inputs include the labor, oxen (and related cultivation tools), seed and the land.

providing planting materials and land, and 75% of the harvest when an ox is provided in addition to land and materials.[27] Most commonly, the wheat sharecropper provides labor alone and returns 25% of the harvest to the landlord (Coke, 2004). Rural farmers rarely engage in non-agricultural, off-farm labor in cities and regional centers because transportation is difficult and expensive.[28] Off-farm labor is thus not an option for many rural households.

Nitrogen*:* The Northern Plains are generally fertile loess soils although most arable soils in Afghanistan have high pH with nitrogen as the main limiting nutrient in crop production (Thieme, 2003)[29]. In non-sharecropping situations, available cash is used largely to purchase fertilizers including urea and DAP (and less commonly seeds, pesticides, and herbicides). In situations where no cash is available, households employ manure as fertilizer. Although manure does provide organic matter and vital nitrogen, it is seldom applied or applied only minimally due to its alternate use as cooking fuel (Thieme, 2003). Manure is also returned to the fields in small quantities as animals urinate and deficate while grazing crop aftermath.

Shocks Affecting Crop-Livestock Systems in Afghanistan

Farmers in Afghanistan have historically faced particularly adverse conditions. Ethnic and military conflict has placed serious strain on the mixed crop-livestock systems of Afghanistan. Many of the irrigation tunnels (*kerezes*) were abandoned during the wars and have since filled with silt. Numerous canals were damaged and are no longer able to transport scarce water, rendering formerly arable land largely un-usable. More

[27] Cokes estimates are roughly consistent with Mercy Corps (2004).
[28] Many rural laborers find temporary shared housing in cities during the week.
[29] From http://www.fao.org/ag/AGP/AGPC/doc/Counprof/afgan/afgan.htm.

persistent shocks to the crop-livestock system, however, are drought, temperature shocks, and price shocks which are discussed below.

<u>Drought</u>: Regular ecological shocks plague Afghanistan, including wide-scale, persistent drought, which decreased availability of irrigated winter wheat and reduced forage yields and availability of supplemental feeds for animals. The drought years between 1998 and 2004 were difficult for Afghanistan's livestock sector; many farmers sustained large cattle losses selling off valuable stock to purchase staple foods for household consumption (FAO, 2003).[30] Nearly 80 percent of all Afghan livestock perished between 1998 and 2002 and in some areas as many as 60 percent of households lost all of their animals, decreasing the average number of cattle per family from 3.7 in 1995 to 1.22 in 2003, although mean community size also decreased during this period (FAO, 2003). Periods of low rainfall occur regularly with varying magnitude, particularly in the plains around Mazar-i-Sharif (see discussion above). Low rainfall and decreased groundwater in the Hindu Kush depress yields and affect household income and food security.

<u>Temperature Shocks</u>: Less frequent but often more serious than drought are temperature shocks. Temperature shocks not only reduce crop production but also directly affect farm assets (particularly livestock) and household consumption. An example of a temperature shock occurred in 2007, when northern Afghanistan experienced the harshest winter in 30 years, with temperatures below -25˚ C (ACT, 2008). Despite the Afghan government dispatching feed concentrate to the most affected farmers, inaccessible roads left many households with insufficient animal feed stocks. Effects of the temperature shock on livestock herds included widespread

[30] The accuracy of the 1995 and 2003 figures have been debated due to inconsistency in sampling.

death from starvation, disrupted lactation cycles for feeding calves and decreased breeding rates. Many animals perished simply because they were not able to physically withstand the extreme temperature.

Effects of the temperature shock on crop production included the inability to plow and prepare the land for rain-fed cultivation due to the long period of snow cover and inability to cultivate crops due to the lack of resources and frozen land. There was significant damage to winter wheat yields during the heavy snowfall in January. This resulted in total crop loss for many winter wheat plots in northern Afghanistan although most perennial crops such as alfalfa were unaffected (ACT, 2008).

Economic shocks*:* Economic shocks often coincide with the shocks discussed above that affect production and assets. Seasonal price and wage fluctuations in response to supply and demand and import and export levels can also become relative 'shocks' to a household depending on the household's market position. The presence of shallow markets or high covariance between household supply and price can be a problem for Afghan farmers. Price changes can affect household production as lower income per annum can mean that a household is unable to afford crop or animal inputs for the coming season. More troubling for households are prices increases or decreases over time relative to one another. For example, the current food shortage in Afghanistan has been exacerbated by the soaring price of wheat, which has risen dramatically in the last year (FAAHM, 2008).[31] Along with the high price of wheat has been a dramatic increase in fuel costs for Afghans, evident from the sharp increase in the transportation index (FAAHM, 2008). There is also wide variation in prices that arise from exogenous factors such as high world wheat prices and the low purchasing power

[31] Graphs depicting prices of wheat and transportation can be found in Appendix 4.

of most of the Afghan population, which mean that the domestic demand for wheat cannot be met by imports. Periods of instability in neighboring Pakistan also cause wheat imports to Afghanistan to become less accessible and more expensive than under average conditions.[32]

Interventions in Crop-Livestock Systems in Afghanistan

Various development agencies have initiated interventions in areas where fighting has subsided and households are beginning to recover from the most recent conflict. A wide range of development efforts exist often with conflicting strategies and different "mental models" of what the problem and solutions are. Many of these projects tend to target high value agriculture, including exporting organic tomatoes, greenhouse production, as well as livestock intensification and dairy production. Recent livestock projects have begun to incorporate extension and training for livestock farmers, genetic improvement of animals, promotion of fodder crop production, improved varieties of forage grasses, and localized dairy commercialization as household livelihood strategies.[33]

Interventions curently underway in Afghanistan include cow gifts to households that have lost animals or to recently returned livestock farmers. In some cases, this is a shared animal. This is a common intervention in National Solidarity Program (NSP). Another intervention is the reduction of transactions costs. This is an intervention that Catholic Relief Services (CRS) has been working on in Herat, organizing farmers into cooperative groups where they can sell milk at a local collection point and a trader will

[32] FAO/GIEWS Global Watch: Extreme winter weather in Central Asia and its effects on food security. April 2008

[33] Aga Khan Foundation, ICARDA and FAO have been implementing livestock projects under RALF that focus on increasing milk production through improved management as well as improved feeding.

come to the village to collect milk daily taking a cut of the final price. Another intervention is the introduction of new fodder species with higher yielding potential than current varieties. FAO is implemnting this strategy in many areas, primarily where they have established milk processing plants. FAO reports yield increases for alfalfa of approximately 200 kg/jerib/year (1000 kg hectare) without additional costs. In conjunction with this effort, FAO is also encouraging households to plant more forage, including improved alfalfa as well as improved clover (*berseem* and *shaftal*) and grain crops (including sorghum and wheat). This type of land reallocation intervention implies that farm households need to shift land out of other crops to accomodate increased forage production.

The next chapter focuses on an appropriate method for addressing the research problem in the context descriped above. Relevant characteristics of the problem, possible methods and important theoretical comments are discussed. Specific interventions used in model simulation are also discussed in more detail in Chapter 4.

CHAPTER 3

METHODS FOR EX-ANTE ANALYSIS OF INTERVENTIONS ON CROP-LIVESTOCK SYSTEMS

Nature and Characteristics of the Research Problem

There are many reasons for delays in the planning and implementation of agricultural production projects in developing countries (Nicholson, 2005). This is especially true in Afghanistan where shocks regularly disrupt normal biological cycles and influence dynamics in agriculturally-based livelihoods. In agricultural systems, a dynamic model specification is required to capture important time delays, cropping patterns, seasonal fluctuations in weather, and other factors that change over time. Dynamic specifications are also important for impact assessment where exogenous parameters such as rainfall or prices change over time.

In evaluation of the biological impact of production systems, the timing of management operations and activities is an important determinant of whether soil nutrients are adequate, nutrient flows in animal waste are recycled, or whether nutrient losses are likely. Depending on the production system, the key indicators, and the subsequent scenario analysis, dynamic production models may best capture crop rotations or the endogenous timing of production decisions (Antle et al., 1994). A dynamic specification is also important to capturing the results of interventions fed back through economic and biological channels. In developing transition strategies that might improve the effectiveness of development interventions, particularly for activities like dairy production, it is essential to capture dynamics appropriately.

Subsistence and semi-subsistence farm households in crop-livestock systems are best understood as integrated biophysical and economic units, combining biological cycles of crops, soil, and livestock with economic decision-making. The underlying biophysical cycles involved in crop-livestock farming (such as animal reproduction and nutrient absorption) are dynamically complex and can influence economic outcomes. Given the focus of the research question on the interaction between biophysical and economic processes, an approach conducive to integration of these components is of primary importance. When considering the economic outcomes and constraints for higher-valued agricultural production, specifically dairy production, it would be a mistake to ignore these underlying biological processes.[34]

A principal limitation for this analysis and crop-livestock modeling more generally, is the lack of sufficiently detailed data to allow estimation of an integrated model. Because the question is multi-disciplinary and requires a wide variety of household survey data, a variety of sources and an appropriate method for testing sensitivity of certain parameters is also required. Causal or "soft" variables are also difficult to capture and often difficult to collect using survey methods, so alternative methods of data collection and flexibility in data use are required.

There are multiple empirical methods that could be used to address the research question given the nature and characteristics of the problem. To evaluate the profitability of a mixed crop-livestock system basic choices must be made, including whole versus partial farm analysis and static versus dynamic evaluation. A whole farm approach is appropriate in the context of livestock interventions in Afghanistan

[34] Dairy production is being evaluated on its own merits in the context of an emphasis on high value production but not as a proxy for high value production.

given the crop livestock interactions and a dynamic approach is more appropriate to address transitions, delays, and responses to shocks that are important dynamics for crop-livestock systems.

Ex-Ante vs. Ex-Post Analysis

In Afghanistan, limited data exist on crop-livestock systems due to the frequency of conflict over the last three decades. Ex-ante impact assessment for farms can be extremely useful in this setting, allowing practitioners to examine the feasibility or impact of a given intervention. The goal of ex-ante studies is to identify research areas that will likely provide the greatest beneficial impact among possible interventions in a system.[35] The effects of many of the interventions in Afghanistan have not been studied previously in any detail. Ex-ante analysis is useful in situations where it would be costly or infeasible to conduct multiple interventions in order to identify priorities for interventions and information.

Ex-ante analysis can be conducive to realistically representing the explicit relationship between productivity and the physical environment if economic outcomes of crop production can be linked to empirical biological modeling. Ex-ante modeling also can more easily address periodicity problems.[36] The statistical relationships identified using *ex post* regression methods often are assumed to persist into the future, but this is often an important research question (Thornley, 2000). Alternatively, ex-ante assessment can, when designed appropriately, explicitly address relationships that

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[35] Ex-ante policy analysis is almost always a contentious area practically and methodologically (Herrero, 2002). Ex-ante methods are often discouraged in agricultural economics in favor of more empirical ex-post methods, in part due to past abuse of ex-ante methods, typically based on a wide variety of (unrealistic) assumptions and insufficient transparency.

[36] Periodicity refers to the dilemma when the data required to answer a question is longer than that of the phenomenon of interest.

change over time. The following work is thus an ex-ante assessment of relatively new but previously introduced technologies (or interventions) currently being implemented in Afghanistan by governmental and non governmental organizations.

Characteristics of Similarly Specified Models

Numerous previous studies have employed various types of models and model specifications to address similar questions. One common approach is optimization modeling. For example, Bernet (2001) used a household level crop-livestock linear-programming model based on fixed production activities, constraints, and variable features related to crop and livestock production. Site-specific inputs (irrigation water, labor, capital, and feed) are optimized given variation in production factor needs and availability with user-defined data to maximize annual farm profit. The major assumption of the model, typical of linear programming (LP) models more generally, is that the single goal to be optimized is farm profit at the end of the period, neglecting the transition to the goal and the dynamic interaction between crops, livestock, and soil dynamics over time. Optimization models such as LP include a specific algorithm for optimization and require a set of well-defined choice alternatives. Optimization models are thus useful for making prescriptive statements to maximize objective function decision variables given resource constraints. The objective function, however, embodies fixed values and preferences that may not well reflect values that are difficult to quantify, preferences, and goals of the farm household. While this type of LP model addresses a similar question, it fails to address dynamics in the depth desired or fully integrate the biological and economic components of the problem.

Another frequently used set of methods are referred to as bio-economic models that integrate, as their name suggests, biological and economic decision making components. Brown (2000) noted that there is a continuum of emphasis on biology or economics for these models and few successfully integrate both disciplinary perspectives. Many interdisciplinary analyses (or models) make highly simplified assumptions about either the biophysical or economic component of the problem, ranging from empirical biological process models using biological data to economic optimization models with biophysical features (Brown 2000).

One relevant example model monitors nutrient flows and economic performance in African farming systems (NUTMON; de Jager and Van den Bosch 1998). NUTMON uses stocks and flows of nutrients (animal, plant, soil and household) and financial resources based on empirical measures for a given farm household. NUTMON, however, simplifies biological processes using a fixed set of parameters for a finite set of activities (a biological indicator is used as a proxy for the sustainability of the system).[37] NUTMON is thus not a true biological process simulation model, but an exploratory empirical evaluation of the performance of a farm household (Brown, 2000).

Other integrated models rely heavily on economic optimization given identified objectives and biological resource constraints, such as the Mali Bio-Economic Farm Household Model (Kuyvenhoven et al, 1998; Ruben et al, 2000). The Mali Bio-Economic Farm Household Model simulates households with different resource endowments in a multi-objective optimization framework and links simulated biological processes, although not in a dynamic sense. Economics-based models such as this often make assumptions about information and choices available to decision

[37]The balance of the major nutrient flows and the financial flows are assessed for a given situation in terms of long term sustainability given current levels (Brown 2000).

makers which may be important for the integrated research question (Brown, 2000)[38]. While this type of approach is integrated, it ignores the dynamics and delays of the economic and biological processes.

Another example of a dynamic integrated model that addresses biological-economic research objectives is the Trade-Off Analysis (TOA) (Stoorvogel, 2004). The TOA model is an ex-ante evaluation of technologies for potato-pasture production systems in the Andes, simulating land use and input use decisions based on household economic and biological data to quantify the tradeoffs between economic and environmental policy objectives. TOA avoids simplification of a production function by incorporating a process model without using ad hoc indicators for biological processes.[39] TOA does not rely on a single representative farm and is able to explain spatial variation in economic behavior and link that behavior to a spatially explicit bio-physical process model. The TOA model uses parameters drawn from the literature, expert knowledge, and sensitivity analysis to simulate changes in productivity. TOA is thus an example of a dynamic model that incorporates biological and economic components in addition to drawing on a range of alternative data sources to evaluate farm households.

Another example of an integrated dynamic simulation model is the CLASSES model, which used empirical livestock and crop components as well as economic decision-making (Stephens et al, 2008). CLASSES explained soil degradation in Kenya through a dynamic specification and linking biological and economic components

[38] Such as marketing behavior, allocation of resources to farm and non-farm activities, consumption choices and patterns, and the possible implications of different objectives for the household.
[39] TOA is an econometric model (using a range of input combinations) but not simplified to generalized form: *f* (v, z, e), where v is a vector of variable inputs, z is a vector of fixed inputs, and e is a vector of biophysical factors

using system dynamics simulation. The CLASSES model draws on a variety of sources for parameter estimation, including expert opinion, survey data, crop data, and an empirical livestock nutrition model.

System Dynamics Method

Similar to the CLASSES model, this study uses the conventions of System Dynamics (SD) to develop a dynamic simulation model used for ex ante analysis. System Dynamics is a subset of formal computer simulation, based on the application of systems engineering to social and economic systems. It combines a numerical integration method of computation with a particular perspective on the modeling process.[40]

System Dynamics is considered particularly useful for impact assessment in complex dynamic systems (Sterman, 2000). The SD method focuses on stocks, flows, and dynamics resulting endogenously from system structure. The most relevant element of SD modeling for this research question is the focus on the dynamic, rather than detail complexity, of a problem. Dynamics are important when an action has dramatically different effects in the short and long run (referred to as dynamic complexity) and when there are significant delays in the system. System Dynamics modelers believe dynamic behavior can result even from a small number of causally-linked variables. Although many economic models focus on external or exogenous shocks to the system, SD focuses on the internal structure and behaviors of the system. The SD perspective views dynamics as a function of the causal structure of the system and SD modelers believe that the 'structure and decision rules' reveal 'patterns of

[40] A more detailed discussion of the SD perspective can be found in Nicholson (2005).

behavior created by those rules and that structure and explain how the behavior may change if you alter the structure and rules' (Sterman, 2000).

The SD modeling perspective is conducive to integrated biological and economic modeling. Computer simulation using SD can both link empirical biological (crop or livestock) simulation models and can also be used for optimization.[41] Because SD emphasizes the structure of the system and is solved with numerical integration, it is possible to incorporate the aspects of an empirical biological model that are necessary to explain or explore the dynamics of a particular problem. There is an emphasis on the conditions that make a system stable or unstable, not solely on point predictions or the qualitative outcome of a model.

The SD method is also advantageous because it lends itself to incorporation of information from a wide variety of sources. Inclusion of unknown or difficult to quantify variables is possible through parameter testing, structure testing, and sensitivity analysis to explore uncertain variables that may be left out of more traditional economic models. The result is often a more logical model that can process complicated assumptions into logical error-free conclusions (Meadows and Robinson, 1985). This can be particularly advantageous for applications to crop-livestock simulation where sufficiently detailed survey data do not exist.

Depending on the research question, research environment, data restrictions, importance of dynamics to the problem, and objective of the research, computer simulation using SD can be an appropriate method of analysis. An SD *ex-ante* impact

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[41] Optimization routines can be useful to identify promising strategies and interventions, even if it is assumed that farmers are not strictly optimizers and can be used to identify appropriate intervention parameter values.

assessment tool is the method chosen here to model the impact of an intervention on the dynamics of a mixed crop-livestock system. The SD model is specified using a theoretical framework discussed below.

Agricultural Household Model as a Theoretical Framework

When considering ex-ante whole farm analysis in a dynamic context, production and consumption of the representative farm are interdependent. Given the description of mixed crop-livestock systems in Chapter two and the subsistence and semi-subsistence nature of farm households in Afghanistan, it is logical to consider the literature on Agricultural Household Models (AHM). In the development economics literature, the AHM is used as a theoretical framework to explain seemingly sub-optimal decision-making among subsistence farmers. The AHM was developed as an extension of neoclassical economic theory, incorporating interdependency of production and consumption with decision-making in response to the change in relative prices of input and output variables (de Janvry, Fafchamps, and Sadoulet, 1991).

For subsistence households that face incomplete markets, it is potentially important for policy design to address production and consumption simultaneously, in a non-separable agricultural household model (Singh, Squire, and Strauss, 1986).[42] When markets are incomplete, as they are in many less developed countries, the magnitude of the price of a good may be increased within the household causing apparent sub-optimal decision-making (de Janvry and Sadoulet, 1991). If the market is not used for a transaction because the subjective equilibrium price falls within a price band[43], an internal equilibrium of supply and demand determines the shadow price or effective

[42] Market failure can be caused by (a) high transaction costs, (b) shallow local markets, and (c) high price variation and risk aversion behavior. This is discussed in much more detail below.
[43] The price band is the range of possible prices on the household's suply or demand curve.

decision price for the household. Without complete markets, consumption decisions and production decisions jointly establish the *shadow* price, and are thus non-separable.

The AHM is a useful explanatory framework for modeling because it encompasses conditions occurring in Afghanistan that can constrain high value production at the household level. These include high transaction costs in product markets and a high-risk production environment. Transactions costs arise from many factors common to farmers in developing countries. If transactions costs are significantly high, households find it unprofitable to buy or sell a good and thus remain autarkic (de Janvry, Fafchamps, and Sadoulet, 1991). Farm household responses have been documented under various high transactions costs scenarios, including imperfect labor markets in Mexico (Sadoulet, de Janvry, and Benjamin, 1998), the maize market in Kenya (Omamo, 1998), and capital (de Janvry, 1992). These studies demonstrate that seemingly inefficient cropping choices can be explained as 'rational food import substitution' given the high transactions costs in product markets. If these transaction costs are high, then the high internal value of food production may be a constraint to higher value production.

Moreover, transaction costs are not always observed because high transaction costs inhibit participation of households and communities in the markets. This appears to be true for a large portion of rural Afghanistan.[44] Afghanistan has some of the poorest infrastructure in the world, as a function of distance, topography, and extreme

[44] Qualitative interviews in Herat Province revealed that despite relatively high milk levels of milk production among peri-urban households it was reportedly unprofitable to sell milk once transport and transactions cost were factored in.

weather conditions, which result in high transport costs.[45] In addition to high transport costs, market studies indicate that excessive marketing margins exist due to an informal social hierarchy, cronyism, and merchants with local monopoly power (Pain, 2006). This informal social regulation restricts competition and participation, increasing transactions costs further (Pain and Lister, 2004; Lister and Karaev, 2004).

Subsistence households often adjust agricultural production strategies to favor household consumption. Paxson (1992) found this to be due to multivariate risk and uncertainty as a function of the spatial nature of farming, dependence on weather and water resources, and other location-specific factors. In complete markets, food market integration reduces the need for food self-sufficiency, but in many developing country scenarios "food security at the household level is best assured by food self-sufficiency" (Fafchamps, 1992). Rational preferences for food security can lead to the development of ex-ante risk aversion tactics, such as enterprise selection and diversification on and off the farm (Fafchamps, 1992).

Other observed ex-ante risk aversion measures include accumulation of assets such as livestock that can be liquidated in a bad year (Rosenzweig and Wolpin, 1994; McPeak, 2006). The low input-low output strategy of livestock ownership in less developed countries livestock may seem irrational or unprofitable. However, feeding strategies to increase milk production can be even more unprofitable given the high risk of death from external shocks. Desta (2003) found that given the high risk environment and possibility of loss in Ethiopia (due to disease, theft, and starvation of livestock during drought), the seemingly sub-optimal practices may actually be the optimal decision for the household.

[45] Such as drought, harsh winter temperatures, flooding from early summer warming.

There is also a significant body of literature on expectations and uncertainty of agriculture due to water resources in Afghanistan (MIWRE, 2004). The traditional water management system in Afghanistan is frequently plagued by unequal development interventions, negative downstream externalities, and disruption by commanders and political leaders causing many irrigation systems to lack proper maintenance and fall into disuse (Anderson, 2006). Risk and uncertainty in Afghanistan is also associated with scarcity of water as a function of persistent low rainfall and drought, particularly on rainfed cropland. Battacharyya et al (2004) concluded that drought is at least partially to blame for the degradation of resources and falling productivity in Afghanistan. Drought and water mismanagement has also been linked to internal conflict in Afghanistan, a factor which can compound production risk with a social component (Lee, 2005). Another facet of social risk in Afghanistan is the risk of producing illegal crops. Mansfield (2002) suggested that given the low water requirements for poppy, the risk of eradication is potentially lower than the risk of crop failure of other crops due to extreme weather events. Mansfield (2002) concluded that poppy is a low risk crop in a high risk environment.

Constraints on high value agricultural production such as high transaction costs in factor markets and high risk in production can have implications for food and labor markets. These constraints and incomplete markets more generally can result in quickly changing shadow prices that may lead the household to perceive more serious labor and food scarcities than external actors (de Janvry and Sadoulet 1995). For a household that both produces and consumes wheat, a bumper harvest lowers the price of wheat and may actually diminish the food security of a household, if it decreases their purchasing power (Coke, 2004). However, if wheat prices rise due to a food shortage, households which are net buyers of wheat will face higher consumption costs than households who are self sufficient in wheat.

High negative co-variation between household supply and effective prices is known as a "shallow market".[46] Shallow local markets for staple crops can lead subsistence farmers to believe every year is a bad year and limit their response to price incentives and new technologies (de Janvry and Sadoulet, 1995). Shallow local markets for food and or labor can constrain a farm households' ability to respond freely to price incentives and other external shocks (or policies) as policy makers might predict. Shallow local markets can thus force subsistence farm households to produce more non-traded products such as food crops and allocate more resources such as household labor to food crop production (de Janvry, 1991).

Adjustments to prices that are not established in product markets may also spill over into the labor market. Returns to labor are especially important to subsistence farmers who demand hired labor, allocate labor to internal household production, or allocate labor to off-farm activities. If there is a high opportunity cost for labor, internal allocation of labor can be affected in a seemingly irrational way. Factors that possibly influence the opportunity cost of labor in northern Afghanistan are a) variable flows of wages and labor due to movements of returnees and refugees, b) off-farm and casual labor related to development projects (such as road-building), c) remittance opportunities in neighboring countries, and d) poppy production.[47]

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[46] Wheat prices can vary negatively with supply since all farmers in a given region experience similar conditions and have similarly high or low yields.
[47] The casual wage rate in Mazar is about $4/day, generally higher than other regions of Afghanistan.

If there is a high opportunity cost of labor, this can lead to a backward bending labor supply curve, wherein the income effect of increased wages from off farm labor outweighs the substitution effect (as a result of the change in the opportunity cost of labor). If there is a low opportunity cost of labor, the household might choose to devote more labor resources to staple crops or less water intensive crops than off-farm labor, thus mitigating its production risk.[48] In Balkh province, there is a relatively high amount of poppy production (for northern Afghanistan), an abundance of development projects, and substantial immigration. However, there is an apparently limited supply of labor opportunities and many casual laborers anticipate work in Mazar-i-Sharif daily, but are unsuccessful.

Thus, to model the current situation in northern Afghanistan's crop-livestock systems, a dynamic simulation model that incorporates elements of the AHM framework is appropriate. The model developed for this study employs a whole farm approach, modeling both production and consumption. Chapter Four describes the SD model in additional detail.

[48] This is assuming that there is a demand for labor which is not necessarily the case for unskilled labor.

CHAPTER 4

MIXED CROP-LIVESTOCK SYSTEM DYNAMICS MODEL

Model Overview

This chapter describes a household-level mixed crop-livestock SD simulation model constructed to assess the impact of alternative interventions proposed to increase livestock production among Afghan households. System Dynamics computer simulation models, such those using Vensim® simulation software, use numerical integration to calculate numerical solutions to systems of differential equations. Because many such systems of differential equations cannot be solved analytically, algorithms are used to compute an approximation. The Runge–Kutta method of solving differential equations is used in this model.

The model is a stylized representation of the crop-livestock system at the household level and is intended to capture the basic dynamics and relevant feedback loops associated with crop and livestock production. The household is assumed to produce staples (wheat), forage (alfalfa), and livestock (cattle) and model parameters are based on survey data collected in Balkh Province in July 2006.[49] The model includes components that describe the cattle herd structure, inputs and outputs of crops, inputs and outputs of livestock, and the household as well as underlying soil dynamics and cash balance. Household decision rules and interaction with the market are simplified, to allow an examination of the dynamics of the interventions if they were to be adopted and maintained by the household indefinitely. Thus, many resource allocation

[49] The household survey instrument is included in Appendix 8 and the methodology is described in the section entitiled "Description of Model Scenarios" below.

decisions are assumed to be exogenous or excluded, which is appropriate given the nature of the research question. These assumptions and their justification are discussed in more detail below.

Simulation scenarios examine alternative interventions to increase livestock production: increasing herd size, raising forage productivity, reallocating staple land to forage, and lowering transaction cost for marketing milk.   These scenarios form the basis of an *ex-ante* impact assessment of the associated transition constraints, pathways, and outcomes. The transition dynamics to higher levels of livestock and forage production assume the same land area, but involve reallocation of land and reflect current development interventions being implemented in Afghanistan.[50] The welfare of the household given implementation of these interventions is evaluated first under baseline conditions that assume no significant environmental and market shocks, then using scenarios that shocks common to this system (such as low rainfall or drought in 2001-2 and 2006 and severe cold weather in 2008). Indicators of household welfare reflect the notion of "full income" and are evaluated with respect to the baseline simulation and outcomes of other interventions.[51]

Basic Elements and Assumptions of the Current Model

This section documents the general assumptions of the model by model view.[52] Parameter estimates and mathematical assumptions are documented when relevant to the discussion.[53] A key assumption in any dynamic model is the assumed length of

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[50] These interventions are discussed in more detail in Chapter 3.

[51] Full income accounts for the value of all production by the household, whether or not that production is sold for cash.

[52] Graphics of Model "Views", or a collection of related stocks, flows, and auxiallry variables in the Vensim© computer simulation software, are included in Appendix 9.

[53] Comprehensive parameter estimates and assumptions can be found in Appendix 1 and Appendix 2 respectively

the simulation. The model time horizon in this case is set at 120 months (ten years) to evaluate interventions over a period consistent with the delays inherent in herd dynamics and other elements of the crop-livestock system.

Herd Structure: This "aging chain" structure is based on discrete animal stocks and flows using a combination of fixed and variable delays (referred to as material delays in Vensim®) to track individual animals through various growth stages. There are six different classifications of animals including: calves, heifers, lactating open cows, open dry cows, dry bred cows, and bulls. Initial herd dynamics arise based on an initial animal population and average growth and reproduction rates estimated from household survey data.[54] Parturition is a function of either first calving (for heifers) or the calving interval (for open dry cows) and generates a calf of random gender based on these delay times.[55]

Female animals age and move through the stock flow structure, growing and reproducing at fixed rates (maturation delay from calf to heifer, lactation length, and gestation time)[56] and variable rates (heifer and open dry cow parturition times) until the end of their average productive lifetime. Maturation delay (time to become a heifer or one year by definition) and gestation time are constant across farm systems. These variable reproduction delay times (heifer parturition rate and calving interval) are endogenous based on the ratio of metabolizable energy (ME) intake to ME for maintenance requirements. The variable parturition delay time (Y*) is a function of

[54] Households were surveyed in two communities, Sherabad and Charbolak. The survey methodology and the differences between the two communities are described in more detail below. Focus groups were also conducted and are described below.
[55] Average first calving across survey data was 27 months and average calving interval was 31 months.
[56] These times are fixed at 12 months, 10 months, and 9 months respectively. Only lactation is an average from survey data.

the effect of the ratio of ME intake to ME required for maintenance on reproduction (E) as a lookup function (μ) and the average parturition delay time given average feed requirements (Y_a)[57]. It is calculated as follows:[58]

$$(1) \qquad Y^{*}= \mu (E)^{*}Y_a$$

If the ME intake falls below the maintenance requirements, this will precipitate the decision to sell an animal[59] [60]. Female animals are also sold when they reach an age equal to their average productive lifetime. Male animals are tracked separately and the structure assumes exogenous maturation rates. Oxen sales take place when the HH accumulates two draft animals and a third male calf reaches the maturation, or at two years, when oxen are reportedly used for draft in Afghanistan.[61] Oxen are maintained for draft and kept until they reach average productive lifetime.[62]

Livestock Inputs: Staple residue (wheat straw and stubble), forage (alfalfa), local grass, and cottonseed meal are allocated to animals by priority by class.[63] Lactating animals receive the highest priority, open dry and dry bred animals the next priority whereas heifers, calves, and male animals receive the lowest priority. Feed is also allocated in accordance with reference or average diets drawn from farm-level average intake data per animal by class (see Appendix 2). Characteristics for each class of cattle are entered into the Cornell Net Carbohydrate and Protein System (CNCPS) model to estimate animal outputs (discussed below).[64] Lactating animals receive highest

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[57] All model variables and some model parameters are time dependent. Time subscripts are supressed in equations in this chapter for for ease of exposition.
[58] Note that (E), the ME Intake: ME Maintenance Ratio (for each animal) is smoothed over one month.
[59] In reality the animal could die if this occured (depending upon the body condition score) but since this is based on monthly feed intake, it is assumed the household will anticipate the dwindling feed supply.
[60]Note that animals are not sold to meet unanticipated cash needs but are sold when feed stocks get low.
[61] From focus group discussion in Mazar-i-Sharif.
[62] Average productive lifetime of lactating animals was estimated to be 108 months and 120 for oxen.
[63] Feed priority specification is based on farmer interviews and focus group data.
[64] CNCPS Version 6.1.0.12. This is a dairy nutrition model designed at Cornell University which can be accessed on the internet at: http://www.cncps.cornell.edu/

priority, then dry open cows and dry bred cows, with heifers, bulls, and calves receiving the lowest priority in terms of quantity of feed offered.

If the household does not have sufficient feed (forage or staple residue), the household will purchase additional feed at the market rate up to animal reference feed values (and incur the transaction costs associated with monthly purchases of feed).[65] It is assumed that there is a seasonal feeding pattern, wherein households purchase and feed a small quantity of cottonseed meal to lactating animals in the winter months.[66]

All feed estimates in the model are on a dry matter basis (not as-fed), and crop production is also reported on a dry matter basis. Energy from various feeds is predicted from the NDF content of the forage samples collected from the communities where the survey was conducted (Table 4.1).

Table 4.1 Dairy One Forage Testing Laboratory Results (collected July 2006)[67]

Sample (*local name*)	**DM (%)**	**CP (%)**	**NDF (%)**	**TDN (%)**	**Lignin**
LocalGrass (*alaf*)	95.3	10.6	25.7	67	N/A
Lucerne- fresh (*rishka*)	91.6	22.8	31.9	63	7.7
Lucerne- dry groud (*beta*)	92	18.5	31.4	62	7.7
Cotton Seed Meal (*kunjara)*	94.9	27.8	52.7	56	8.8
Wheat Straw- ground (*tarrit*)	93.8	7.0	68.3	60	3.5

[65] This assumes that houeholds purchase feeds regardless of price. This simplification was necssary to maintain animal performance within appropriate bounds, and is consistent with other crop-livestock models (e.g., CLASSES, Stephens et al., 2008).

[66] This practice was common among households surveys in northern Afghanistan, ranging from 0.25 to 2.5 kg cottonseed meal per day.

[67] This Dairy One Forage Analysis Laboratory is located in Ithaca, NY. A description of the procedures used to determine the components of the forage samples can be found on the internet at: http://www.dairyone.com/Forage/Procedures/default.htm

ME intake for animals is calculated based on the reference diets and the Mcal per kg estimates for the reference level fed of each feed using ME predictions from the CNCPS.[68] For non-lactating animals, a ratio of ME intake to ME maintenance requirements is computed where maintenance requirements are estimated based on the animal's physiological state and supply of ME using the CNCPS Version 6.1.0.12. (Traxler, 1997; Tedeschi, 2002; Fox, 2004). This ratio is used to determine the reproduction delay times (as mentioned above) as well as used as a decision rule for animal sales (also discussed above).

For lactating animals, the quantity of ME allowable milk is calculated using the ME balance (Monthly ME Intake less Monthly ME Maintenance and Milk) and a simple tissue mobilization structure represents repletion and mobilization of tissue when feed nutrients are limiting.[69] Actual tissue mobilized (T_m*) and repletion (T_r*) are computed using a mobilized tissue per Mcal constant (T_m) and a replenished tissue per Mcal constant (T_r) and the magnitude of the ME balance, where T_m=0.13 and T_r =0.08 from CLASSES model, specified as follows:

$$(2) \qquad T_m^* = -(\text{MEbal}) * T_m$$

$$(3) \qquad T_r^* = (\text{MEbal}) * T_r$$

ME from mobilized tissue is available when the energy from tissue mobilization is added to the ME allowable for milk (when animals are drawing energy from reserves). The monthly ME available for milk per lactating animal is the difference between the monthly ME intake plus energy from tissue mobilization and the ME requirements for

[68] For example, if the reference diet contains 5kg of alflafa then the Mcal per kg estimate for alfalfa is based on CNCPS simulation of feeding 5 kg of alfalfa to a cow.
[69] Note that the mobilization rate is constrained by a minimum of 0 and maximum fractional mobilization rate (0.5) and the minimum body fat content of the animal (initial body fat*0.25).

maintenance (note that growth and gestation requirements are not included in the energy estimates). This value then is used in the livestock outputs view to compute actual milk production levels. Tissue repletion takes place when the ME balance (intake less requirements) is greater than zero.

Livestock Outputs: The three livestock outputs are milk, additional calves, and manure. Total milk yield per lactating animal is a function of the surplus ME, or ME available for milk from the livestock inputs view. ME available for milk (E_m) (from the livestock inputs view), ME to net energy for maintenance efficiency (α) and milk energy potential (E_p) are used to determine the daily animal response or milk yield based on the ME available for milk, as follows:

$$(4) \qquad E_m = \alpha / E_p$$

Milk energy potential (E_p) can be predicted from the Mcal per kg Fat constant (f_m), the average fat content of milk (f_a) and a milk constant (m).[70] Milk energy potential is given as:

$$(5) \qquad E_p = (f_m * f_a) + m$$

Fed the basal diet, animals produce an average of 6.9 kg of milk (M_a), a value that varies during the average ten-month lactation. For simplicity, lactation length is assumed to be constant regardless of nutrient availability. Lactating animals produce higher or lower levels of milk based on the ME content of the diet. The milk yield is calibrated based on a series of estimations for an average (or baseline) diet, a low-nutrient diet, and high-nutrient diet using the CNCPS (Table 4.2).

[70] Estimates for these parameters can be found in Appendix 1.

Table 4.2 High Endowment Household Lactating Cow Diet Inputs and ME Outputs from CNCPS

CNCPS runs for model calibration	Sherabad Low Diet	Sherabad Base Diet	Sherabad High Diet
Wheat Straw (kg)	4	5	5
Alfalfa Hay (kg)	4	5	8
Local Grass (kg)	0	0	0
Cottonseed Meal (kg)	0	0.5	1.8
Total DM diet	8	10.5	14.8
ME Supply	15.6	20.1	29.1
ME Maintenance	10.1	10.5	11.
ME Lactation	7.3	7.3	7.3
ME Balance	-1.8	2.4	10.7
Allowable Milk (kg/day)	2.86	6.83	14.79
Manure, fecal (kg)	17	23	32
Manure, urine (kg)	9	12	20
Total Wet Manure (kg)	27	36	52

The quantity of daily ME required to produce milk is also calculated based on coefficients drawn from CNCPS and values calculated above. Daily ME milk or the amount of energy required to produce milk (E_L) is determined by milk energy potential (E_p), average daily milk production (M_a), and ME to NEm efficiency (α).

$$(6) \qquad E_L = (\alpha / E_p) * M_a$$

Daily ME Milk depends on the average milk daily milk production of the animals and is used to estimate the ME balance for each animal. Of total milk produced per day, a fixed proportion of milk is assumed to be consumed by the household (3.75 kg/month). The remainder (if any) is sold if the value of the milk is greater than the daily transactions costs of selling milk. A social rate of taxation is placed on milk production to capture the culture of gifting milk and receiving gifts of milk.[71] The

[71] Milk gifts are ssumed to be roughly twenty percent of total household production based on FAO data (5 kg sold, 2 retained) and Levitt estimates (1kg consumed). It should be noted that this is an imperfect

household donates milk to neighbors when there is a lactating animal and receives milk when the household animals are dry. The total yield of milk (Y_m) is thus defined by ME Available for milk (E_m), ME to NEm efficiency (α), milk energy potential (E_p), and milk gifts (M_g) as follows:

$$(7) \qquad Y_m = E_m*(\alpha/ E_p)+M_g$$

The total quantity of livestock manure production is based on CNCPS using reference diets and output for animals by class. Manure is not commonly applied to crops in Afghanistan. However, a portion of manure produced is returned to the soil while animals graze crop aftermath, following staple and cash crop harvest.[72]

Labor for livestock is disaggregated by activity (feeding, grazing, feed collection, and milking).[73] Total livestock labor (L_t) is of the sum of these disaggregated labor activities.[74] Grazing labor (L_g) is assumed to be a fixed amount for the herd whereas feeding (L_f), feed collection (L_c), and for milking (L_m) are calculated based on the number of animals (A_{nl}) and lactating animals (A_l) in the milking labor case. Total livestock labor is calculated using the equation specified below:

$$(8) \qquad L_t = 2\ L_g + (0.5\ L_f + 0.5\ L_c)\ A_{nl} + 0.5\ L_m * A_l$$

Crop Inputs and Production: Land allocation to staples, forage, and cash crops reflect fixed production strategies that are assumed to be maintained throughout the model time horizon. That is, the household does not endogenously reallocate land during

formulation since many households experience the same conditions and thus have dry animals at the same time (eg. winter months).

[72] This is estimated to be 25% of herd manure production since animals spend approximately 25% of their time grazing (for approximately one month) following the cash crop and staples harvest.

[73] Livestock labor estimates are rough approximations based on a combination of household survey responses (for grazing and feed collection) and discussion with farmers (for feeding labor).

[74] These equations are parameterized with a combination of survey data and focus group data.

simulation, consistent with the objective of evaluating each intervention's impacts if adapted and maintained indefinitely. Perennial alfalfa is often cultivated by farmers who have sufficient water and it is usually managed for seven to ten years, at which time rotation between alfalfa and other crops is common. However, for simplicity, it is assumed that forage is grown independently whereas staple and cash crops are rotated. Variables associated with land use are accounted for in the soils and nutrient flows view through the use of subscripting land by perennial type for forage and annual type for staple and cash crop rotation.[75] All parameters related to forage are based on alfalfa data, staples on winter wheat data, and cash crops on multiple sources of vegetable data.[76] A schedule of crop activities (see Appendix 5) is used to coordinate crop production (and labor activities, discussed below) with time =1 representing January. It is common that crops are rotated in two to three-year fallows (for staple crops), although in many cases, fallow is by default because a lack of rainfall limits cash crop production. In the model, it is assumed that there is no rotation other than staples and cash crops and, when there is insufficient rainfall for crop growth, there is a fallow period.

Crop production (Y) is assumed to be a function of the amount of land planted to each crop in jeribs (J) and three variable inputs: labor (L), water (W), and nitrogen (N), as described in chapter three.

$$(9) \qquad Y = f(x) = (J, L, W, N)$$

The final determined value of production is a function of the land quantity and the most limiting variable factor of production. Each of the input limiting yield values is determined in a different way. Labor affects yield through a multiplicative effect on

[75] Subscripting is a way to seperate different portions of the model into vectors, where elements are calculated independently (in this case to differentiate land types).
[76] These data are from various sources described in the table in Appendix 1.

the maximum observed yield. The labor limiting crop yield (Y_L) is determined by the ratio of actual labor available for each crop (L_{act}), the required (or average labor for that crop) (L_{ref}), and the maximum crop yield achievable (Y_{max}).

$$(10) \quad Y_L = (L_{act}/L_{ref})*Y_{max}$$

Nitrogen and water (including rainfall data and irrigation norms) affect yield through the use of lookup functions and reference values of nitrogen and water for crop production. Nitrogen allowable yield is based on the amount of soluble nitrogen in the soil multiplied by a lookup function[77] of the ratio of the actual nitrogen available to the reference (or average value) divided by the fraction of nitrogen in the crop biomass. Nitrogen limiting crop production (Y_n) is determined by the soluble N in the soil (N_s), the reference N for crop production (N_{ref}), the effect of N on (crop production) efficiency (μ), and the fraction N in crop biomass (N_b). The relationships are specified in the following way:

$$(11) \quad Y_n = (N_s * \mu(N_s/N_{ref}))/N_b$$

Water allowable production (Y_w) is a function of rainfall limiting production (Y_r) and irrigation limiting production (Y_i). Water allowable production is calculated as such:

$$(12) \quad Y_w = (Y_r+Y_i)$$

Each crop has a unique reference value for production because the average rainfall over each crop growth period is different. Reference values of rainfall thus represent the quantity of rainfall necessary to reach the maximum crop yield.[78] Similar to N limiting production, the effects of rainfall on crop production are also estimated based on based on the average rainfall and average yield. Rainfall limiting crop production

[77] Vensim permits the specification of nonlinear relationships through the use of "lookup functions", which return an output y value given the input x value and the shape of the function. The shape of this particular lookup function takes is approximately equal to y = (x / 2.5). Graphics of lookup functions can be found in the Appendix.

[78] Reference values for rainfall are calibrated based on average yield data and average rainfall data with upper (maximum crop yields reported) and lower (minimum crop yields reported) values matched with low rainfall periods. Specific values can be found in the model parameters table.

(Y_r) is determined by the effect of rainfall on crop production (μ),[79] and the actual (R_{act}) and reference values (R_{ref}) of rainfall to achieve average and maximum crop yields.

$$(13) \quad Y_r = \mu(R_{act}/R_{ref})$$

If rainfall is insufficient to meet maximum yields, it is possible to achieve higher yields through the use of irrigation. Irrigation can be applied in the same proportion as actual rainfall to reference rainfall, thus increasing the water-allowable crop production (Y_w) to the maximum allowable yield. Irrigation required for maximum crop yield (I_{max}) is thus specified as $(1-(R_{act}/R_{ref}))$ or the proportion of expected crop yield not achieved by actual rainfall (equal to the reference value R_{ref}). Irrigation allowable crop yield (Y_i) is thus specified in the following way:

$$(14) \quad Y_i = (1- I_{max}) * Y_{max}$$

However, irrigation is not always an option and thus depends on the specific household and conditions being simulated (discussed in more detail below). When irrigation is an option, it is assumed households will irrigate and incur average irrigation costs.[80] Cash crops are not irrigated in summer months because even in river valleys water is often too limiting for many households.

Actual crop production or yield is determined by the most limiting factor (allowable yield), given the lookup functions for nitrogen and water, and the multiplicative effect of labor.

[79] Each of the lookup functions for the effect of rainfall on crop production are normalized at the respective reference values (R_{ref}) and exhibit diminishing returns to rainfall.
[80] Irrigation rights are highly coveted and there is a seemingly robust market for irrigation in northern Afghanistan.

Crop Outputs and Allocation: Crop production is allocated to the household and livestock in the form of staple grains for human consumption and staple residues and forage for animal consumption. Staple production yields both grain (wheat) and residues (wheat straw) at a ratio of 40:60, straw to grain.[81] The amount of total staple grain in storage (G_{total}) is determined by the amount of staples produced (G_p), staple grain consumed (G_c), staple grain reserved for seed (G_r), staple grain lost to thresher (G_l), and staple grain sales (G_s).

$$(15) \quad G_{total} = G_p - G_c - G_r - G_l - G_s$$

Where staple grain consumed by the household (G_c) is a constant rate given the average requirements for staple consumption per person per month (discussed below), staple grain reserved for seed (G_r) is estimated to be 35 kg per harvest per hectare planted (Mercy Corps, 2004), staple grain lost to the thresher ($G_l = 0.1\ G_p$) is given to the owner of the thresher as payment for services (Mercy Corps, 2004). Staple grain sales (G_s) are governed by a conditional statement, taking place if the consumption requirements can be met for the whole interval between harvests (which is 12 months for winter wheat- see crop calendar in Appendix 8).[82] If the quantity of staples to be sold is worth less than the cost of the transaction, then sales do not take place.

Staple residues are specified similarly to grain, with household consumption replaced by animal consumption and no residues are explicitly reserved by the household. Staple residues are a function of the amount of staple residue from staples produced, staple residues fed to animals, residue losses, and residue sales. The stock of staple residues stored is allocated to animals by priority (as described in the livestock inputs

[81] Estimate based on personal communication with livestock consultant, Euan Thomson.
[82] Maletta (2006) suggested that this strategy is common as is a strategy where households wait until confirmation of a coming harvest to sell surplus wheat stocks. It is also possible that some households estimate needs and sell stocks right after harvest only to buy it back at a higher price later.

section). Staple residue sales occur monthly if animal reference feed diets can be met until the next harvest period (given current animal numbers). A fractional rate of staple residues in storage is lost each month due to the practice of leaving residues in poorly covered structures and even uncovered.[83] Total revenues from staples (Y_s) are the total revenues generated from both wheat straw and excess grain production given the respective market prices for staple grain and residues (g, r) and harvest transaction costs for grain and residues (t_g -t_r).

$$Y_s = (G_s*g) + (R_s * r) - t_g - t_r \quad (16)$$

This estimate does not take into account the actual value of staple residues to animal diets and thus contribution to milk production.

Forage production is common among households with access to irrigated land and animals. Forage is generally fed both wet and dry, although this is simplified in the model. Forage is specified in the same way as staple residue. Produced forage is assumed to all be placed into "storage"[84] and then is either fed to animals, lost due to poor storage conditions, or sold if animal requirements are met. The quantity of forage fed is based on the 'allocate by priority' function discussed in livestock inputs or the reference feed requirements when feed availability is not limiting. Similar to staple residues, forage fed is also assumed to be constrained by the stock of forage available until the next harvest. A conditional statement governs forage sales, which occur when there is more feed in storage between harvests than required to fulfill animal reference requirements for that period. Residues and forage are assumed to be complements, not substitutes and there is no allowance for combined quantity

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[83] This is set at 5% based on rough estimates from personal communication with Emal Jafar, FAO.
[84] In some cases the first cut of forage is fed fresh while subsequent cuts are stored for winter months. In the model it is assumed that all forage is placed in storage for a week minimum and fed out as needed.

substitution of types of feed stocks if feed consumption of one feedstuff becomes low. Revenues from forage are a function of the market price (held constant) and quantity sold each month. Similar to staples, forage sales will not take place if the quantity to be sold is less than the assumed value of the transaction.[85]

Soil Dynamics: For simplicity, the structure of soil dynamics accounts only for the level of soluble N, which is the form accessible to crops for uptake. This assumes that longer-term soil dynamics are constant for other forms of N and are unimportant for the purposes of the model. The focus of the model is on household impacts for a five- to ten-year period and analysis of interventions in the livestock sector and not on interventions concerning agronomic practices. Soil organic matter available is assumed to be unchanged over the length of the model because the timeline of this process is on a longer scale than the annual uptake of nitrogen influencing crop yields.[86] It is also assumed that crops can take up both soil ammonium and nitrate, all in the simplified form of soluble N in soil. There are two land types, land for annual crops and perennial crops, which are used to distinguish between land where forage crops are grown long term and land that is rotated. "Annual" land implies that winter wheat and a fall cash crop are rotated.[87] It is assumed that there is no crop rotation between staples/cash crops and forage, and they are grown on separate pieces of land for the duration of the simulation.[88] Households generally keep alfalfa planted and

[85] The cost of monthly market transaction costs are included in the model parameters table in Appendix 1.
[86] David Parsons, personal communication. If interventions were to be evaluated over a longer time horizon, soil organic matter would need to be modeled differently.
[87] On irrigated land it is common to follow a wheat crop with a fall crop and sometimes land is set aside for a spring crop (not planted to wheat). Correspondance with Mark Henning (crop production specialist in Mazar-i-Sharif).
[88]Note that when land is reallocated from staples to forage as an intervention, crop rotation does take place.

just reestablish or rotate after the seven to ten years, which is the time horizon of the model (hence perennials).

The stock of soluble N in the soil is determined by the quantity of N mineralized, N in manure applied to fields, N from fertilizers, N in crop uptake, nitrate N leached, and N lost through denitrification. Nitrogen is returned to the stock of soluble N in soil (N_{total}) in the form of residues as a fixed proportion of crop residue left in the field through the process of mineralization (N_m). A small quantity of N, from the proportion of the yield (Y) is returned to the soil as residue in proportion (r), determining the quantity of crop residue returned to the soil (Q_r) as follows:

$$Q_r = Y * r \tag{17}$$

A fractional rate of this quantity or the fraction of N in each type of crop residues (n) is then mineralized to become soluble N in soil:

$$N_m = Q_r * n \tag{18}$$

This is a small amount since animals heavily graze stubble following harvest.[89] N can also enter the soil through the application of manure excreted by animals while grazing crop aftermath (N_e).

Soluble N in the soil is also a function of the fraction of N in the inputs of DAP and urea (N_f). It is assumed that fertilizers are applied at an average rate that supports the reference production levels and the households incur costs given market prices of inputs. Average application rates are based on multiple sources (Coke, 2004; Mercy Corps, 2004). Fertilizer application occurs based on the crop establishment schedule with the level of soluble N in the soil, smoothed over the period of crop growth to determine the average level of N available for uptake by crops and the subsequent

[89] This is estimated to be approximately 15% for wheat straw and cash crops (no source).

effect on crop yields. Application rates are based on averages from gross margin data and are used to calibrate the average crop yield given the soluble N in soil (Mercy Corps, 2004). The level of N introduced to the soil by these fertilizers is also a function of the average fraction of N in each fertilizer type (0.46, 0.2 kg N/kg respectively from CLASSES model (Stephens et al., 2008).

It is assumed that nitrogen does not limit alfalfa production and thus the level of soluble N in the soil does not affect forage production. Soluble N is assumed to be lost through denitrification (N_d) and leaching (N_l) both as first-order delays of the nitrate N stock (0.5 * N_{total} and 0.15 * N_{total} respectively from CLASSES model). Crop uptake of soluble N (N_u) is a function of the crop yield (Y) and the fraction of N in crop biomass (μ). Where the fraction of N in crop biomass (μ) is a function of the protein content of crops (p) and the fraction N in protein (n), specified as follows:

$$(19) \qquad \mu = p/n$$

The average crude protein (CP) content of the crops (p) is based on analysis of forage from collected from field samples (wheat is 7% CP, alfalfa is 22.8% CP, vegetables (cabbage) are 1% CP) and the average fraction of N in protein (n) is a constant 6.25 (Van Soest, 1994).[90]

$$(20) \qquad N_{total} = N_m + N_e + N_f - N_u - N_l - N_d$$

The level of soluble N uptake (N_{total}) is used to determine the N limiting production yield (Y_n) as described in the crop production section above.

Household Inputs and Outputs: The household is assumed to consume an average level of wheat per year based on available estimates (Chabot and Dorosh, 2007; World

[90] Forage samples were collected in Mazar-i-Sharif and analyzed at Dairy One Forage Analysis Laboratory in Ithaca, NY as described above for Crude Protein, neutral detergent fiber and lignin.

Bank, 2005).[91] If there is deficit of staple production available for consumption, the household will purchase staples. The household is also assumed to consume a minimum level of other food less wheat based on available consumption norm data for a 2100 kcal/day diet (World Bank, 2005) represented as a constant monthly consumption expenditure. The consumption value of expenditures per year from World Bank (2005) is \$92.42 for a 2100 kcal diet, which is approximately \$0.25 per day, 25% of which is not wheat (5.5 kg per month is 25% of the 16.7 kg per month wheat consumption estimate). Because the household makes up the consumption by purchasing staples and other food, the consumption variables are always assumed to be fulfilled first.[92] Implicit in this portion of the model is that household utility is characterized by a prioritization of household consumption regardless of prices and other cash constraints.

The household inputs and outputs view also depicts labor availability and flows. Household labor supply is assumed to be fixed, based on the average number of persons per household and the average number of persons per family involved in agricultural labor, given labor hired-in and labor hired-out.[93] Generally, available agricultural labor (L_a) is determined by total household labor available per month (L_h), allowable hired agricultural labor (L_{in}),[94] and available off-farm labor (L_{out}).

$$L_a = L_h + (L_{in} - L_{out}) \tag{21}$$

[91] Estimates across sources range from about 16 to 20 kg wheat per month per household. This parameter is tested for sensitivity.
[92] Note that in the model cash can go negative so in effect food security is met even if the household lacks the cash to do so.
[93] It is assumed that women do not provide agricultural labor (and that only 50% of the average household of working age from survey data provides labor). The average household size is eight people of working age in Sherabad, so only four would be considered laborers.
[94] Hired labor (L_{in}) is not used in the current version of the model since hiring workers is not possible for the lower income households modeled.

Labor and inputs are allocated to staples, forage, and cash crops based on land size, labor activities, and availability. Labor for livestock activities is disaggregated into various activities (described above) and assigned based on the number of animals in the herd as well as a fixed amount for the herd. Staple, forage, and cash crop labor is disaggregated based on timing of the activity given the crop schedule and average labor requirements for crop establishment, irrigation, weeding, and harvesting.[95] Each crop has specific labor requirements based on cultivation of land without the use of hired mechanization. The use of oxen for crop cultivation replaces household labor (L_h) use when more than one ox is available for plowing, using a conditional statement and given the timing of labor activities. Otherwise, it is assumed the household supplies its own labor for agricultural activities.[96]

Available agricultural labor is allocated by priority assigned to each labor activity using lexicographic preferences.[97] It is assumed that a household allocates labor primarily to satisfy staple needs (for household consumption), secondarily to maintain assets (with forage and livestock labor having equal weight), and lastly to produce cash crops with the surplus labor.[98] Any excess household labor beyond these activities is assumed available for off-farm labor at the given wage rate, although only a small portion, 15% of the available labor pool is assumed to be able to find work.[99]

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[95] Estimates for labor activities come from the literature and have been dissagregated as much as possible by the timing of activities.

[96] Wealthier households (than in this sample) may value leisure higher than the opportunity cost of labor or a household may decide that returns to hiring labor to make up a deficit may be optimal, although given the current prices it is not profitable to hire any labor in.

[97] This 'objective function' is implicitly used in other parts of the model as well. Note that while it is assumed the household will always satisfy consumption needs, and will retain livestock as long as possible there is no specification for the allocation of cash across activties.

[98] The source of this assumption is based on focus group discussions described in the section below. "Description of Model Scenarios"..

[99] The estimate for the amount of surplus labor possibly working off-farm is set arbitrarily low at 15% of the agricultural laborers in the household.

Allocation of labor by priority then is compared to the total labor requirements per crop month to determine whether labor availability will affect crop production.

Cash Balance Sheet View: In the cash balance view, the outcome of all revenues and costs of agricultural activities, off- farm labor, and consumption are summarized. This view includes one stock (cash balance) and represents inflows of receipts and outflows of input costs from all cropping activities (staples, forage and cash crops) as well as sales and revenues generated from selling livestock and selling livestock products. The major assumption of the cash balance view is that factor inputs are purchased regardless of the degree to which cash is constrained and regardless of the price. Implicit in this assumption is that the stock of cash balance can go negative and purchases will still be made. In effect, it assumes that households can borrow without cost to maintain assumed consumption levels. Thus, the cash stock is an indicator variable of cash balances over the time horizon of the model if the given intervention is maintained, rather than a representation of behavioral responses of the household to cash shortfalls. This assumption to simplify economic decision-making was made because the model was already rather complex dynamic model and the assumption is consistent with the objective of simulating the effect of a given intervention maintained indefinitely over the time horizon for the model. In this sense, the model formulation is similar in spirit to a partial budgeting analysis, which examines the financial implications (although typically in a static form) given the assumption that a given technology is implemented by a household. Negative cash balances, of course, indicate that the intervention is inappropriate and that households would respond differently. Alternative behavioral assumptions for the household (such as allocating land and labor to the most profitable activities) would make it more difficult to evaluate the longer term impact of an intervention since household activities would be driven by the most profitable activities, which might exclude the intervention under consideration.

Livestock price is assumed to be constant for each animal type and does not depend on animal weight or conformation. Livestock prices are estimated from market visits to the Mazar-i-Sharif livestock market in July 2006 and prices reported by Thomson et al (2004).[100] Similarly, prices for crops are assumed constant at July 2006 prices reported by the Ministry of Agriculture.[101] Costs of transportation and other informal market fees are included in the final revenue from livestock and come from Thomson et al. (2005). Costs for agricultural activities fall into five categories: livestock costs (veterinary costs per head),[102] purchased feed costs (including the transaction cost of purchasing feed), the sum of crop transactions costs, irrigation costs (which is the amount of land irrigated times the costs of irrigation per unit of land), soil amendment costs (for DAP and urea), and establishment costs (which include estimates of seed and pesticide use for each crop). Net margins (revenues less costs) for each crop are also calculated for reference.

Income from off-farm labor (Y_l) is determined by the quantity of surplus agricultural laborers in the household per month (L_h), the casual wage rate (w), and the costs of participating in the labor market (t_l). This is specified as follows:

$$(22) \qquad Y_l = (0.15L_h * w) - t_l$$

It is assumed that a very small proportion of household labor is able to find casual employment on a monthly basis (see discussion above).

[100] See table in appendix for prices reported by Thomson (2005) in Appendix 4.
[101] All crop and other commodity prices reported come from the Ministry of Agriculture (FAAHM) and can also be found in Appendix 4.
[102] Veterinary costs are estimated from the household survey data collected and described below.

Consumption purchases for staples and other food are also calculated including the market transaction costs. The costs of other consumption are based on the World Bank (2005) estimates described above and assumed to be \$0.33 per kg based on the estimate of the value of a 2100 kcal diet described above.

Description of Model Scenarios

As one component of defining model scenarios, it is necessary to define a representative household for this type of model, including initial stock values, resource endowments and constraints. The communities of Sherabad and Charbolak were chosen for household surveys because they represent two distinct situations for access to water and access to markets. More than 400 dairy cow owners were identified by development organizations and interviewed about livestock holdings and feeding patterns, land allocation, and resource access over a one month period in July 2006.[103] Other harder to quantify differences were solicited through focus group discussions in multiple locations, presented in more detail below.

The initial conditions for Sherabad represent a 'higher resource endowment' household and are based on survey data collected in Mazar-i-Sharif in July 2006 from the village of Sherabad, a peri-urban community in the Balkh river valley. The Balkh River provides irrigation water and allows for an intensive double cropping system without fallowing and a high proportion of water intensive crops like alfalfa (Lee, 2006).[104] The average household in this community has access to irrigated farm land (an average of 9.1 jeribs or 1.82 hectares). Sherabad households also reported a small

[103] The survey instrument is included in Appendix 8.
[104] In Charbolak the possibility of cash crops/double cropping is limited and there is reliance on rangelands for fodder in summer.

amount of external income in the form of off-farm labor activities (often urban wage labor in Mazar) due to the proximity to Mazar-i-Sharif, and relatively low marketing transactions costs (more specifically transportation costs) as a result of this proximity. They generally do not own any land that is only rainfed, have access to pastureland, or own small ruminants (and this is assumed in the model). The households in Sherabad have relatively high 'crop diversity' for Afghanistan due to their access to water and are sometimes able to irrigate a limited area of land in summer months.

The lower resource household is based on survey data from Charbolak Village about 30 kilometers north west of Mazar-i-Sharif. There is a system of irrigation from a north-south tributary of the Balkh river, but it is limited in scope and water access is sporadic, particularly in the summer and particularly for those at the north end of the river where the survey data were collected. This agriculture in this area is more livestock-based than most areas in northern Afghanistan with a reliable single cropping system and second summer crop undertaken only opportunistically. These households on average own a very small amount of irrigated land but mostly farm rainfed land outside of the village (a total of 18 jeribs average or 3.6 hectares), which has lower yields and higher risk.

Charbolak households also face a lack of off-farm labor opportunities and higher transactions costs in marketing goods due to the increased distance to the market. When off-farm labor opportunities do exist, this typically entails working on nearby farms for a much lower wage than skilled laborers in Mazar-i-Sharif are paid. Some workers do travel to Mazar-i-Sharif for work on a regular basis, but in the model it is assumed that Charbolak workers have no access to off-farm labor employment. Typically Charbolak households own more livestock than Sherabad households (an average of 5 cows), including draft animals.[105] Small ruminant ownership is also more common in Charbolak, although the representative households defined are only cattle farmers. Many Charbolak households do not have regular access to irrigation and therefore are unable to produce crops during summer months (or only minimally cultivate land which can be irrigated, less than 33% of households sampled). Households in Charbolak tend to gather more feed and depend more on the range since they cannot grow much alfalfa (slightly more than 50% of households do grow alfalfa). The rainfed households are therefore more affected by the rainfall patterns than are those in Sherabad. Despite farming larger land areas, they apply significantly less total fertilizer presumably because the risk of crop failure is so high and returns are often low.

Reference Mode Behavior

In the SD literature, it is common that a "base model" should reflect the observed qualitative and quantitative behavior of the system over time. Although no time-series data are available for the households in the two communities modeled, the observed qualitative behavior reported by farmers is seasonal fluctuation in cash income that is neither decreasing nor increasing over time due to the frequency of shocks to the system. In the base model, without shocks, it is hypothesized that the herd numbers increase over time and there is an oscillating seasonal pattern of cash income from agricultural activities. It is also hypothesized that high rainfall years would potentially contribute to an increase in income through staple and cash crop sales under the base model without shocks.

[105] Note that while it is quite common to own sheep in Charbolak, many households that maintain cattle do not own both cattle and sheep, so sheep have not been included in the model.

Baseline Model and Baseline Model with Shocks

As mentioned above, the annual cycle of crop-livestock farming driven by the unimodal rainfall pattern in northern Afghanistan is also affected by frequent shocks of various types. A baseline simulation run without shocks, characterized by increasing herd numbers (and thus increasing cash balance) is used as one basis for comparisons with other simulations that will be described below. The historical unimodal rainfall data are used in the model to drive variation in crop production.[106] This rainfall pattern is simulated using historical monthly rainfall data from Mazar-i-Sharif and has a dampening effect on crop yields (see rainfall data discussion above). Droughts occur commonly in northern Afghanistan, so low-rainfall scenarios are developed that simulate a shock that affects crop production, but not assets. This past year Afghanistan experienced the harshest winter in 30 years with temperatures dipping below -25˚ C. This shock particularly affected Dehdadi district (where Charbolak is located) with effects described above.

Interventions

Simulated interventions examine the impacts of a shift to higher levels of both livestock and forage production, based on interventions currently recommended by organizations engaged in livestock development in Afghanistan. Specific interventions examined include are presented in Table 4.3.

[106] In the results section, rainfall from the period 1975 to 1985 is simulated although other periods were also used to test the model for sensitvity.

Table 4.3 Table of Simulated Interventions

Intervention	Implementation of intervention
Cow gift	Adding an additional lactating open cow into the household herd
Improved germplasm	Increasing fodder yield given a fixed land base with adjustments for increased input and nutrient requirements associated with a higher yielding variety
Transaction cost reduction	Reducing transaction costs of marketing milk to zero through trader pickup and decreasing price received for milk
Land reallocation	Switching land in staples to forage and accruing attendant establishment costs and nutrient conditions of the land[107]

In the results section, there is a discussion of what conditions must exist for these interventions to work, or what interventions might improve welfare indicators. These indicators are discussed below.

Ex-ante Assessment Indicators

Indicators are used to evaluate the effect of shocks and interventions on the "welfare" of the household. Indicators of household welfare chosen for this analysis are accumulations of two key assets, livestock and cash balance. Much of the analysis reported in Chapter 6 will be visual or graphical evaluation of these two indicators, although a tabular summary of indicators will also be included for each simulation. In some cases, other physical indicators such as feed in storage or crops in storage are reported. A more detailed discussion of household welfare is included in the results section below and implications of the temperature shock and interventions will be discussed.[108]

[107] Because nitrogen is assumed to not limit alfalfa yield, planting alfalfa on staple land does not require a shift in nutrients. It does require the costs associated with the crop, such as water.
[108] In the current model, the cash balance stock is permitted to become negative although most decisions are constrained by the availability of cash.

CHAPTER 5

MODEL EVALUATION AND LIMITATIONS

Model Evaluation

The goal of model testing is to critically assess the model boundary, time horizon, decision-making structure, and level of aggregation relative to the model's purpose. Model evaluation in this chapter focuses on tests to reveal the adequacy of the model for its stated purpose, based on the guidelines of Sterman (2000). A series of tests and assessments are described below.

Boundary Adequacy Test: The purpose of the boundary adequacy test is to evaluate the whether important concepts for addressing the problem are endogenous to the model. The boundary adequacy test is also an indicator of the consistency of the model, whether the behavior of the model or the outcome of a simulated policy changes significantly when boundary assumptions are relaxed.

Table 5.1 Model Boundary Diagram

Endogenous	Exogenous	Excluded
Animal reproduction	Reproduction rates (some)	Animal sales decisions
ME levels of animals	Animal Diets	Feeding strategies, range resources
Crop response to labor, N, and water	Rainfall, labor requirements, fertilizer	Phosphorus
Crop output allocation	Prices, transaction costs	Land reallocation decisions based on profitability.
Nitrogen cycling from residues, N uptake	Fertilizer application, manure rates, N losses	Organic matter, NO_3, NH_4
Labor allocation by priority	Labor requirements and supply	Labor reallocation in response
Cash allocation for next period	Prices, wages, transaction costs, input costs	Prioritization of cash allocation

Models with narrow boundaries typically do not capture the system's range of responses to policy interventions and can often lead to policy resistance (Sterman, 2000). In this case, the model has a wide boundary, with most of the biological cycles captured endogenously, although economic decision making in response is largely exogenous (Table 5.1). Almost all of the exogenous parameters are estimated from survey data (with some exceptions including price data), but the model does not rely on exogenous parameters alone.

Notably, economic decision-making is largely exogenous or excluded from the model. As noted earlier, this is done to simplify the model structure and to allow evaluation of the intervention over a sufficiently long time horizon. Although this exclusion is a limitation of the model structure, it is useful to briefly discuss the complications of alternative assumptions. Imposing endogenous decision-making would be most appropriately focused on land allocation, which could be based on returns to labor as in Stephens et al (2008). This would add a great deal of complexity to the model structure and would obscure interpretation of the results concerning evaluation of the alternative interventions over time because a given intervention may not maximize returns to labor. Additional endogenous decision-making could be included for household sales and consumption decisions, but these are often modeled relatively simply, even in dynamic household-level models (Stephens et al., 2008, Bontkes, 2000). For the stated purpose of the model, it is sufficient to evaluate the interventions without the detailed level of endogenous decision-making by households. Recommendations of how to include greater endogeneity of household decisions as an extension to this model are discussed in Chapter 7.

Structural Assessment Tests: Structural assessment testing is done to determine "whether the model is consistent with knowledge of the real system, relevant to the model purpose" (Sterman, 2000, p.863). The main structural foci are the level of aggregation, the conformance of the model to basic physical realities, and the realism of decision rules. This household level model does not capture the interaction of households with the market other than through prices, except in the case of milk exchange among households. The household level was chosen because the goal of the model is an ex-ante evaluation of livestock interventions on household welfare. Prices are held constant over the model time except when step changes in prices are imposed as simulation experiments. It is likely that one household cannot influence prices, or that aggregation effects in the region are minimal.

Another component of structural assessment testing focuses on the physical consistency of the system represented. The model was constructed modularly and the components tested individually to ascertain whether each generated behavior that is consistent with the system represented. Examples of this are occurrences of physical stocks taking on negative values or modeling fractions of discrete units. The livestock section of the model is a good example of how these physical realities were modeled. Animal stocks are modeled using a particular function in Vensim®, where discrete units are maintained, using a combination of fixed and material delays as described above. Animal sales are constrained to occur only when animals exist and it is assumed that animals only lactate for a fixed amount of time.

The third important component of a structural assessment test is an evaluation of the appropriateness of the decision rules of the agents. In this model, many of the decision rules of the agents deliberately simplified (as discussed above). This is justified for the purpose of the model, but implies that the results of the simulations do not accurately represent the outcomes of interventions that might actually occur if household decision-making was more flexible.

Extreme Conditions Test: The extreme conditions test is performed to evaluate whether the model behavior conforms to basic physical relationships, and to determine appropriate limits on the application of the model (i.e., which simulation experiments are appropriate). An example of a consistent outcome from an extreme conditions test (to paraphrase Sterman, 2000) would be "no rainfall, no crop production." Extreme conditions are explored in the current model both quantitatively and qualitatively, to determine whether the model behaves realistically under extremes. One such parameter to be assessed is rainfall, which when equal to zero for a period of crop growth (assuming irrigation is turned off), there is no harvest and no feed, and no milk production. On the other hand, if there is extremely high rainfall (consistently above reference rainfall), there are diminishing returns with respect to crop yield and the maximum yield is returned when rainfall is sufficient for healthy crop production.

Livestock production is also bounded by upper and lower extremes of certain parameter values. When animal energy intake (ME) falls below the level required for the animal to maintain basal requirements, the animal is sold. Conversely, when feed stocks are increased greatly, all animal requirements are met and excess feed is sold.

Nitrogen levels and crop response to nitrogen are also evaluated for conformity to physical laws. The function used to relate crop production and N includes an approximately linear direct relationship among the two variables. The function does not exhibit diminishing returns because it is assumed that even at high levels of nitrogen application; the rates are still lower than the point of diminishing returns. As soluble N in soil approaches zero, so does crop production.

Dimensional Consistency: The dimensional consistency test is important to determine whether each equation is dimensionally consistent, with parameter dimension and units reflecting real world consistency and measurement. A full units check was conducted regularly in building the model. Equations and units are consistent with actual quantities and mathematical relationships between variables.

Parameter Assessment: The parameter assessment test is conducted to ensure that parameter values are consistent with relevant descriptive and numerical knowledge of the system. Parameter estimates are thoroughly documented in the model and in a table in the appendix 1. They come from a range of sources and in some cases multiple estimates were compared and tested for sensitivity. Experts were consulted for uncertain parameters and cross checked with as many sources of data from northern Afghanistan as possible. This included consultation with experts in the fields of animal science, crop science, horticulture, and economics.

Integration Error: Model results can be sensitive to the choice of the time step of the model or the choice of numerical integration method. Integration error assessment was conducted on the model using a series of values for the time step. The results are compared to the current model time step of 0.125 (Table 5.2).

Table 5.2 Times Step and Integration Error of Model

Time Step (dt) (years)	Simulated Cash Balance at time = 120 months	% difference from dt=0.125
0.015625	$4,137	-5.37 %
0.03125	$4,171	- 4.59 %
0.0625	$4,237	- 3.08 %
0.125	$4,372	0 %
0.25	$4,666	+ 6.72 %
0.5	$5,409	+ 23.71 %

After testing multiple time steps, it appears that a time step greater than 0.125 is too large since the integration error increases significantly. The current time step of 0.125 is large enough that round off error will not compromise model accuracy significantly yet small enough that integration error will not compromise accuracy. Rounding error is produced from truncated results that occur as a result of rounding at every time step. Integration error occurs when the time step is not sufficient to capture relevant delays indicated by time constants in the model. The results of the integration error test indicate that a time step equal to or less than 0.125 is appropriate. Sterman (2000) suggests a time step that is approximately between one-fourth and one-tenth of the smallest time constant in the model. The model time step was changed from 0.125 to 0.0625 because of this test.

Behavior Reproduction: The behavior reproduction test is to determine whether the model reproduces the behavior of interest in the system. Typically behavior reproduction is best tested by comparing the reality with the model behavior. Behavioral comparisons can include point-to-point comparisons with historical behavior (when data are available), but also include modes of behavior (such as trends or oscillations). Because only limited time series data are available on crop livestock production at spatially and temporally aggregated levels, behavioral reproduction assessment in this case relied on qualitative behaviors developed by farmer focus groups. Farmers reported (qualitatively) widely fluctuating income and revealed strategies based on coping with seasonal oscillations and a broad variety of shocks. There are reportedly wider oscillations in income over time and greater unpredictability in weather, but there is no specific bench mark or behavior over time graph for the reference mode. Values of average data from the household survey are compared with the first few years of the baseline model.

Descriptive statistics can demonstrate points where the model and reality may diverge. Since very few data exist, there are few points of possible comparison. One point is the number of lactating animals per household, where the sum of the mean and one standard deviation from the mean is less than two and a half lactating animals. The standard deviation suggests that the number of animals in a Sherabad household data range could from zero to three, while the model allows animals to increase continuously due to access feed stocks from the market. With positive cash flow, the herd continues to grow well beyond the maximum size of herds reported in the community. A closer look at the average data on Sherabad animals is presented below.

Table 5.4 Animal Population in Sherabad from 2002 to 2006 and Baseline Model

Animal Population			
	2002	2004	2006
Average Milk Cows per HH	1.36	1.26	1.25
Average Heifers per HH	0.22	0.30	0.87
Average Calves per HH	1.32	1.17	0.76
Average Bulls per HH	0.06	0.08	0.37
Average Oxen per HH	0.27	0.26	0.21
Average Cattle per HH	3.47	3.07	3.44

Animal Population (baseline model)			
	t=0	t=24	t=48
Average Milk Cows per HH	1	0	2
Average Heifers per HH	1	2	0
Average Calves per HH	1	0	2
Average Bulls per HH	0	0	0
Average Oxen per HH	0	0	1
Average Cattle per HH	3	3	5

Source: (FAO, 2006)

In some categories, numbers of animal by class are oscillating, increasing or decreasing. Overall, there appears to be oscillating behavior among cattle stocks (average cattle), implying that there is a good deal of turnover in the herd. This behavioral anomaly is a function of the economic decision rules excluded from the model (discussed above). There is also an inconsistency in the sense that the Charbolak household continues to make purchases once they have reached negative cash balance, implying that they will not sell off animals to generate income.

Sensitivity Analysis: The purpose of sensitivity analysis is to understand which uncertain parameter values (or lookups or other structure) the model is sensitive to, noting that the types of sensitivity include numerical, behavioral and policy sensitivities. *Numerical sensitivity* exists when a change in a model parameter or structure changes the numerical values of the results. *Behavioral mode sensitivity* is when a change in assumptions changes in the pattern of behavior exhibited, such as a switch from stable behavior to oscillations or exponential decay. *Policy sensitivity* exists when a change in assumptions reverses the impact, desirability or relative ranking of proposed interventions (Sterman, 2000, p.883). In this case, univariate sensitivity analysis is conducted on a limited number of uncertain parameters to determine how influential the variation in these parameters is on outcomes. Parameters that have little effect on the dynamics are of little consequence compared to variables that significantly change the dynamics numerically or behaviorally.

Staple consumption norms were estimated from available literature and exhibit considerable inter-household variation across Afghanistan. As discussed in Chapter Two, there is a range of estimates by region, which vary depending upon the source. Because consumption data were not included in the FAO (2006) household survey and staple consumption can have important impacts on the outcomes of interventions and household welfare, this variation in staple consumption should be evaluated. Similarly, animal veterinary costs vary widely in survey data between households and should be tested for this reason. In general, the gross margin estimates are all uncertain parameters since they did not come from the household survey and are thus not averages drawn from data like most of the other parameters used in the model. This is particularly true of labor requirements for crop production which were reported in different ways, depending on the source. Constants such as fertilizer use are also important to test given the variation in estimates and the potentially significant effect on model outcomes given the high price of fertilizers in Afghanistan.

The lookup functions for crop production, including the effect of rainfall and the efficiency of nitrogen and the corresponding reference values could have behavioral implications for the model. However, these lookup function formulations reflect average values and basic physical relationships such as diminishing returns to rainfall or nitrogen application and therefore were not tested. The reference animal diets by class were developed synthetically, and thus could imply large estimation error. However, an empirical animal science nutrition and production model (CNCPS) is used to calibrate these estimates with milk production and energy to ensure that these estimates are internally consistent, so these are not formally evaluated herein.

The few variables in the biological portions of the model which are behavioral (such as the proportion of manure applied to crops or proportion of crop residues returned to field) are appropriate for sensitivity analysis. Transportation costs for crop sales are also rough estimates from interviews with community leaders and are not based on survey data. Storage loss rates for crops are estimated without any empirical data and should also be tested to explore the importance of the uncertainty in this assumption. Table 5.5 presents a summary of selected univariate sensitivity analysis.

Table 5.5 Univariate Sensitivity Analysis Simulations

Parameter Adjusted	Units	Distribution Type	Model Estimate	Simulated Parameter
Staple norms	kg/person/ month	Random uniform	16.67	(13.3 to 20)
Other food consumption norms	kg/person/ month	Random uniform	5.56	(4 to 7)
Vet costs	$/animal/ month	Random normal	0.22	μ= 0.2, σ = 0.4
Irrigation labor (staple, forage, cash crop)	days/person/ month	Random uniform	(8, 12, 26,6)	(0 to 16) (0 to 24) (0 to 54)
Proportion of crop yield returned to soil	dmnl	Random uniform	0.15	(0 to 0.5)

Univariate sensitivity analysis of irrigation labor requirements on cash balance was conducted using a Monte Carlo simulation technique (Figure 5.1). Sensitivity to labor requirements for irrigation is tested assuming a random normal distribution between zero and twice the values estimated by FAO and RAMP.[109] The model displays little sensitivity to adjustments in irrigation labor until the last quarter of model time.

[109] Revitalizing Agricultural Markets Program (RAMP), is a USAID funded effort that targeted high value agricultural activties.

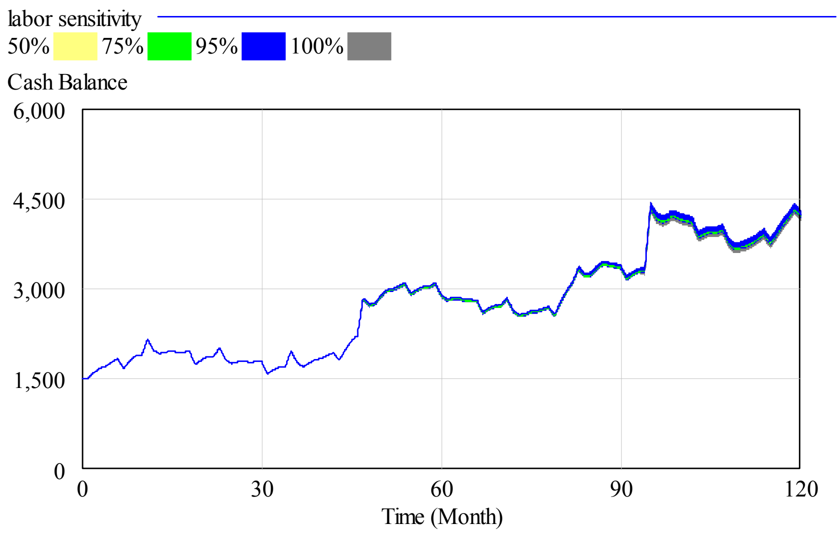

Figure 5.1 Sensitivity of Cash Balance to Assumed Irrigation Labor Requirements for Sherabad

The sensitivity analysis indicates that assumptions concerning unit labor requirements in general have little effect on cash balance, particularly not until near the end of the simulation when livestock labor becomes substantial and household labor is constrained. Labor was not a major constraint in household surveys and it is not common for Sherabad or Charbolak households to hire labor into the household.[110]

Sensitivity analysis is conducted for staple consumption norms with allowed variation between 13.3 kg per person per month and 20 kg per person per month, using a random uniform distribution. Because detailed data on household consumption were not available, these upper and lower values are rather arbitrarily specified.

[110] When it is assumed that the household will hire labor to meet labor shortfalls, cash balance for the household drops quickly since it is less profitable than using own labor and suffering production shortfalls. Because this appears to be more realistic hired labor is excluded from the model.

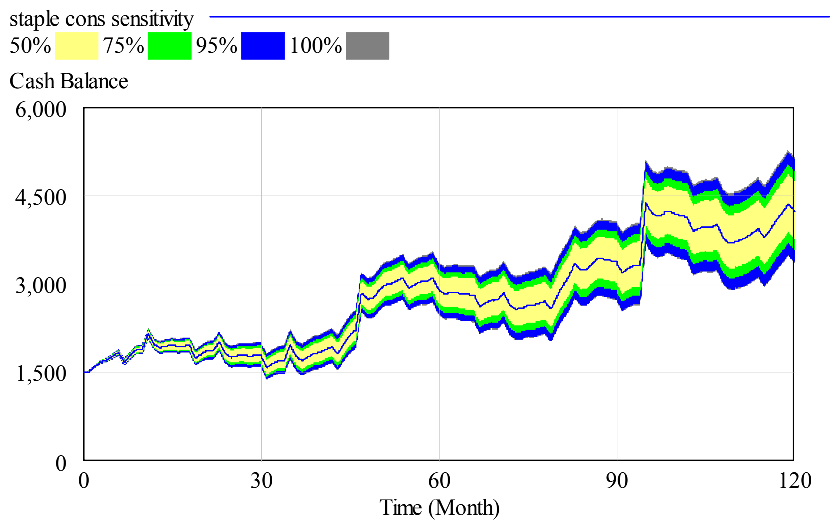

Figure 5.2 Sensitivity Analysis of Staple Consumption Norms for Sherabad per Month

The model demonstrates significant numerical sensitivity to the parameter change (Figure 5.2). However the analysis demonstrates reasonably consistent behavioral patterns (i.e., fluctuation around an increasing trend). Other food consumption norms are tested using a random uniform between 4 and 7 kg and yield similar results to staple consumption norms. Thus, they are not shown separately here.

Fixed costs for animals also varied considerably across households in survey data. Varying veterinary costs with Monte Carlo simulation using random normal distribution[111] with a mean of 0.22 (from survey data) and standard deviation of 0.4 (from survey data) (Figure 5.3):

[111] This analysis was conducted using random normal specification since detailed survey data was available to calculate the mean and standard deviation.

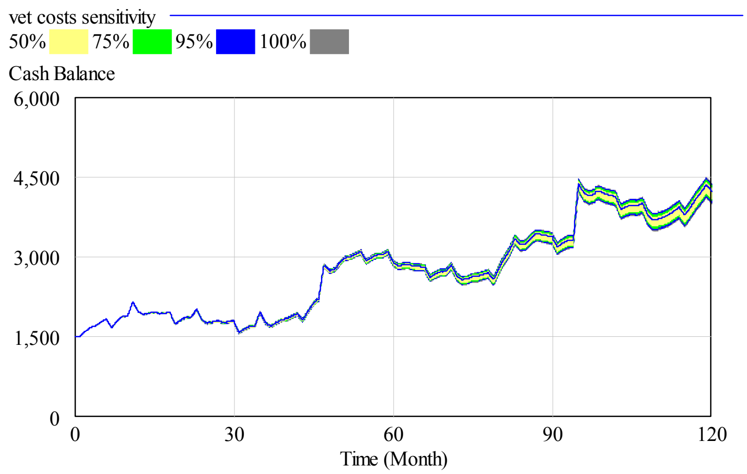

Figure 5.3 Sensitivity of Cash Balance ($) to Veterinary Costs per Head (Sherabad)

Another assumption for which sensitivity analysis is appropriate is the proportion of crop residues returned to the soil. In the current version of the model, it is assumed that only 15% of crop yield is returned to the soil as residues. This estimate is based on the assumption that animals graze crop stubble following harvest. If animals did not graze the stubble, perhaps 25% of total crop yield biomass would be returned to the soil. To test the importance of this assumption sensitivity analyses assuming no residues (0%) and 50% are tested.

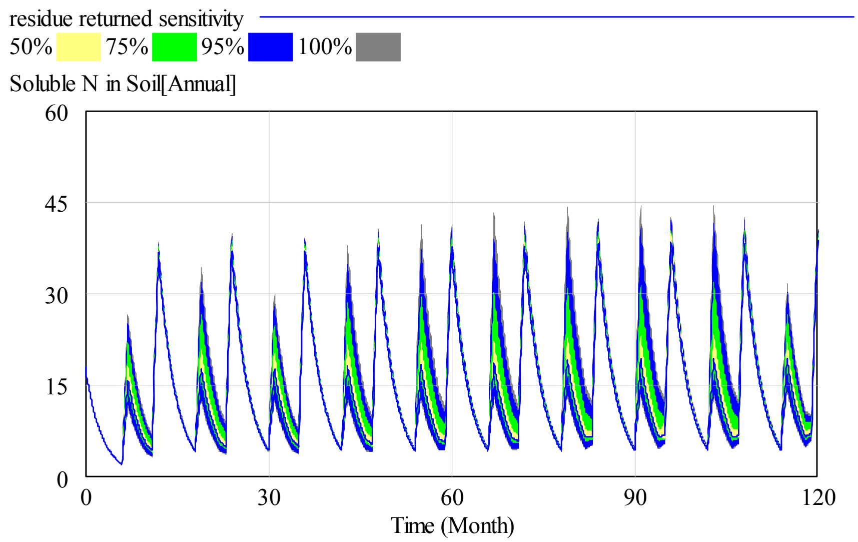

Figure 5.4 Sensitivity of Soluble N (kg N) Crop Residue Returned to the Soil (Sherabad)

The analysis demonstrates that whereas there could be wide variation in the level of soluble N in the soil, most values are close to the actual level of soluble N in the soil, between about 15 and 20 kg/ N (Figure 5.4). The effect of the simulation on cash balance is substantial (Figure 5.5).

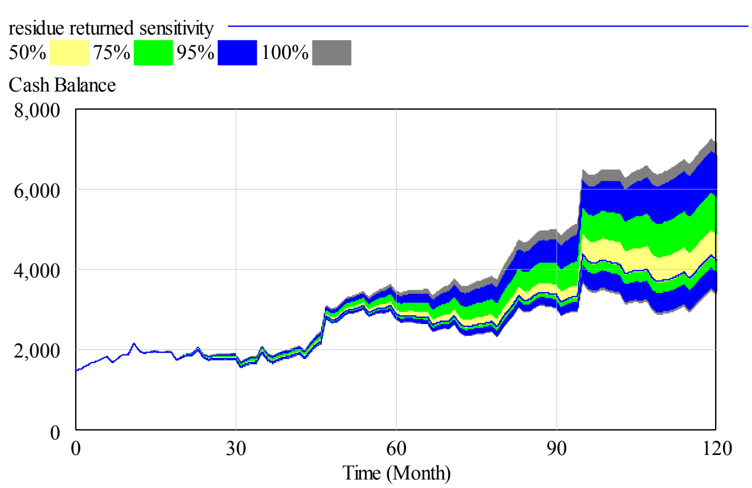

Figure 5.5 Sensitivity of Cash Balance ($) to Crop Residue Returned (Sherabad)

Similar to sensitivity analysis simulations in consumption norms, there is a wide confidence interval for cash balance. The difference here is that 50% of the values are centered on a much smaller range of about $300 over ten years. The results suggest that this uncertain parameter is less influential on model dynamics than consumption norm parameters. However, it does appear that this has some reasonably large numerical impact, and this may suggest that strategies to capture greater returns of organic matter to soil effectively may be beneficial.

Sensitivity analysis allowing simultaneous changes in multiple variables was done to test more generally whether the outcomes of the interventions differ when underlying assumptions or parameter values are changed. Although many possible scenarios could be examined in this way, a relevant example is used to illustrate both the process and the outcomes for this particular model. This example focuses on policy sensitivity, in this case with an emphasis on returns to alfalfa yields. The maximum achievable yield alfalfa yield is varied between the upper and lower bounds reported in the literature (4.5 T/hectare and 7.5 T hectare) while simultaneously varying the average fertilizer (DAP) rate to achieve these yields between zero and twice the average figure reported by Mercy Corps (2004).

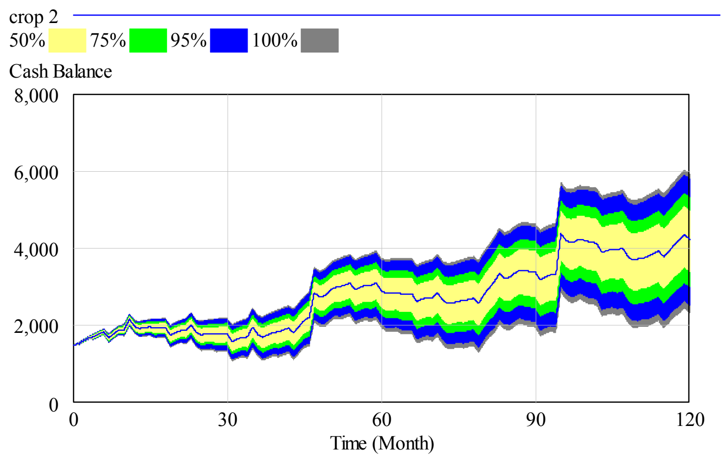

Figure 5.6 Sensitivity of Cash Balance ($) to Fertilizer Application and Alfalfa Yield (Sherabad)

The results resemble the sensitivity analysis conducted for consumption norms, but there is wider variation in model-predicted cash balance (Figure 5.6). This analysis demonstrates the need for additional empirical information about returns to fertilizer and alfalfa yield potential improvement or returns to fertilizer because the range of estimated outcomes is broad. When the range of possible outcomes increases over time, this generally demonstrates that the system is driven by positive feedback (as opposed to negative or balancing feedback). Uncertainty in these parameter values means that prediction involving these variables should be done with caution.

Limitations

One limitation of this research concerns the lack of comprehensive, high quality, empirical data from households covering all revenues and costs of farm-level activities upon which to base model structure and parameters. In this regard, however, it is not that different from other ex ante analyses that rely on limited farm-specific information. Although meticulously collected data are not always the most revealing for policy makers because the modeled (or statistically sampled) households may not be the households the decisions are intended to support, they are, of course, useful in understanding the current situation and predicting the range of possible future behaviors. Without this type of comprehensive crop-livestock data, uncertain parameters can be tested to build confidence in the model, as has been done herein, but there are limits to the insights that can be gained in this manner. Ultimately, further refinements and testing of the model with relevant household-level data would be advantageous. This is likely to be particularly important for specifying the initial conditions for a particular representative household.

Another limitation of the approach followed in this research is that the model strives to be an integrated biophysical-economic model, yet falls somewhat short of fully integrating biological processes with the dynamic nature of the model. This is true of the animal nutrition component, which is not fully endogenous and based on a limited set of inputs. As a result, the current model structure does not allow evaluation of endogenous changes in animal diets, and limits the range of responses in animal productivity. This likely does not significantly affect the analyses of the interventions, but it does imply greater impacts than might be actually observed on outcomes such as cash stocks, because the model assumes in many cases that biological effects of production shortfalls will be minimized by input purchases.

The SD method was chosen in part because of the ease of modeling alternative assumptions. As discussed earlier, behavioral assumptions are represented with a set of fixed and possibly unrealistic decision rules in order to facilitate extended analyses of an intervention's impacts. A main initial objective of the modeling effort was to avoid assuming profit maximization or optimization by the household. However, the omission of more fully endogenous decision rules regarding animal sales or changes in investment in a given enterprise based on profit undoubtedly influence the simulated outcomes. Future models could include additional structure to examine how alternative behavioral assumptions influence household welfare dynamics and the persistence of interventions currently being implemented by development agencies. This is beyond the scope of this study, but is, of course, a relevant consideration.

CHAPTER 6

RESULTS AND DISCUSSION

Representative Households

Two representative households are developed based on survey data and relevant characteristics for the purposes of model analyses are identified (Table 6.1). [112] The data from Sherabad indicate that these households were slightly better off than the Charbolak households, and so the representative household for the Sherabad region will referred to subsequently as the 'high endowment' household. Similarly, the representative household specified for Charbolak is referred to as the low endowment household. The initial conditions for these households differ in a few significant ways (Table 6.1).

The initial stock of cash differs for each household, with Sherabad households holding more significant savings ($1500 as opposed to $500 in Charbolak). The average land owned per household in Charbolak is 18 jeribs (or 3.6 hectares), although this was almost entirely rainfed land whereas only a single jerib was irrigated. In the model, the representative household has 18 jeribs of winter wheat on rainfed land although the yield is half that of the irrigated wheat yields (400kg/jerib as opposed to 800 kg/jerib in Sherabad). These lower yields are a function of numerous factors that depress production on rainfed land (such as rainfall), although they are also attributable to the much lower fertilizer application rate for Charbolak households (25 kg urea and no

[112] All data used to construct the representative households are average figures from household survey data in the two communities except when stated otherwise located in appendix 8. Over 400 households that owned dairy animals were randomly selected in Sherabad and Charbolak and given the survey included in the appendix. Focus groups of community elders were conducted in multiple locations to gather more general community level information and solicit information difficult to draw out of a quantitative survey.

DAP fertilizer). For this reason, the reference value of nitrogen per land unit is lower and the initial level of soluble N in the soil is lower in the model (18 kg per jerib in Sherabad and 10 kg per jerib in Charbolak).[113]

The Charbolak representative household owns one jerib (or 0.2 hectares) of irrigated land that is adjacent to the centrally located irrigation canals. It is planted year-round to alfalfa and achieves a yield on par with the yields reported in Sherabad. Because the distance from market is further for Charbolak (more than 30km), households in this area experience higher transportation costs for milk, animals feeds, and higher costs for marketed surpluses and animals sales ($1.50 round trip for milk and feeds versus $0.67 in Sherabad). Costs to transport crops to market were approximately $5 for one truckload of wheat grain from Sherabad to Mazar, $12 for one truck load of fresh alfalfa and $32 for the total transport of a truck full of melons or cabbage (transportation estimates are $15 for one truckload of staples and $30 from Charbolak).[114] Charbolak households also encountered slightly lower agricultural wages ($2 as opposed to $2.5 in Sherabad) and are unable to work as off farm laborers due to the costs of commuting to Mazar-i-Sharif.[115] Households in Charbolak also reported paying significantly higher veterinary costs, an average of $0.68 per head versus Sherabad where farmers reported paying an average of $0.22/head.

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[113] Equivalent to 90kg/ hectare and 50/kg hectare respectively.
[114] Crop transport prices are not averages from survey data but rather are estimates from focus group interviews based on the rate of hiring a local vehicle to transport regardless of actual crop weight. In some cases the fee is based both on distance and on the amount sold, but this is simplified here to a single average estimate for an average yield.
[115] Some households did report remittances and/or off farm labor but this was not the norm for either community so was ommitted from the represenatative household's cash balance.

Table 6.1 Sherabad vs. Charbolak: Differences in Initial Conditions for Model

Parameter	Sherabad	Charbolak
Initial Herd Size (total animals)	3	5
Initial Land in Staples (jeribs)	6	18
Initial Land in Forage (jeribs)	3	1
Initial Land in Cash Crops (jeribs)	6	0
Initial Cash Balance ($)	1,500	500
Maximum Yield of Land in Staples (kg/jerib)	800	400
Reference N for Staples (kg N/month)	18	10
Urea used for Staples (kg)	75	25
DAP used for Staples (kg)	25	0
Irrigation for Staples (dmnl)	1 (yes)	0 (no)
Reference Staples Fed per Animal per Day [lactating]	5	4
Reference Forage Fed per Animal per Day [calves]	0.5	0
Reference Forage Fed per Animal per Day [heifers]	2.5	2
Reference Forage Fed per Animal per Day [lactating]	4	3
Reference Forage Fed per Animal per Day [open dry]	3.5	3
Reference Forage Fed per Animal per Day [dry bred]	3	2
Reference Forage Fed per Animal per Day [bulls]	2	1
Reference Grass Fed per Animal per Day [calves]	0	0.2
Reference Grass Fed per Animal per Day [heifers]	0	2
Reference Grass Fed per Animal per Day [lactating]	0	2.2
Reference Grass Fed per Animal per Day [open dry]	0	2.5
Reference Grass Fed per Animal per Day [dry bred]	0	2.5
Reference Grass Fed per Animal per Day [bulls]	0	2
Reference Cottonseed Fed/Purchased [lactating open]	0.5	0
Daily ME Maintenance Requirements [heifers]	7.9	6.5
Daily ME Maintenance Requirements [lactating open]	9.1	8.5
Daily ME Maintenance Requirements [open dry]	6.5	8
Daily ME Maintenance Requirements [dry bred]	7.9	5
Daily ME Maintenance Requirements [bulls]	5	4
Average Daily Milk Yield (kg)	6.91	5.1
Average Milk Market Transportation Costs ($/trip)	0.67	1.5
Crop Sale Transportation Price (staples)	5	15
Crop Sale Transportation Price (forage)	12	30
Crop Sale Transportation Price (cash)	32	55
Proportion off Off Farm Labor (dmnl)	0.15	0
Average Transportation Price per Animal Sale ($)	9.7	25
Market Transactions Costs for Staples ($)	0.4	1.2
Average Daily Agricultural Wage ($)	2.5	2
Feed Purchase Switch (dmnl)	1 (on)	0 (off)
Cash Crop Switch(dmnl)	1 (on)	0 (off)
Irrigation Switch [staples] (dmnl)	1 (on)	0 (off)
Average Monthly Vet Costs ($)	0.22	0.68

Model Baseline

In the baseline run of the model, given these initial conditions and in the absence of shocks, Sherabad, the higher resource endowed household experiences an increasing cash balance that closely resembles the herd growth dynamics (Figure 6.1).

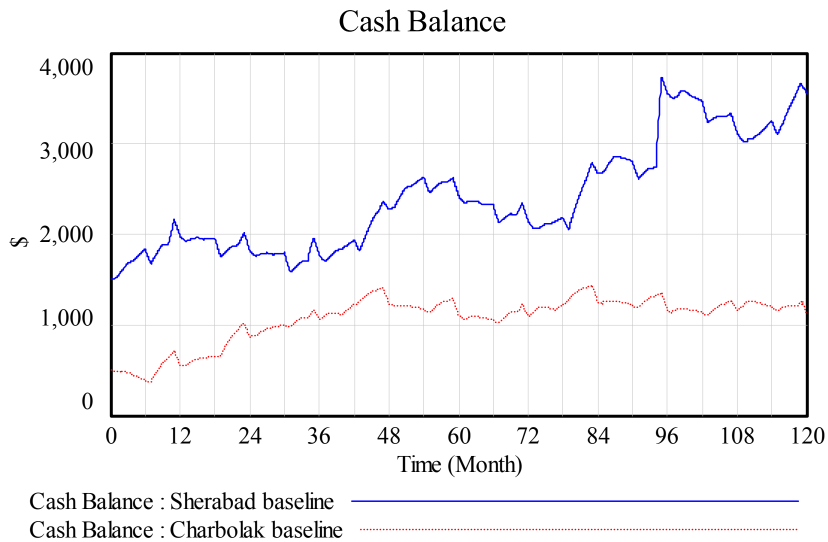


Figure 6.1 Simulated Cash Balance for Representative Households, Baseline Scenario

The cash balance of the household is driven by both animal reproduction and cash crop revenues. With adequate levels of animal nutrition, reproduction rates are at a maximum because variable parturition delays are lower and milk production is at the average value given the current diet (thus increasing milk revenues). Cash crop production is sporadic given the rainfall pattern, but higher rainfall years generate substantial amounts of cash which increase the overall cash balance in steps at 43, 80 and 94 months.[116] The Charbolak household, on the other hand, experiences less

[116] At time = 94 months the household experiences the highest rainfall and thus highest yield and increase in cash balance over the simulation.

growth and a lower level quasi-equilibrium in cash balance. There are two reasons for this. First, animal reproduction does not drive the household's cash balance because feed stocks limit growth in animal numbers, resulting in the sales of animals with respect to both feeding prioritization and maintenance requirements. Second, Charbolak does not have access to irrigated land for staple production because this land is fallow every dry season when Sherabad farmers are planting irrigated cash crops.

In the baseline model, both households do not experience any shocks other than normal rainfall patterns which fluctuate seasonally and inter-annually and affect crop yields. It is assumed that households are only selling cattle due to low feed availability (when animal maintenance requirements cannot be met) or if the animal reaches the average productive lifetime for a cow or oxen. Households are not producing animals for sale in either village. For this reason, the number of animals owned (Figure 6.2) does not reflect the actual livestock asset holding patterns of either representative household, even though households in Sherabad tend to own fewer animals than the average Charbolak household.[117]

In reality many Sherabad households sell off animals periodically, thus maintaining fewer animals whereas Charbolak herds tend to be slightly larger and fluctuate around a steady quasi-equilibrium of livestock, by selling animals regularly due to an internal 'carrying capacity' of the household determined by feed availability.[118]

[117] Note that 'animals' in the graphs that follow refers to the units of cattle since small ruminants are excluded from this analysis as discussed previously.
[118] This carrying capacity is obviously affected by the availability of range resources given numerous exogenous variables. These are ommitted from this model and are thus not discussed here.

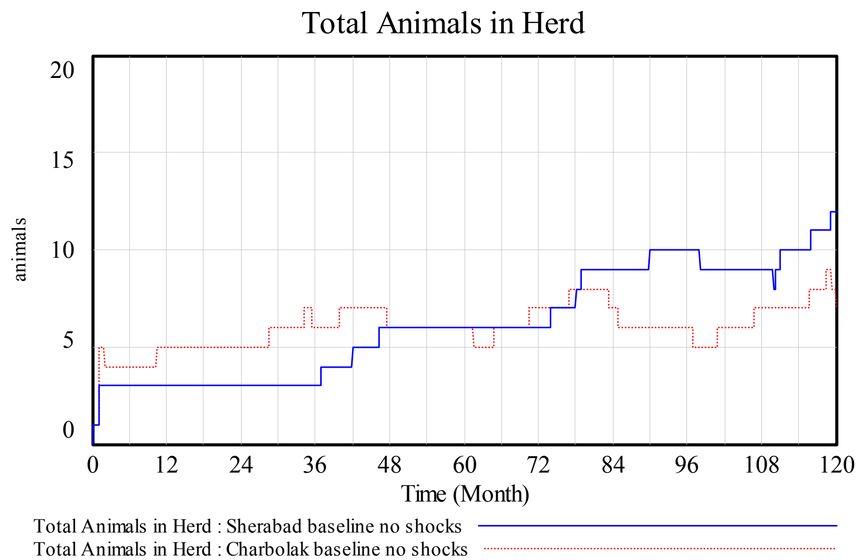


Figure 6.2 Simulated Herd Size for Representative Households, Baseline Scenario

Sherabad households engage in market transactions, and are able to purchase feeds when availability is low. Charbolak households, on the other hand, are unable to purchase feed due to the high transactions costs of sourcing feed in Mazar-i-Sharif. Charbolak households use range resources (one variety of grass in particular), which is considered to be a fixed portion of each animal's diet (discussed above in more detail). Sherabad households reported more interaction with the market (purchase and sale of feeds to maintain the average diet) whereas Charbolak households do not typically purchase any feeds and rely heavily on collected pasture grass to make up dietary deficits. The model considers the availability of range resources, but it is assumed the household can only gather the average amount reported to be collected by all households in Charbolak on a daily basis.

The main difference in herd dynamics in the model is that Sherabad households purchase feed to make up for any deficit, whereas Charbolak households maintain animals until ME intake falls below ME maintenance. Charbolak animal diets are thus different in that they contain grass but no cottonseed meal. The maintenance requirements of Charbolak animals are slightly lower given the smaller animal size reported and the average levels of milk production reported, which were 6.9 kg/day in Sherabad and 5.1 kg/day in Charbolak (requirements estimated using CNCPS and shown in appendix 3). Reliance on grass translates into much higher labor requirements, but does not incur additional cash expenses. This is not an option for Sherabad where grazing land is not nearby and land in general is quite constrained. The diets are also more representative of the proportions of alfalfa and wheat produced, with Sherabad reference diets containing more alfalfa than Charbolak reference diets.

Simulated Interventions

All interventions are simulated as beginning at 30 months, following the second season of winter wheat production in the model. The cow gift intervention increases the household herd by one lactating animal regardless of the feed base. The transaction cost intervention is a representation of a milk collection scheme where traders pick up milk from points in local communities and the trader absorbs the transport costs. This intervention lowers the cost per daily transaction in the milk market for the household to zero (from 30 afs/trip) and the household receives a lower cash price per kg of milk sold than in the market (15 afs per kg fresh milk as opposed to 17 afs per kg in the baseline run). The forage improvement intervention is a simulated improvement in forage yield by 400 kg/jerib (or 2000kg/hectare), which is the increase reported by the FAO on demonstration farms in the Mazar-i-Sharif area. This intervention assumes no additional costs for the improved yield, based on the FAO results and given the amount of land in forage each household farms. The land reallocation intervention is a simulation of a shift in crop area planted to alfalfa. At the time of the intervention, each household is assumed to shift three jeribs (0.6 hectares) of staple production into forage production. As currently modeled, this assumes that animals are fed using the same feeding strategies in other simulations (the same reference diets). Land reallocation is simulated only for Sherabad households because Charbolak households only maintain a single jerib of irrigated land and are not able to plant alfalfa on rainfed land.

Intervention Impacts for High and Low Endowment Households

The interventions are simulated for both the high and low endowment households in the absence of the shocks. The results for the four alternatives and the impact on key variables are presented.

In the baseline scenario, the Sherabad household accumulates a positive cash balance of approximately $3,500 over the ten years. The forage improvement intervention and the cow gift intervention increase the cash balance over the ten years relative to the baseline, while the transaction cost intervention and the land reallocation intervention decrease the cash balance (Figure 6.3).

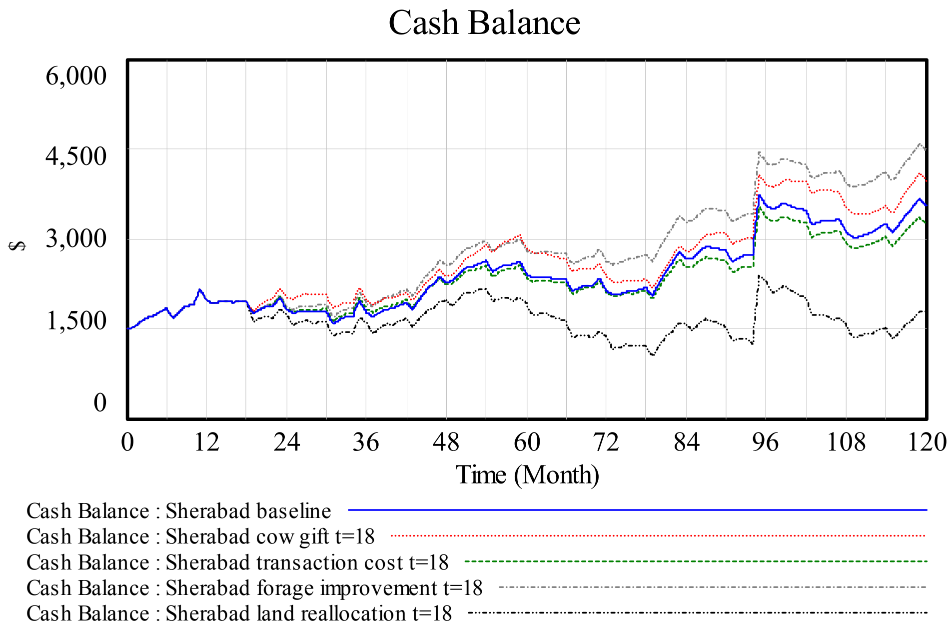


Figure 6.3 Simulated Cash Balance for the Sherabad Household with Interventions

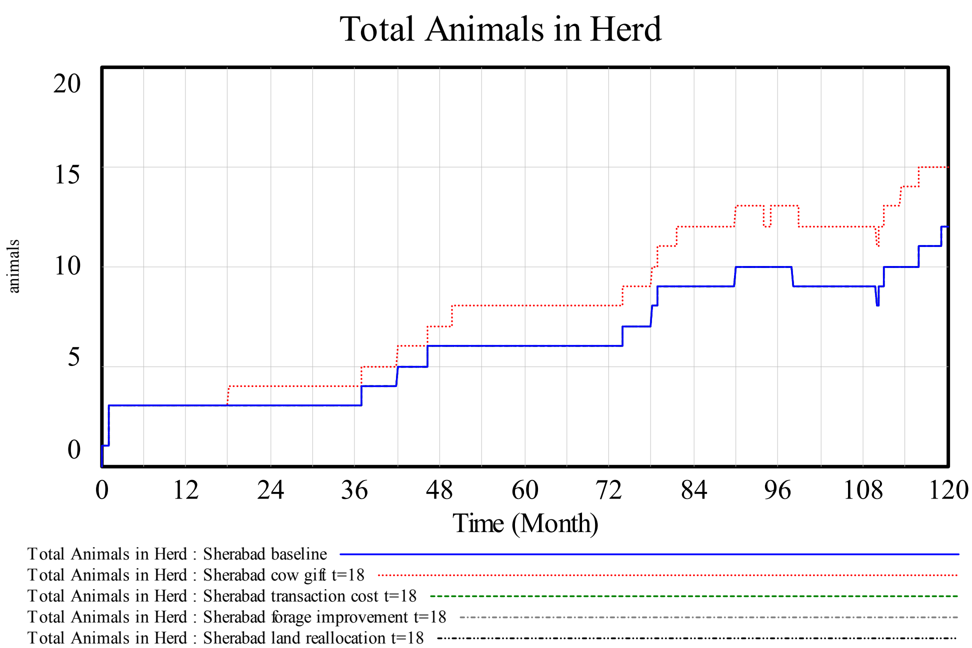


Figure 6.4 Simulated Herd Size for the Sherabad Household with Interventions[119]

[119] Only 2 lines are visible since all of the treatments are the same as the baseline, except for the cow gift intervention.

Within two months, the cow gift intervention has a positive effect on the high endowment household cash balance, as the household is able to generate additional revenues from the gift of one lactating animal to the herd. These revenues are greater than the costs of maintaining the additional animal. By the end of the model simulation, this animal can produce two more offspring, increasing the herd by three animals (Figure 6.4).

The forage improvement intervention is the most beneficial for the higher endowment household cash balance as a result of the higher forage yields with no additional cost and no risk of crop failure due to their ability to irrigate. However, model evaluation using multivariate sensitivity analysis reveals the existence of policy sensitivity regarding fertilizer application rates and alfalfa yields. While DAP is not necessarily the best fertilizer for alfalfa, this was reportedly used by farmers in the Mercy Corps (2004) estimates. The improved forage germplasm intervention is based on FAO projects in multiple locations of Afghanistan. In these trials, FAO reported improved yields with the same level of fertilizer application (contrary to the intuitive explanation that higher yielding varieties require additional inputs since more nutrients are utilized in producing the additional yield).

The transaction cost intervention lowers the household cash balance for Sherabad because the transaction costs of selling milk are already low due to the proximity to Mazar-i-Sharif. The lower price paid by traders does not offset the transaction costs incurred when milk is sold directly by the Sherabad household.

The land reallocation intervention has a negative effect on the cash balance for the Sherabad household because the household lacks the staple residues to maintain animals and is forced to purchase more feeds (wheat straw). The household revenues from staple grain sales are also reduced because less land is planted to wheat necessitating household consumption purchases of $50/month from $0/month. When land is reallocated, the costs of the staple enterprise decrease and total livestock enterprises costs and revenues increase. There are lower input costs for staples, but also less cash income from surplus staple sales. The net margins for staples and forage vary year to year for Sherabad households although given model parameters and gross margins data used, the net margins for wheat are higher than alfalfa production if both were sold.

The end result for the high endowment household is a difference of almost $2,500 across interventions for the household, with the forage improvement intervention and the cow gift intervention generating nearly $5,000 over ten years whereas the transaction cost reduction intervention and the land reallocation intervention lead to less income than the household would have achieved without any intervention.

The results of the intervention under the baseline scenario are different for the lower endowment household (Figures 6.5 and 6.6).

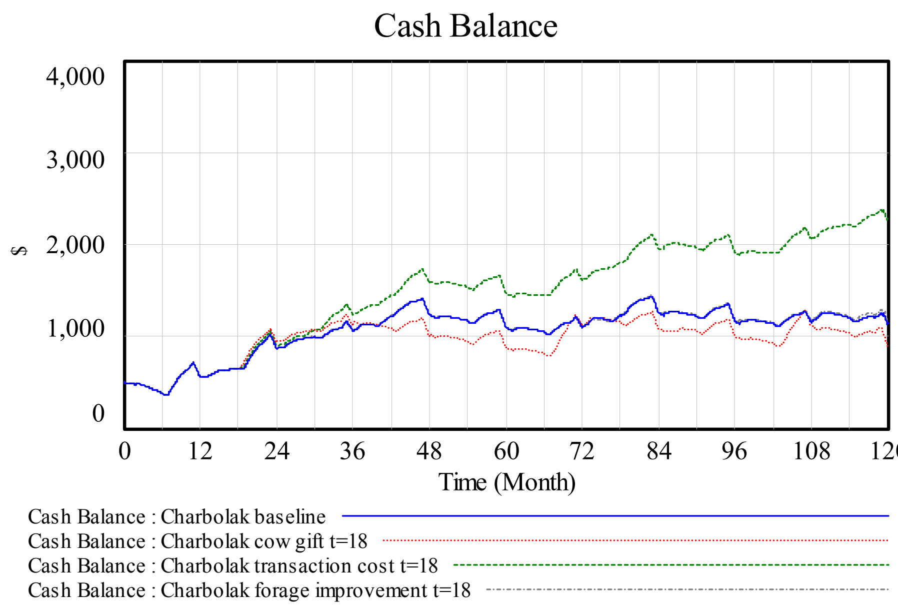


Figure 6.5 Simulated Cash Balance for Charbolak Household with Four interventions and No Shocks

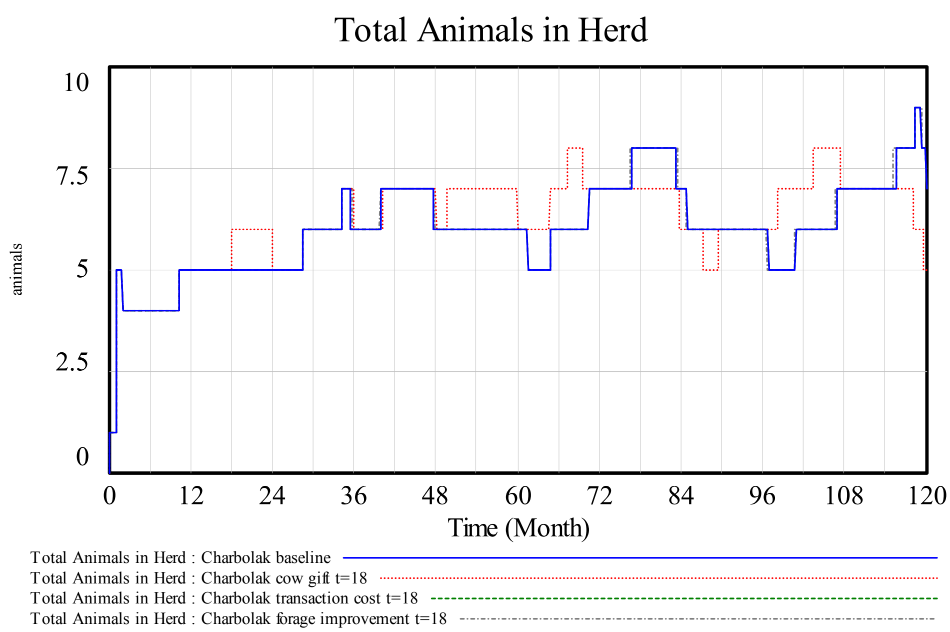


Figure 6.6 Simulated Herd Size for Charbolak Household with Three Interventions and No Shocks[120]

[120] As in the graph above, only two lines are visible since all of the treatments are the same as the baseline, except for the cow gift intervention.

The cow gift intervention leads to a lower cash balance for the Charbolak household as well as a reduction in herd size. This unintended consequence is a result of the internal capacity of the household to support animals. The gift of an additional cow encourages the household to attempt to feed more than one lactating animal at the expense of other younger animals. This alters future herd dynamics and leaves the household worse off at the end of the simulation.

The transaction cost intervention appears to be the most promising intervention due to the higher costs of marketing milk as a function of the distance from market. The transaction cost intervention is beneficial for Charbolak household because in the baseline model, the quantity of milk was often low enough to prevent the household from traveling to the market to sell it. As discussed above, the gains from trading milk are lower for the high endowment household because transportation costs are lower. The Charbolak household experiences high transportation costs so the reduction in the price received from the trader is not enough to offset the gains from the participating in the milk market because of the intervention. Implementing the intervention at alternate times did not affect the household's cash balance.[121] At all times, the model generates the same behavioral response, with a slight numerical difference, consistent with expected outcomes.

The forage improvement intervention generates almost no change in cash balance for the lower endowment household due to the small quantity of land in forage and the availability of grass as a feed supplement. However, the forage improvement intervention allows the household to maintain one more animal than in the baseline

[121] All interventions and shocks were simulated at various times to test for sensitivity.

model. In the baseline mode, the animal was sold because the household was unable to feed all of the animals to meet maintenance requirements. The land reallocation intervention is not simulated for the low endowment household since they have no irrigated land in staple production which could be converted to additional forage production.

High and Low Endowment Household Response to Shocks

Sherabad and Charbolak households may respond differently to various types of shocks given the differences between the households noted earlier. The difference in response of the households can be due to the ability of the household to withstand the shock in terms of assets (livestock in this case) or because of foregone income suffered due to the shock. In this section, three types of shocks are simulated to examine the different responses depending on household resource endowment and other environmental conditions. Shocks are frequent and can play an important role in the welfare dynamics of a houshold. Thus, it is important to examine the comparative impacts of interventions in the presence of shocks. The three main shocks simulated are temperature, rainfall, and price shocks. The likely impact of these shocks, how they were implemented in the simulation and the differences between the households under these shocks (and why they occur) are discussed in detail below.

a) Impacts of a Temperature Shock: The effects of the imposed temperature shock included the death of any lactating animals and new born calves alive during the shock, complete staple crop failure for the following harvest period, and the inability to sell stocks of feed during the three month shock due to poor road conditions. This simulation is consistent with the reports of the effect of a temperature shock on households during the winter of 2008, as described above.[122] The simulated effects of the temperature shock on cash balance (Figure 6.7) and on animal ownership (Figure 6.8) for both the high and low endowment households are evident.

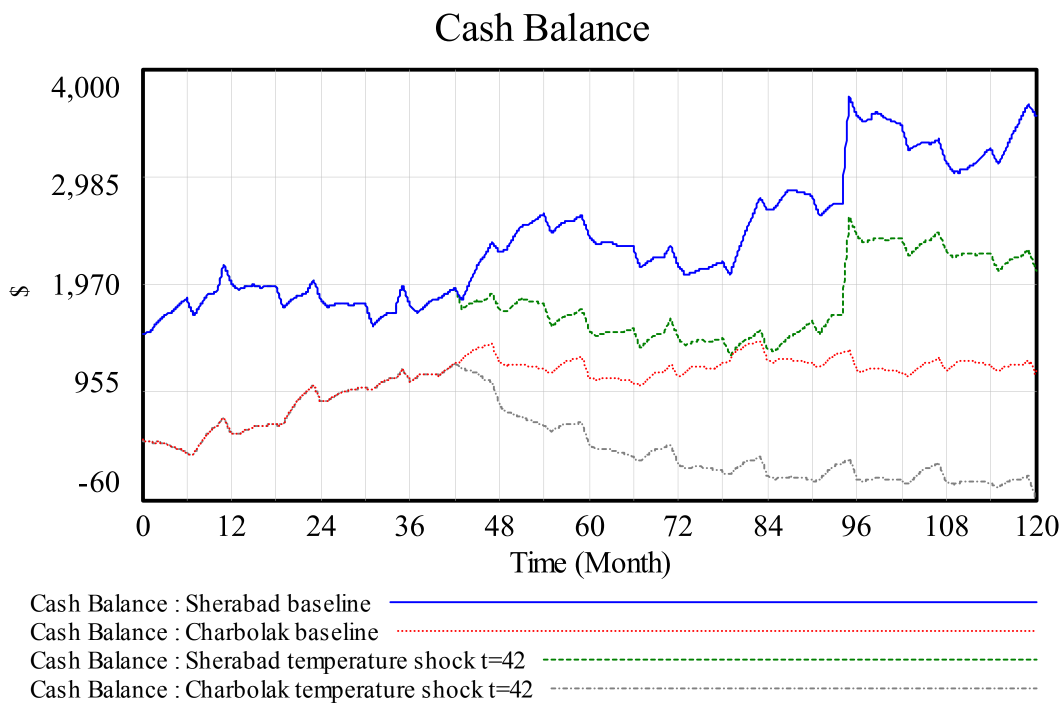


Figure 6.7 Simulated Cash Balance for Representative Households with a Temperature Shock

[122] Note that the shocks are all simulated at time = 42 months so that interventions have two years to run their course before the shock occurs.

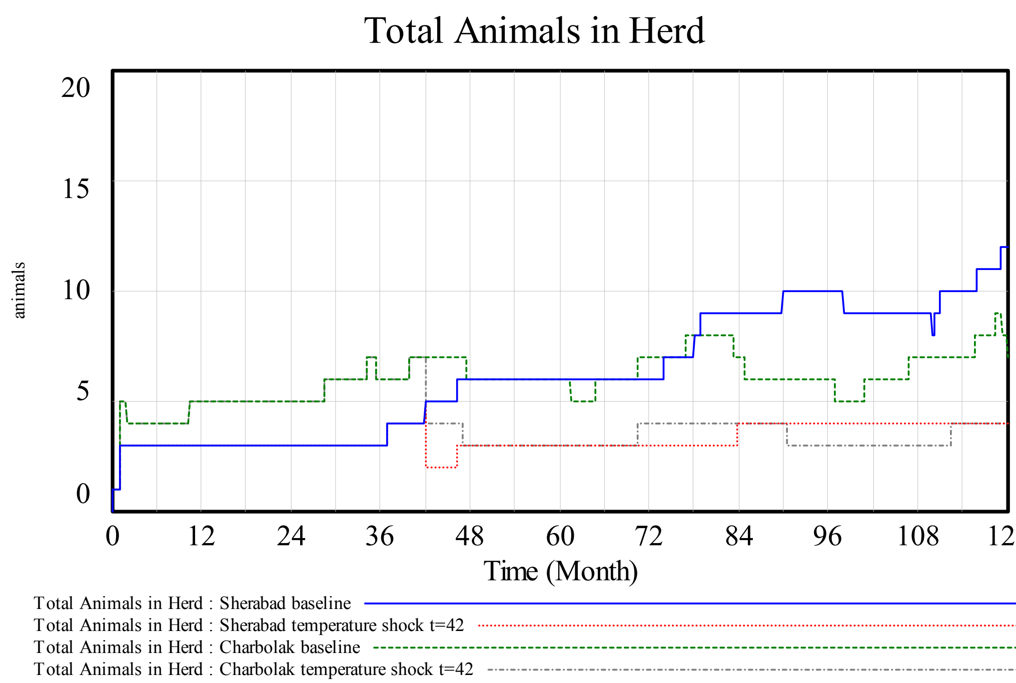


Figure 6.8 Simulated Herd Size for Representative Households with a Temperature Shock

The higher endowment household in Sherabad was able to recover from the temperature shock quickly and followed a similar pattern of income accumulation seen without the shock, albeit at a lower level. In contrast, the lower endowment household, Charbolak, suffered loss of both income and assets from the same shock. The Charbolak household was unable to recover the cash balance they had prior to the shock. For both households, the cash balance indicates the growth in the herd. The high endowment household, however, was able to recover financially from the shock because of the gains from irrigated crop production while the Charbolak household was not able to rebuild feed stocks to maintain the household herd by the end of the ten-year period. The main effect for the Sherabad household was loss of income from sales of wheat during the shock. Charbolak, on the other hand, lost the wheat from the subsequent harvest on more than twice the land area as Sherabad and foregone income from milk sales from animals that were killed during the shock.

The herd dynamics during the shock more accurately represent actual patterns of livestock holdings for the households. The Charbolak household lost multiple animals during the shock as a result of death from cold temperatures and following the shock due to the lack of feed in storage to maintain animal maintenance requirements (note that these animals are sold whereas animals lost during the shock were killed).[123]

b) Impacts of a Rainfall Shock: Multiple years of low rainfall are simulated for each household in years three, four, and six of model simulation (months 36-60 and 72 to 84). This simulation is based on the occurrence of drought in the past decade, which took place during three of the last ten years, in 2001-2, and 2006. Drought limits the potential crop yields through the water allowable crop yield structure. Baseline rainfall imposes variation on crop yields and is already relatively low, although not explicitly a drought period. In the years selected, drought is simulated by decreasing the rainfall amount in that period to zero, which is not uncommon for drought in the northern plains. The effect of simulated drought conditions on household cash balance (Figure 6.9) is shown below.

[123] Note that it is possible for the representative Sherabad household to lose a cow depending on the shock time, although this does not occur in this particular simulation.

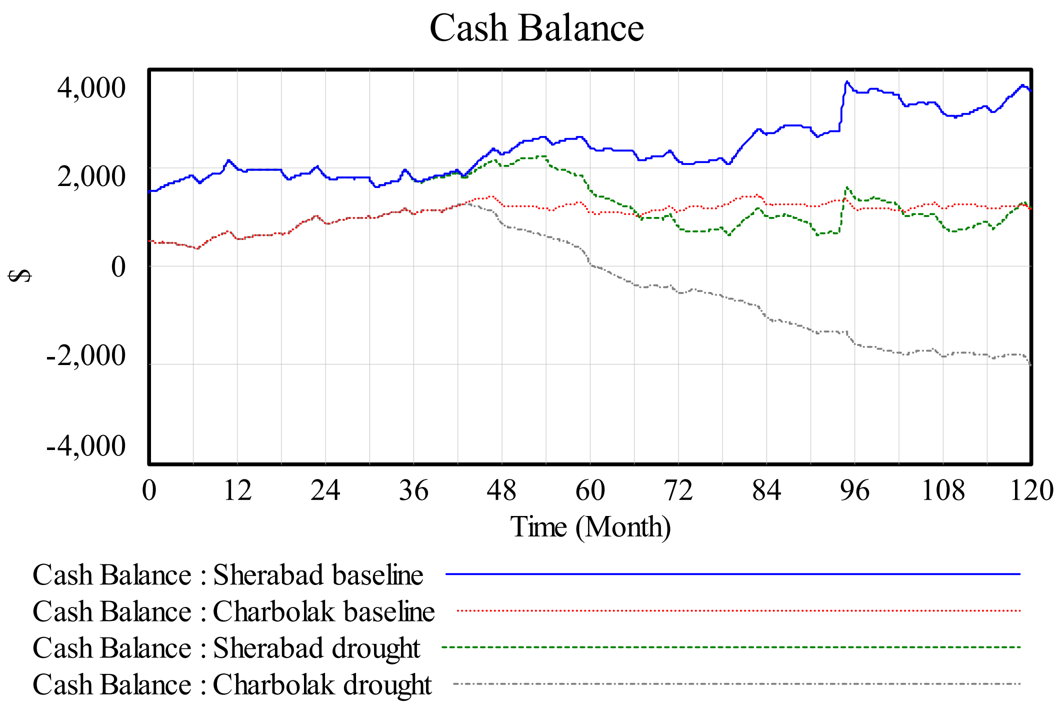


Figure 6.9 Simulated Cash Balance for Representative Households with a Drought Shock

The result of drought on cash balance can be dramatic for both households because their incomes are largely a function of crop production. For the Sherabad household, the behavior of the cash balance indicator changes from increasing to neither increasing nor decreasing over time, oscillating around a cash balance of $1,000. Interestingly, this is about the same level as the lower endowment household without the drought shock. The Charbolak household experiences a rapid decay to a lower level equilibrium from the drought conditions. Because most of the income or growth in cash balance for Charbolak comes from livestock, the household quickly goes into debt with such small returns to crop inputs.

The total number of animals in the herd did not suffer as much as expected under the drought conditions for Charbolak. The herd is able to grow at a steady pace despite the diminished stock of feeds, since they partially rely on local grasses (Figure 6.11).

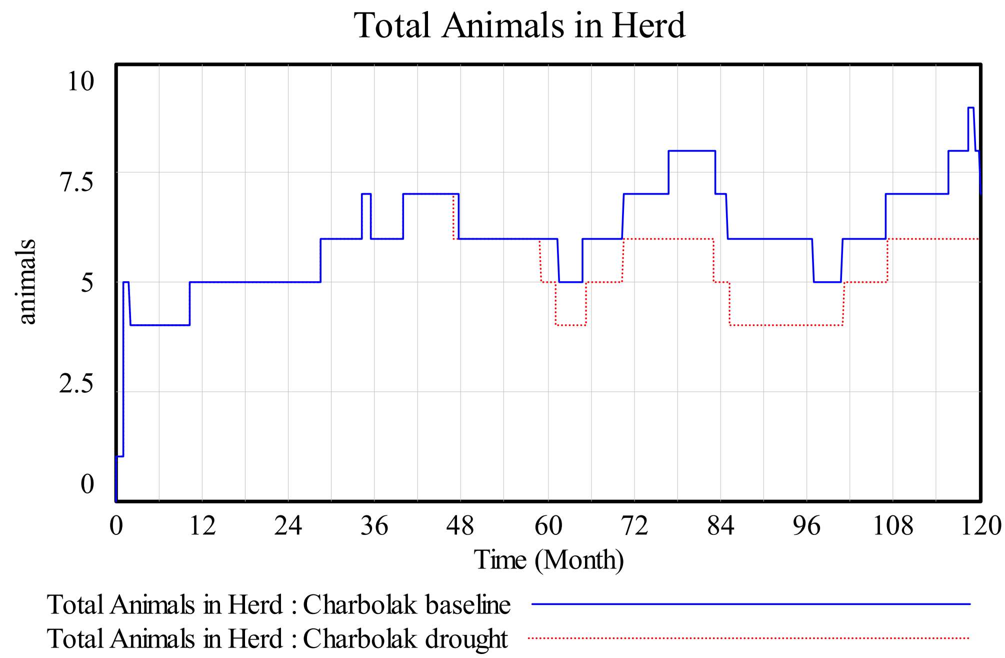


Figure 6.10 Simulated Herd Size for the Charbolak Household with a Drought Shock

Because Charbolak households depend upon range resources, the herd is less susceptible to losses in crop production. This assumes that range resources provide a constant amount of feed even during the low rainfall years, which is not necessarily the case. The herd appears to be oscillating around a mean of five animals for Charbolak under the drought. The Sherabad household does not suffer direct livestock losses from the drought since they are able to import feeds from the market in Mazar-i-Sharif when there is a shortfall.[124]

[124] As a result of the geographical diversity in Afghanistan, a drought in one area does not necessarily affect other areas of Afghanistan.

c) Impacts of a Price Shock

Afghan farmers have recently faced rapidly increasing input and output prices, particularly for wheat and fuel (thus, transportation costs). An increase in the price of wheat from the baseline model 14.1 afs/kg ($0.29/kg) to $0.40/kg at time = 18, is simulated as an economic shock.[125] Transportation costs are assumed to increase by $0.25 at time = 18, based on available price data for the last year (FAAHM, 2008). Without the presence of a rainfall or temperature shock, the households are both net sellers of wheat and thus experience a gain from increased wheat and transportation prices under the baseline model (Figure 6.12).

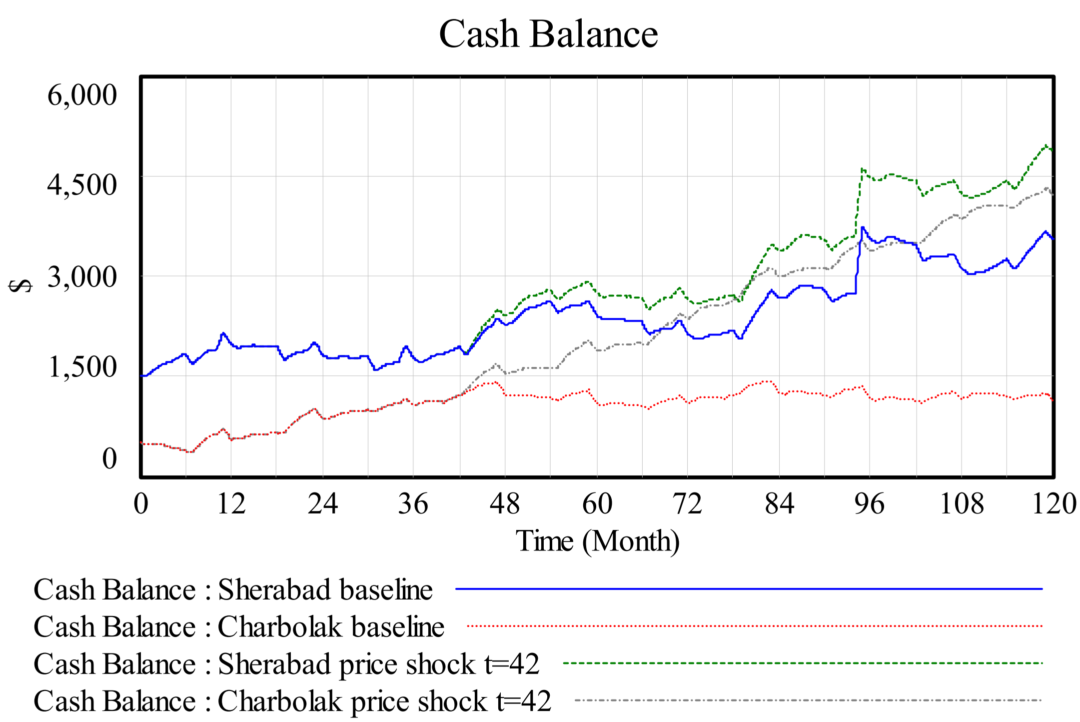


Figure 6.11 Simulated Cash Balance for Representative Households with a Price Shock

[125] Note that this 'shock' is much different than the temperature and rainfall shocks in that under baseline conditions the households are both better off than before the shock.

The price shock increases the cash balance for the Sherabad household by about $1,500 over the model simulation. The Sherabad household is able to increase returns from wheat production because they sell surplus stocks following each harvest in the absence of shocks that affect crop production.

The increase for the average Charbolak household is dramatic compared to the smaller gains made by the higher endowment household due to the larger wheat surplus during high rainfall years. Without a shock affecting either crops or livestock, the household is able to profit from the high prices for wheat. Under increasing wheat prices and no shocks, the lower endowment household could potentially reach the same level of cash balance as the higher endowment household. However, if either household were to shift from being a net seller to a net buyer of staples because of a temperature or rainfall shock, the effect of increasing prices negatively affects cash balances. Because the Charbolak household is more susceptible to shocks as seen in the two previous simulations, it is more likely to be affected by a price shock.

The price shock does not affect the herd dynamics in either household over the model duration. Both households would realize increased revenues from wheat production and experience no loss in crop yields or herd size as in the temperature and rainfall shocks.

Impacts of Interventions with Exogenous Shocks

The following section assesses the impact of the four interventions on each type of household given the three shocks to determine which interventions are robust under the various scenarios. In each of the simulations, the timing of the intervention is assumed to be constant (time=18) and the shocks are simulated two years after the intervention was implemented (time=42) to allow the household to respond to the intervention. The goal of this analysis is to assess whether the shocks alter the relative rankings of the interventions. Note that the simulations here assume that the shocks are exogenous and uncorrelated with other system changes (e.g., the temperature shock does not induce substantial price changes).

a) Assessment of Intervention Impact with a Temperature Shock. All of the four interventions are simulated at time =18 months for both households and the temperature shock is simulated at time =42 months. As in previous simulations of the interventions without shocks, the forage improvement intervention is the most beneficial for the higher endowment household by approximately $1,000 at the end of the simulation (6.13). It is also important to note that both the cow gift intervention and the transaction cost intervention are beneficial for the household, whereas in the baseline scenario without shocks, the transaction cost intervention was not beneficial. Each of these shocks leaves the household with approximately $1,000 more than without the intervention. As in the baseline scenarios, the land reallocation intervention has a negative effect on the household cash balance for Sherabad.

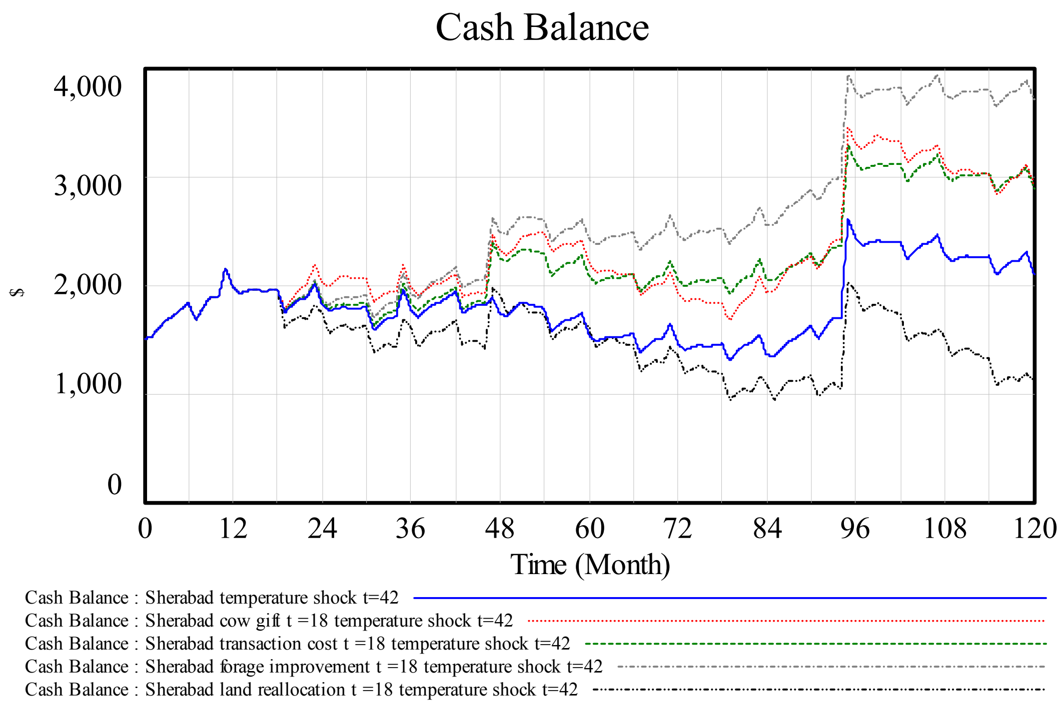


Figure 6.12 Simulated Cash Balance for the Sherabad Household with Four Interventions and a Temperature Shock

Only the cow gift intervention increased the animal assets of the household. It does so substantially, though, over the ten-year period (Figure 6.13). The cow gift intervention doubles the herd size for Sherabad in five years.

The same simulation is presented for the lower endowment household (Charbolak) in Figure 6.14.

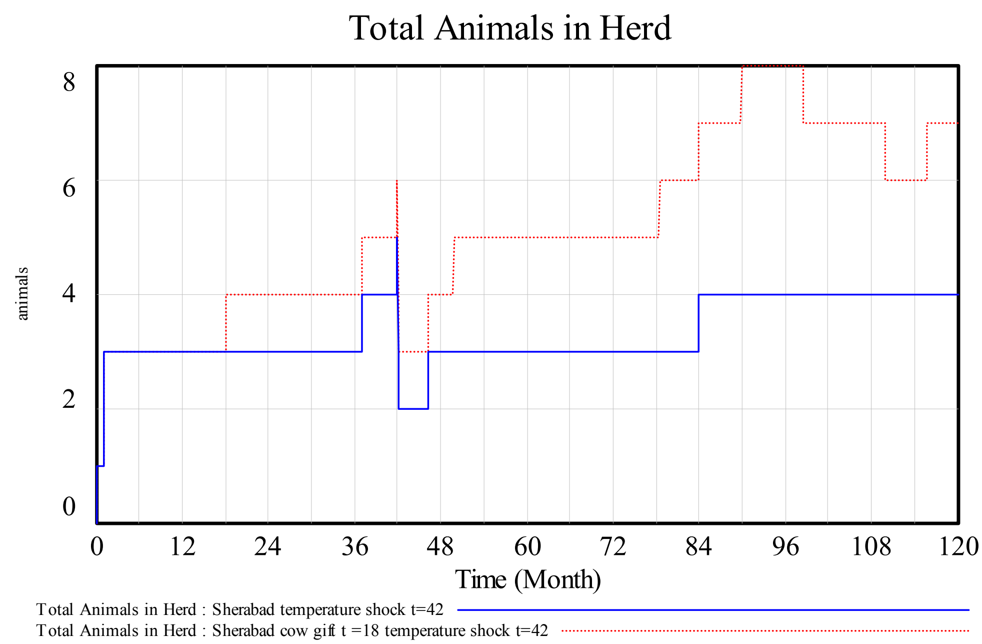


Figure 6.13 Simulated Herd Size for the Sherabad Household with Four Interventions and a Temperature Shock

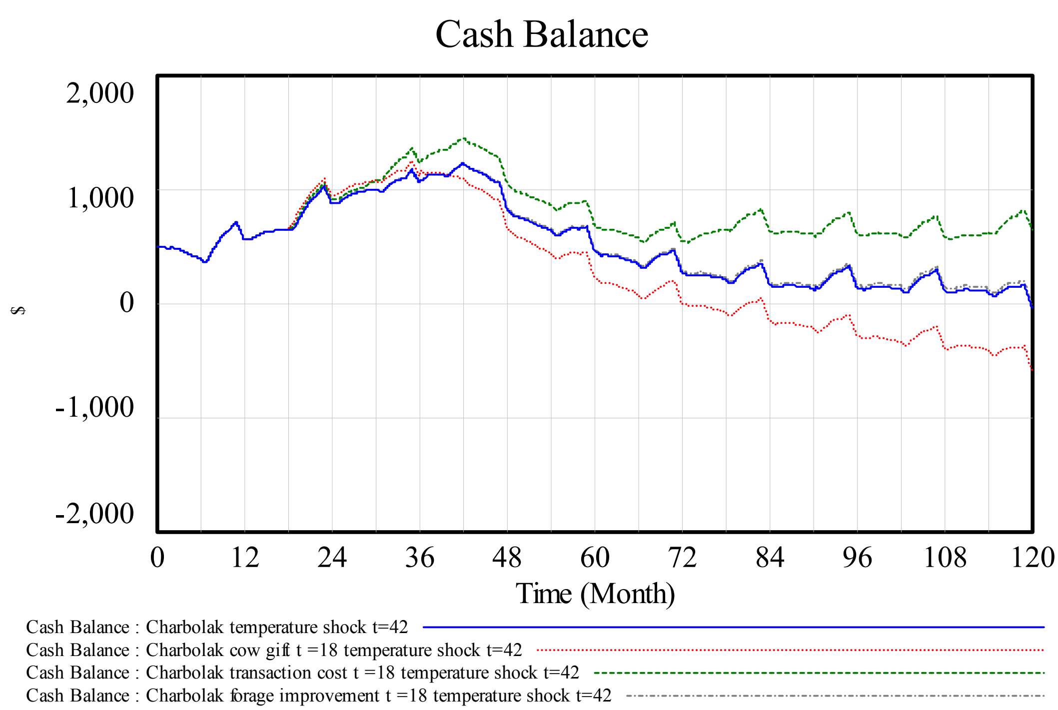


Figure 6.14 Simulated Cash Balance for the Charbolak Household with Three Interventions and a Temperature Shock

For the Charbolak household, different interventions increase the welfare of the Charbolak household more than they did for the Sherabad household. The cow gift intervention decreases the cash balance of the Charbolak household under a temperature shock but has a positive effect in terms of herd numbers (Figure 6.16). The transaction cost reduction intervention has a large beneficial effect on the low endowment household, whereas it had a negative effect on the high endowment household. Reducing transactions costs appears to be the only intervention that is profitable for the low endowment household with the temperature shock. The forage improvement intervention has an insignificant effect on the Charbolak household because the household manages a small plot of forage and the household is not able to irrigate as readily as the higher endowment household.

The Charbolak household is not able to sustain the same growth in the herd from the cow gift intervention as the high endowment household (Figure 6.15).

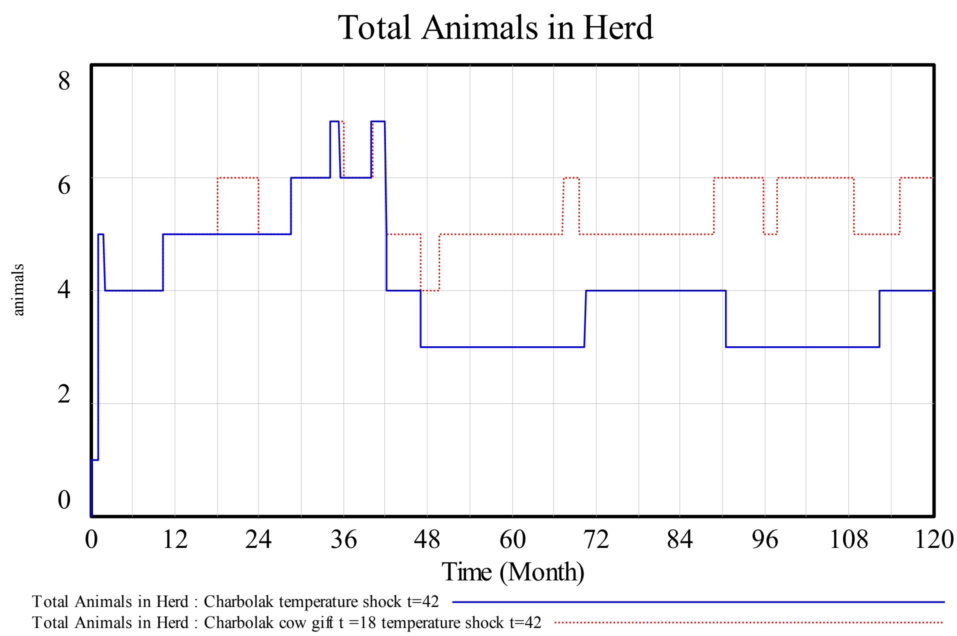


Figure 6.15 Simulated Herd Size for the Charbolak Household with Three Interventions and a Temperature Shock

The household appears to fall back into the same pattern of herd growth by the time of the temperature shock (t=42) although with a different herd structure (more lactating animals). Due to the difference in the herd structure, following the temperature shock with the cow gift intervention, the Charbolak household has more animals than the baseline temperature shock and the other interventions with the temperature shock. However, despite the higher animal numbers with the cow gift intervention, it is not profitable under the assumed decision making framework of the model (given the decrease in the cash balance).

b) Assessment of Intervention Impacts with Drought. The impact of each of the four interventions is evaluated for each of the two types of households in the face of simulated drought conditions. Forage improvement is the most beneficial for the Sherabad household assuming drought conditions (Figure 6.16). There are particularly high gains at time =98 when there is a bumper year. The Sherabad household is able to increase its cash balance from forage improvement in drought years because they have access to irrigation. The cow gift intervention also leads to an increase in the cash balance for the Sherabad household, preventing it from going into negative cash balance. The price received through the transactions cost intervention is not large enough to offset the transaction costs of selling milk for the Sherabad household, even under the shock. Both the transaction cost intervention and the land reallocation intervention leave the Sherabad household worse off than they were without the intervention.

Only the cow gift intervention increases the herd size of the Sherabad household (Figure 6.17). The increase is substantial, at three animals, leaving the household approximately as well off as the forage improvement intervention.

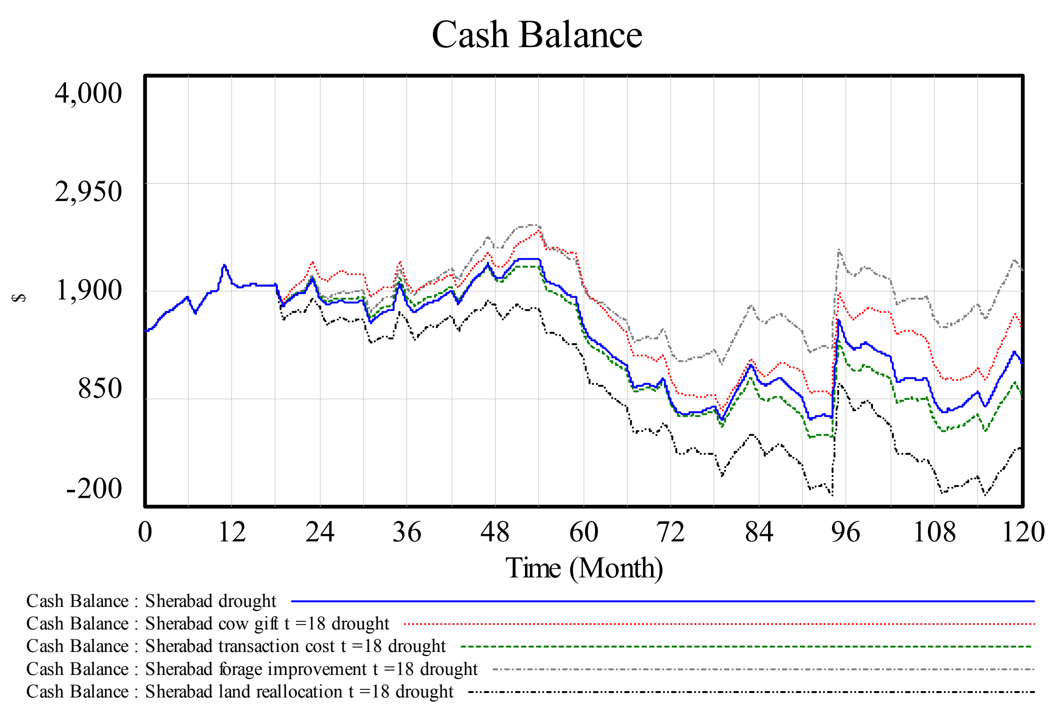


Figure 6.16 Simulated Cash Balance for the Sherabad Household with Four Interventions and a Drought Shock

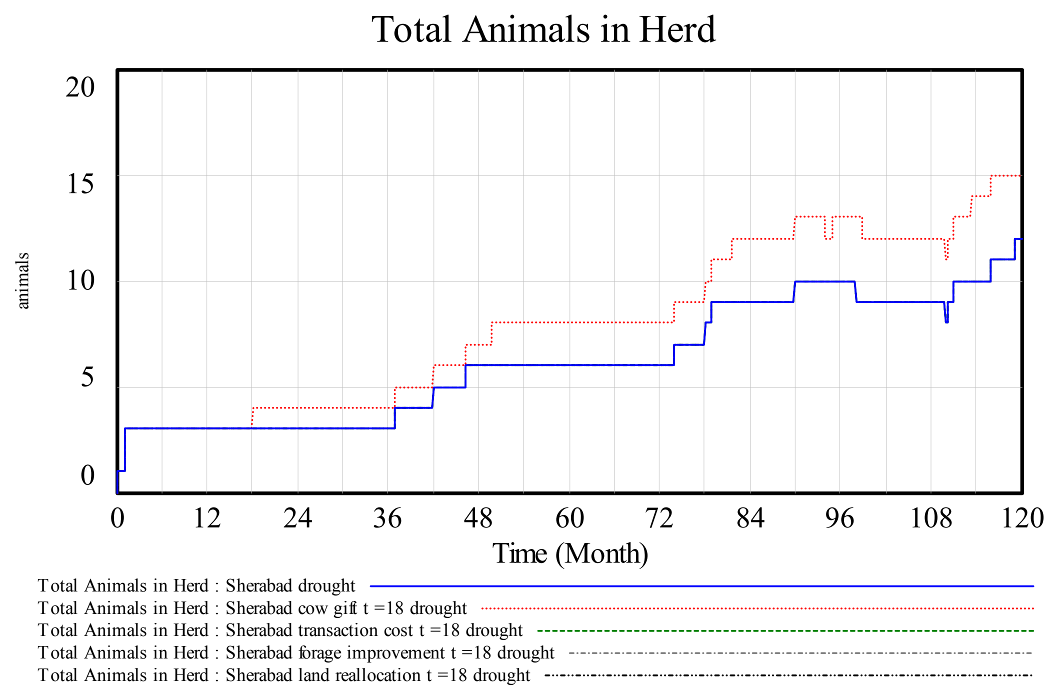


Figure 6.17 Simulated Herd Size for the Sherabad Household with Four Interventions and a Drought Shock

Similar to the temperature shock, only the transaction cost reduction or milk trader intervention has a positive impact on the cash balance of the Charbolak household in the presence of drought (Figure 6.18). The forage improvement intervention appears to have no effect on the Charbolak household. The cow gift intervention once again has a negative impact on the household at time =42 months since the household is unable to support the animal with their own feed stocks.

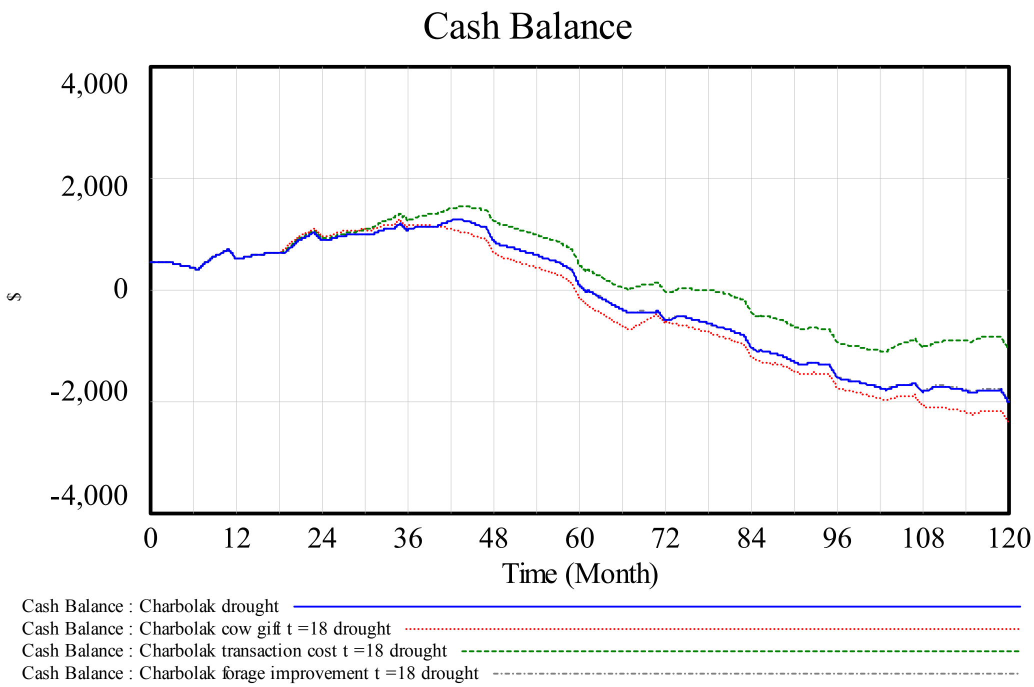


Figure 6.18 Simulated Cash Balance for the Charbolak Household with Three Interventions and a Drought Shock

The cow gift intervention increases the herd size almost immediately but the household is unable to retain the additional animal after a few months (Figure 6.19). This intervention leads to the same level of livestock in the herd by the end of the simulation.

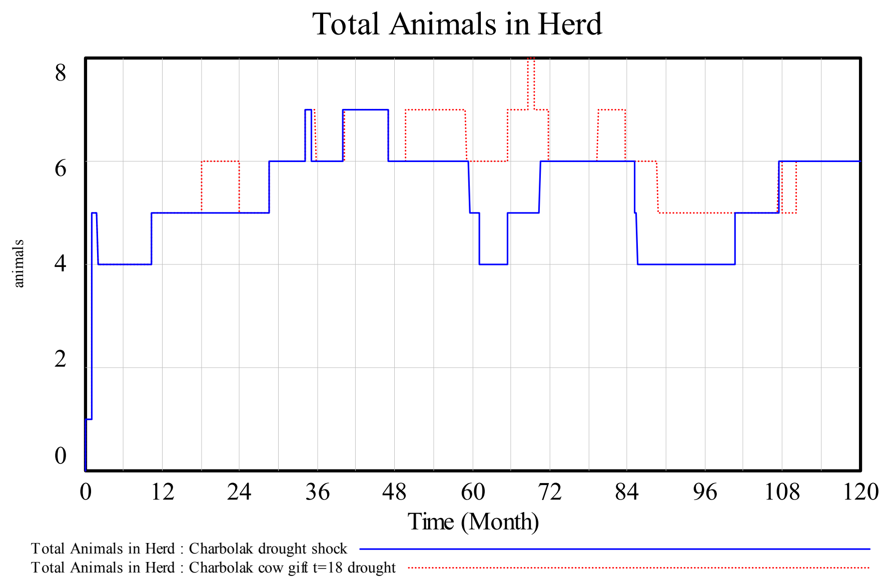


Figure 6.19 Simulated Herd Size for the Charbolak Household with One Intervention and a Drought Shock

All of the other interventions produce the same result for the size of the Charbolak household herd because it is already at their carrying capacity for maintaining the herd.

Impacts of Interventions with an Increase in Prices

The impact of each of the four interventions is evaluated for each of the two types of households in the face of the price shocks. The interventions are simulated at time =18 months and the shocks are simulated in the second year following the intervention (time =42 months) consistent with the simulation of other shocks. The same ordering of interventions results for the Sherabad household as under the other two shocks despite the difference in the type of shock (Figure 6.20).

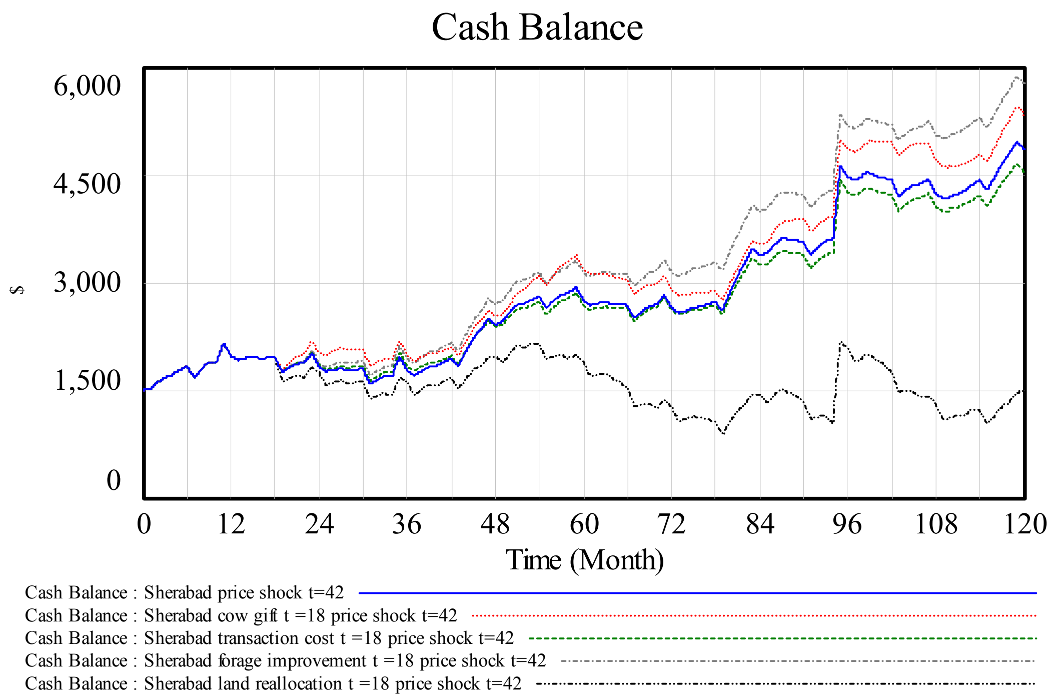


Figure 6.20 Simulated Cash Balance for the Sherabad Household with Four Interventions and a Price Shock

The cow gift intervention and the forage improvement intervention increase the cash balance from the baseline run with the price increase. The transactions cost intervention leaves the Sherabad household worse off than without the intervention. The forage improvement intervention (thus higher forage production) allows the household to expand the herd as well as sell more alfalfa per month. Increasing the herd size also allows the household to sell more milk per month. Only the cow gift intervention increases the herd size for the Sherabad household (by three animals at the end of the ten year simulation).

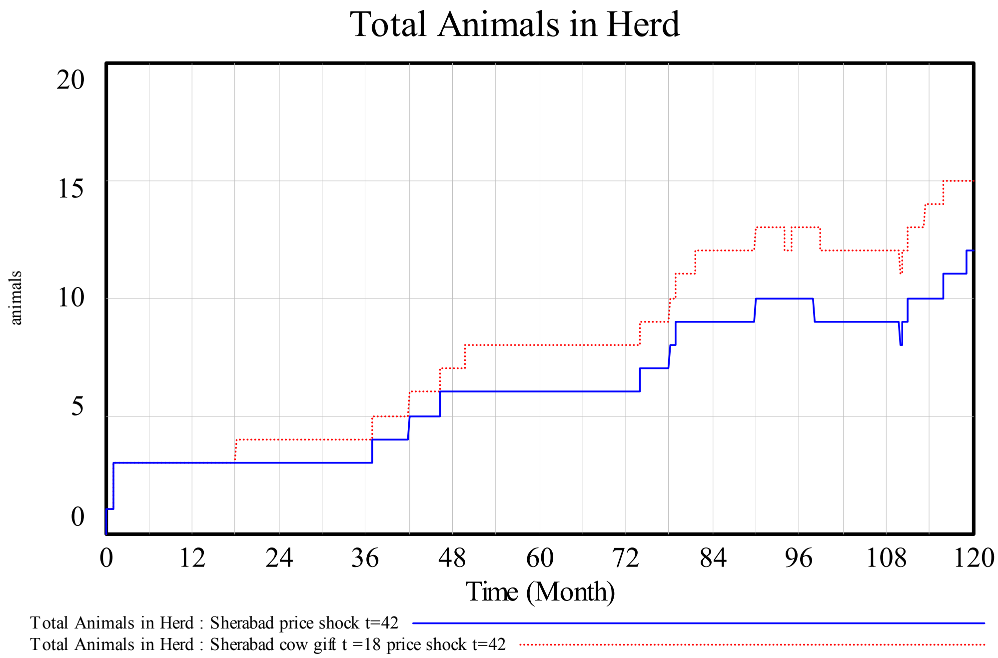


Figure 6.21 Simulated Herd Size for the Sherabad Household with Four Interventions and a Price Shock

In general, an increase in wheat prices appears to be extremely beneficial for the Charbolak household since they have significant surplus of wheat when rainfall is good. As in previous simulations for the Charbolak household, only the transactions cost reduction intervention leads to an increase in income (Figure 6.22).

There is a different pattern in the animal herd for the Charbolak household under the increase in wheat and transportation prices. The cow gift intervention leads to initially higher herd size, but then leads to an actual decrease in the herd size by the end of the model time (Figure 6.23).

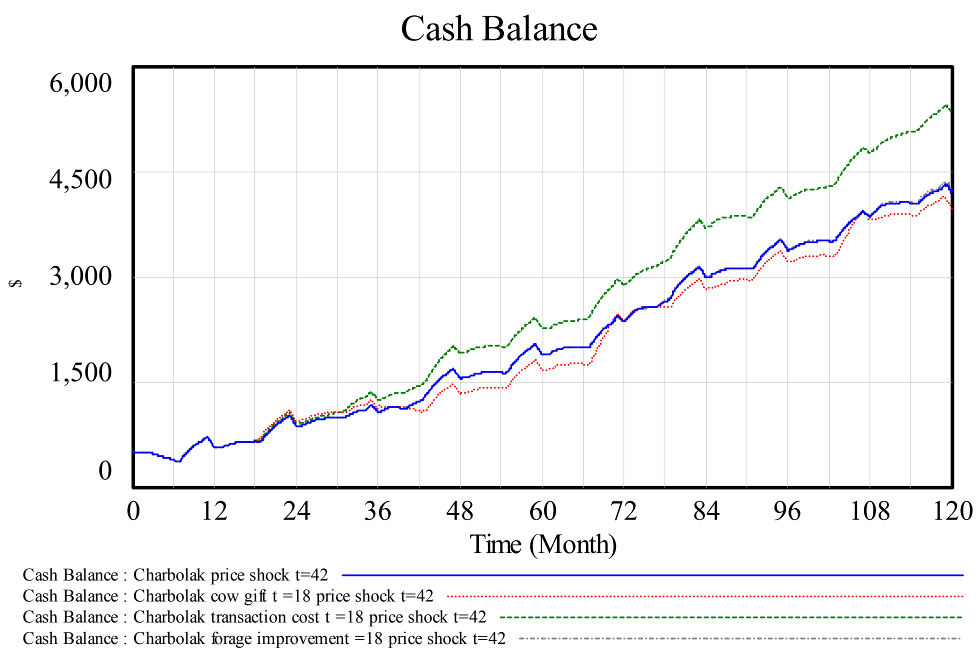


Figure 6.22 Simulated Cash Balance for the Charbolak Household with Three Interventions and a Price Shock

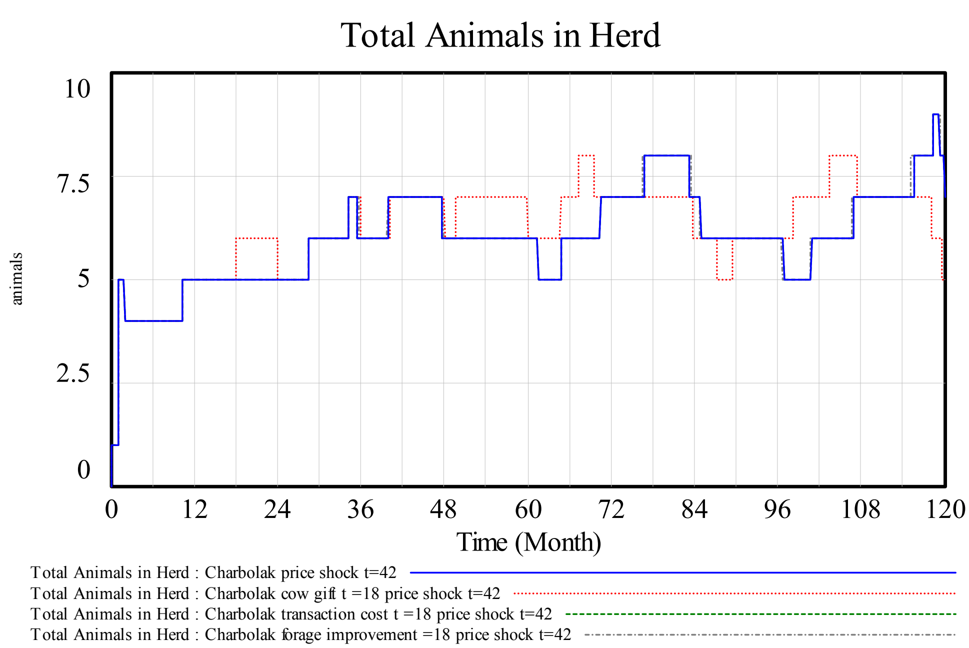


Figure 6.23 Simulated Herd Size for the Charbolak Household with Three Interventions and a Price Shock

This occurs because the Charbolak household reaches the maximum capacity of livestock it is able to support given the level of wheat and alfalfa production. As in the baseline model without shocks, the forage improvement intervention also increases the total animals in the herd by one animal near the end of the simulation.

As opposed to the other shocks, the price shock does not directly affect crop yields or livestock assets. When the same underlying crop and livestock conditions exists, as in the scenarios above and the baseline with interventions, the price shock does not alter the relative outcomes of the interventions. If the price shock were to be combined with a shock such as the rainfall or temperature shock then the relative rankings of the interventions outcomes could be different than those described herein. If the market position of the household changes, the response of the household to the price shock will also be different. These analyses are beyond the scope of this thesis, but are discussed in the conclusions and implications.

Sensitivity Analysis of Interventions

Sensitivity Analysis of Cow Gift Intervention and Timing of Temperature Shock: The cow gift intervention has a beneficial effect on both households in almost every simulation. For this reason, the intervention warrants an exploration of the sensitivity of temperature shock timing relative to the timing of the intervention, because the temperature shock has the largest impact on animal assets. The timing of the intervention is held constant at time =18 and the timing of the shock on the household is varied for each winter period until the end of the model time (t=18, 30, 42, 54, 66, 78, 90, 102, 114). This sensitivity analysis of shock timing consistent with intervening organizations having control over when they intervene, but not knowledge of when a temperature shock might occur.

The results of the sensitivity analysis are presented in below (Figures 6.24 and 6.25).

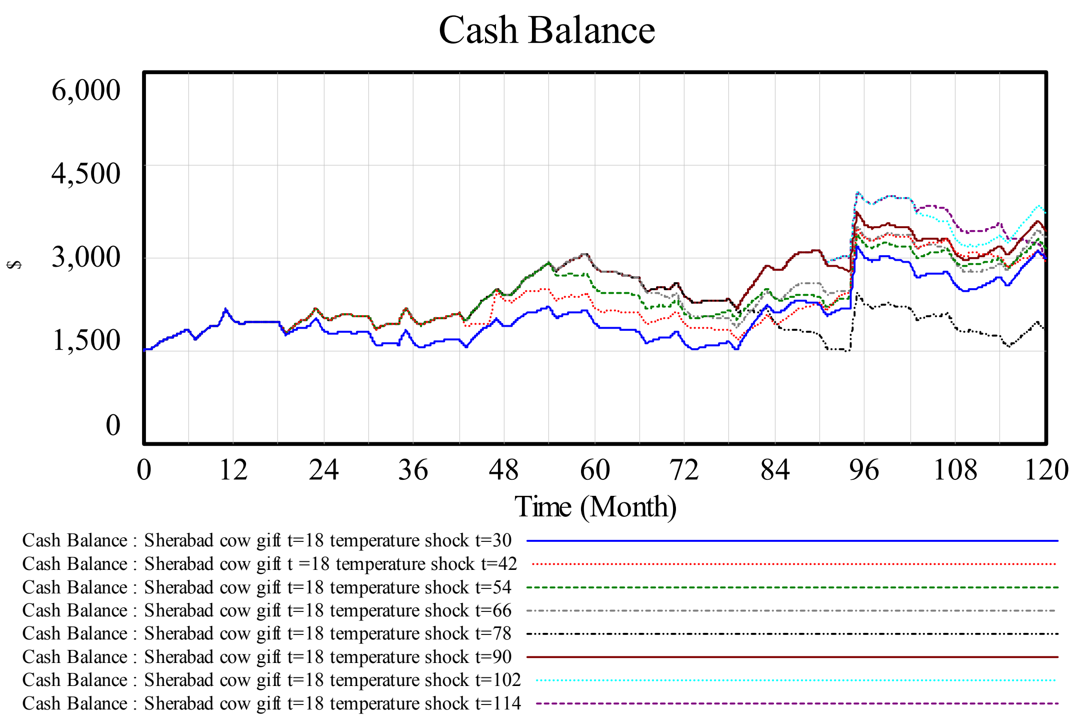


Figure 6.24 Simulated Cash Balance for the Sherabad Household with the Cow Gift Intervention and a Temperature Shocks at Various Times

For the Sherabad household, the temperature shock sensitivity analysis produces some unexpected results. In general, it is true that the earlier the shock occurs in the simulation, the lower the household cash balance is. However, there are some exceptions, such as at time =78, where the temperature shock leaves the household worse off than some of the other earlier or later shocks. At this simulation time, the household suffers more foregone income as a result of a potential bumper harvest in the baseline scenario as well as a loss of more lactating animals that have just matured from the heifers stock into the lactating stock. Another example is the cash balance for the shock at time=114, which is lower than the shock at time=102 because more animals were susceptible to shock at that time. These results imply that it is difficult to predict the outcome of this particular intervention for a shock that affects both production and assets of the household without a dynamic analysis. There is a range of $2,000 for the household cash balance and range of eight animals in the herd over 10 years (Figure 6.25).

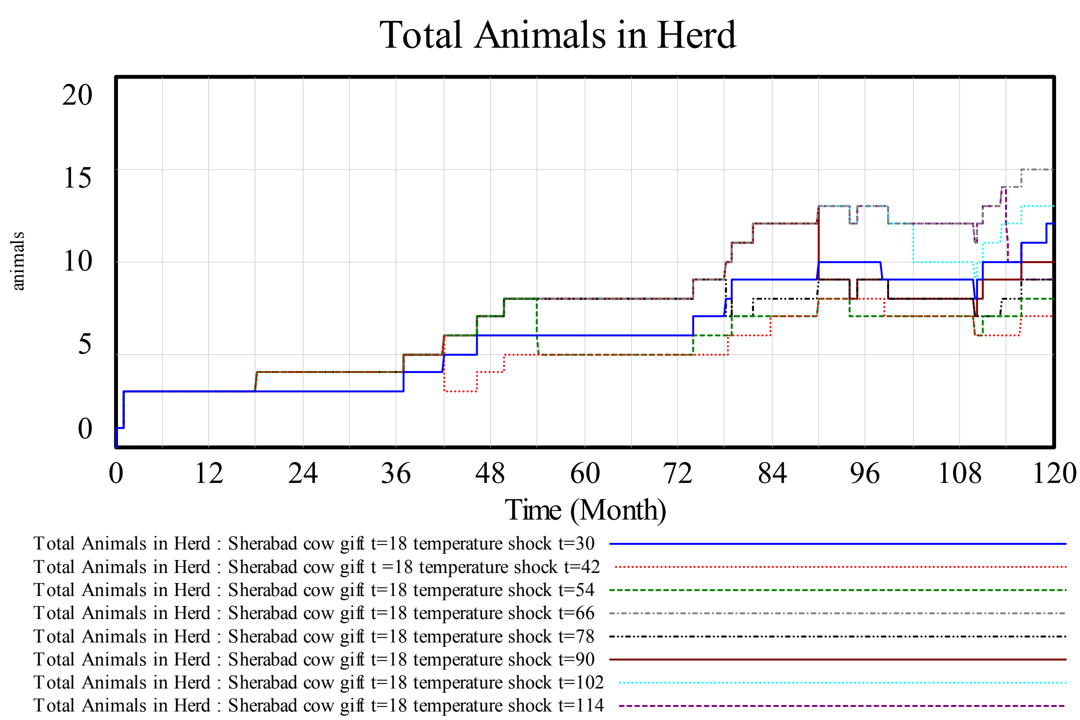


Figure 6.25 Simulated Herd Size for the Sherabad Household with the Cow Gift Intervention and a Temperature Shocks at Various Times

The same simulations of interventions produce different outcomes for the Charbolak household (Figure 6.26).

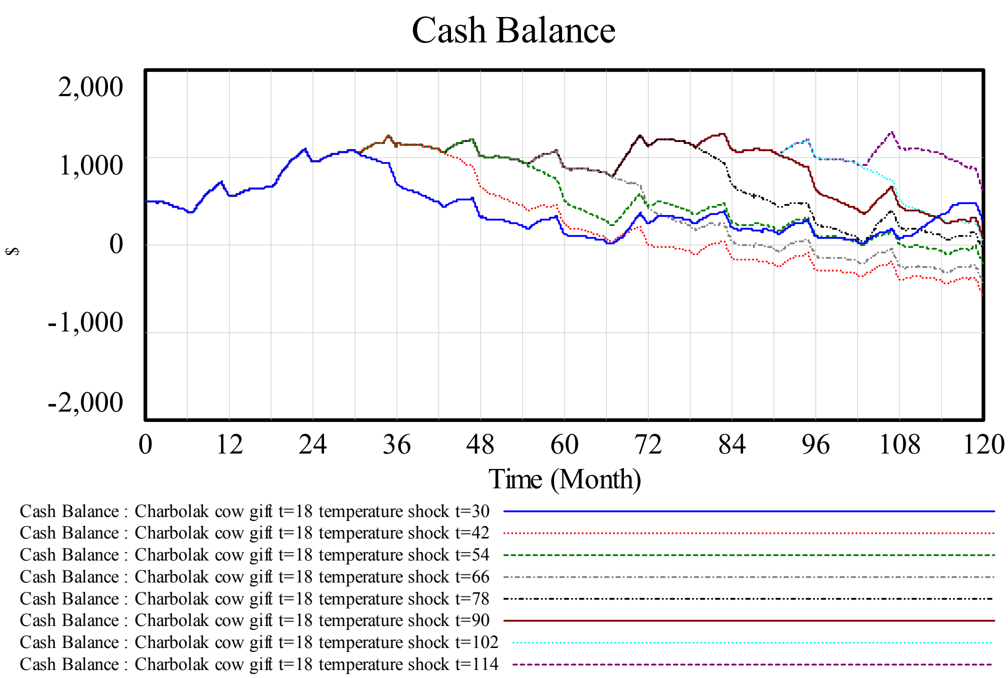


Figure 6.26 Simulated Cash Balance for the Charbolak Household with the Cow Gift Intervention and a Temperature Shocks at Various Times

The cash balance behavior for Charbolak, in response to the temperature shock is qualitatively more consistent than the Sherabad households. This result suggests that it is easier to predict the outcome of a temperature shock on lower endowment households. However, in some scenarios the household is able to recover quicker than others (the household recovers more quickly from the shock at t=30 as opposed to t=42, t=66, where it takes much longer). This implies that the timing of the temperature shock might alter the relative ranking of the interventions. This is truer of the cow gift intervention than other interventions because herd composition at the time of the shock can significantly change the outcomes of the shock for the household. This analysis illustrates an important principal about the uncertainty of intervention outcomes in a risky environment, but a more complete exploration of the impacts of the timing of various shocks is beyond the scope of this thesis and is thus left for future research.

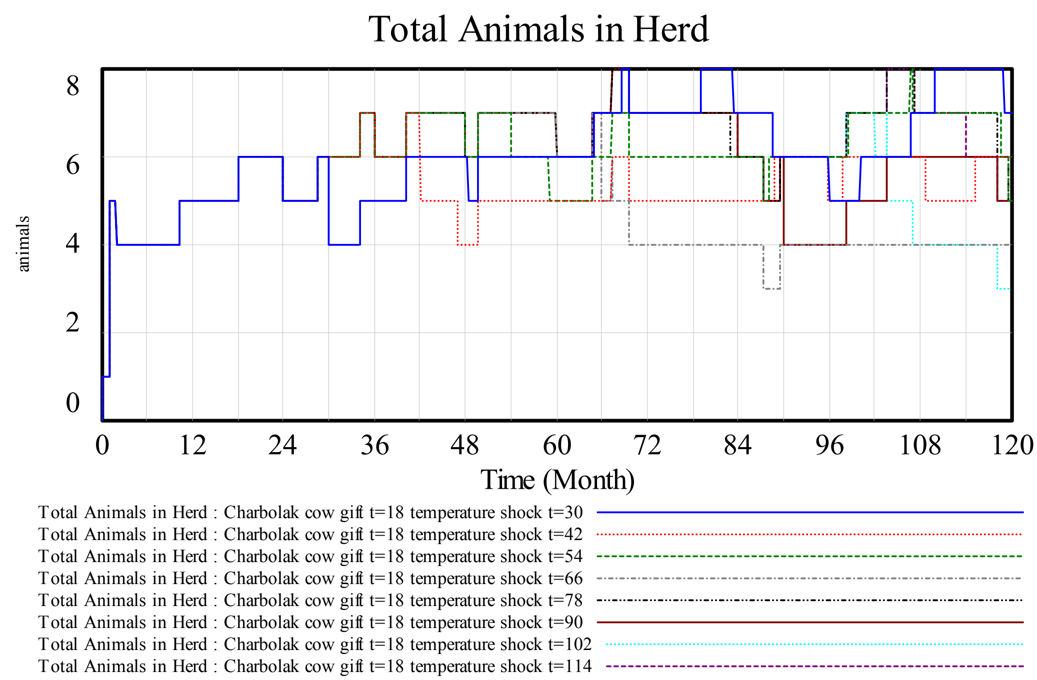


Figure 6.27 Simulated Herd Size for the Charbolak Household with the Cow Gift Intervention and a Temperature Shocks at Various Times

Sensitivity Analysis of the Improved Forage Germplasm Intervention: Analysis of the improved forage germplasm is conducted to test the sensitivity of the households to alternative yields and costs of the intervention. This is motivated by a lack of available empirical data and research on forage germplasm in Afghanistan. Figure 6.28 depicts additional sensitivity analysis of fertilizer application using Monte Carlo simulation given a random uniform distribution of the fertilizer application rate.

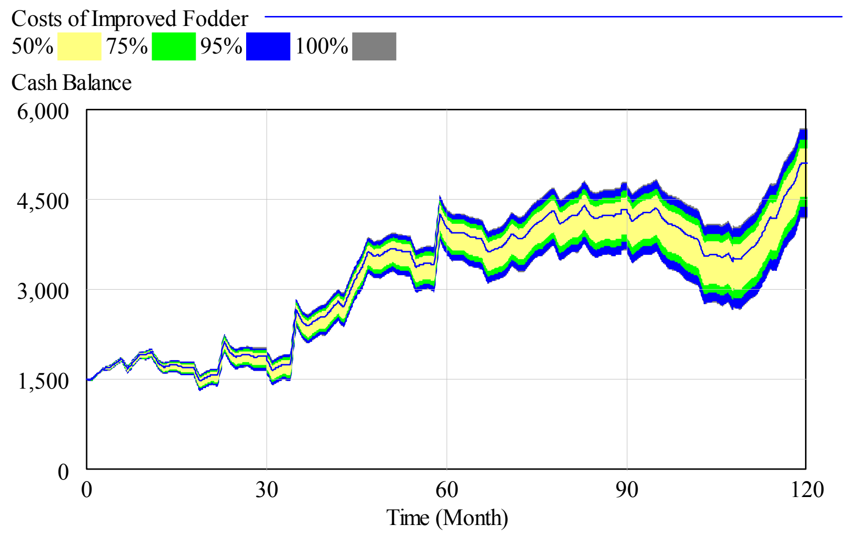


Figure 6.28 Sensitivity Analysis for Cash Balance of the Sherabad Household under Scenarios Assuming DAP Application from 0 to 25kg/jerib

The lower bound of fertilizer use is based on an FAO estimation of higher yields with improved germplasm (400 kg/jerib above the average of 1200kg/jerib/cut, every three months, except winter)[126] without additional factor inputs, whereas the upper bound of fertilizer application represents a modest application of DAP which is commonly used on forage in Afghanistan. In effect, this sensitivity analysis assesses the range of possible costs associated with achieving an increase in yield of 400 kg/jerib or 2,000 kg/hectare. The difference in this estimation over ten years could be as much as a $1,500 net profit (approximately $150/year gain for livestock farmers on three jeribs or a $50 per jerib or $250 per hectare per year improvement) for households over ten years. This also assumes that improved seeds are available and that yield does not decline over the productive lifetime of the crop (for a ten year stand of alfalfa).

Given the sensitivity analyses results reported in Chapter 5 and this simulation, it appears that additional detailed empirical data on alfalfa yields and nutrient

[126] In metric this is 2,000kg above the average of 60,000 kg/hectare average.

requirements are necessary to provide a more definitive assessment of this intervention. In essence, there is insufficient information at present given the sensitivity of simulated outcomes to the underlying range of assumed values.

Summary Discussion

Table 6.2 is a summary of the baseline and four interventions for each of the three shocks for each of the two household type on the ending cash balance and livestock numbers. The total value of the cash and herd is calculated for each intervention and ranked. The total value is equal to the sum of the cash balance column and the cash value of the herd which is approximated at $725 per animal in Sherabad and $700 in Charbolak.

Table 6.2 Summary of Selected Outcomes of Interventions at Final Model Time Under Alternative Shocks[127]

	Sherabad			**Charbolak**		
	Cash Balance	Herd Size	Total Value	Cash Balance	Herd Size	Total Value
Baseline, no shocks[128]	$3,553	12	$12,253	1,151	7	$4,900
Cow gift, change from baseline	+416	+3	+2,591 *	-259	-2	-1,659
Transaction cost, change from baseline	-315	+0	-315	+1,143	+0	+1,143 *
Forage improvement, change from baseline	+921	+0	+921 **	+3	+1	+703 **
Land reallocation, change from baseline	-1,779	+0	-1,779	n	n	n

127 Interventions are simulated at t=18 given shocks (t=42) at final time (t=120)
128 * = most desirable, ** = second most desirable, *** = third most desirable, n = not simulated

Table 6.2 (Continued)

	Sherabad			Charbolak		
	Cash Balance	Herd Size	Total Value	Cash Balance	Herd Size	Total Value
Baseline temperature shock	\$2,104	4	\$5,004	-45	4	\$3,155
Cow gift, change from temperature baseline	+830	+3	+3,005*	-593	+2	+852*
Transaction cost, change from temperature baseline	+787	+0	+787***	641	+0	+686**
Forage improvement, change from temperature baseline	+1,602	+0	+1,602**	-7	+0	+38
Land reallocation, change from temperature baseline	-1,000	+0	-1,000	n	n	n
Rainfall shock baseline	\$1,186	12	\$9,886	-\$2,013	6	-\$2,013
Cow gift, change from rainfall baseline	+349	+3	+2,524*	-2,377	-1	-336
Transaction cost, change from rainfall baseline	-315	+0	-315	-1,062	+0	+951*
Forage improvement, change from rainfall shock baseline	+908	+0	+908**	-1,997	+0	+16
Land reallocation, change from shock baseline	-841	+0	-841	n	n	n
Price shock baseline	\$4,855	12	\$7,030	\$4,231	7	\$4,231
Cow gift, change from price shock baseline	+476	+3	+2,651*	-257	-2	-1657
Transaction cost, change from price shock baseline	-316	+0	-316	+1,142	+0	+1,142*
Forage improvement, change from price shock baseline	+920	+0	+920**	+3	+1	+703**
Land reallocation, change from price shock baseline	-3,376	+0	-3,376	n	n	n

This summary of indicators presents the relative benefits of the interventions under various environmental conditions, which can be useful to development agencies interested in these interventions. Simulation outcomes which lead to a positive outcome for the household are ranked by the combined value (total value in the table) of the cash balance and the livestock assets relative to the other interventions given the environmental conditions.

For the higher endowment household, the cow gift intervention increases the herd size by three lactating animals under all environmental conditions (a market value of about $2,220 in Sherabad). However, the cow gift intervention increases the household cash balance less than the forage improvement intervention. The cow gift intervention leaves increases the cash balance by $416 (baseline), $830 (temperature), $349 (drought), and $476 (price shock) whereas the forage improvement intervention increases the balance by $921 (baseline), $1602 (temperature), $908 (drought), and $920 (price shock). This is about double the gains from the cow gift intervention excluding the value of the additional animals. When the value of the animals is considered, the Sherabad household is far better off with the cow gift intervention.

For the lower endowment household, the transaction cost intervention is beneficial under all environmental conditions. Under the temperature shock, the transaction cost intervention pays $1143 more than the baseline with the shock. Under the temperature shock, the forage improvement intervention does not increase the cash balance but does increase the herd size by one at the end of the simulation. The value of an additional animal ($700 in Charbolak) is less than the amount of additional income from the transaction cost intervention, however. Under the temperature shock scenario the household has $548 less with the cow gift intervention and increases the cash balance by $686 with the transaction cost intervention. The value of two cows is roughly equal to slightly more ($1400) than the difference between the two interventions in terms of the cash balance ($1234). The transaction cost intervention is $951 better under drought scenario, which is the only intervention that increases cash balance. With higher prices, the transaction cost intervention yields $1142 more than other interventions, whereas the forage improvement intervention increases the herd size by one but only nominally increases the cash balance ($3) by the end of the simulation. For the lower endowment household, the cow gift intervention can produce unintended negative results. Only the transaction cost intervention consistently improves the welfare of the household over the course of the simulation.

CHAPTER 7

CONCLUSIONS

A key conclusion of this study is that targeting of development interventions in this region of Afghanistan is essential to achieving desired outcomes, particularly in light of various largely unpredictable climatic and economic shocks. Interventions to improve productivity of crop-livestock systems in the region can have very different impacts on a household, depending on the timing of shocks, the state of the cattle herd, the initial conditions (assets) of the household, and the type of shock. As might be expected, the lower endowment household is more susceptible to shocks given their dependence on rainfed agriculture, larger herd sizes, and greater distance from markets. Moreover, shocks can produce a bifurcation dynamic wherein the lower endowment household appears unable to recover from the shock financially, but the higher endowment household recovers relatively quickly. In addition, the market position (net buyer or seller of staple crops) of the household appears to be a key determinant of how the household will fare under an exogenous shock.

The cow gift intervention appears to be beneficial for the high endowment household because they are able to supplement the animals with purchased feeds with lower transaction costs in order to maintain a larger herd size. However, many of these households maintain fewer animals than the poorer household, suggesting that they are unwilling to develop larger herds and would likely sell additional animals that were gifted. The effect of the cow gift intervention on the lower endowment household is ambiguous given the timing of shocks and the timing of the intervention. Because the Charbolak household is unable to purchase feed stocks to sustain additional animals, it appears to be inadvisable to give them additional lactating animals since the result can be ambiguous.

The transactions cost intervention can be beneficial for the Charbolak household depending upon the difference between the market price of milk and the price the trader is willing to pay farmers for milk. In general, it is not beneficial to implement this type of intervention with households near urban areas, because the household is more likely to suffer more foregone income in the prices paid by traders than the transaction costs of selling in the market, given the assumption that the price paid by traders for the milk is the same regardless of the location of the farm. Reducing transactions costs, however, is beneficial under all environmental conditions for the lower endowment household.

The forage improvement intervention increases the high endowment household cash balance under all environmental scenarios, but has no effect on lower endowment households because it has an insignificant amount of irrigated land to produce forage. However, the forage improvement intervention is more difficult to assess at present given the dearth of information available about potential yield increases and additional costs of improved varieties of forage. Before this type of intervention is promoted to livestock owners it is advisable that more in-depth crop trials and costs and return estimates are conducted.

The land reallocation intervention exhibits the widest variety of results due to the increased risk a household must shoulder when depending upon livestock for cash income. Feeding animals for a higher level of production seems to be a promising strategy although it can be risky for the household to shift land in staple crops to forage crops. Given the current rise in wheat prices, it is unlikely that the risk of shifting into more intensive livestock production is advisable at this time, although changing feeding strategies to favor higher milk production for fewer animals could be advantageous. Drought conditions are so common in Afghanistan that risk-averse behavior is likely to persist among both high- and low-endowment households, probably with good reason.

Policy Implications

The model results show that the household characteristics and their ability to respond to various environmental conditions can greatly influence the outcomes of a given intervention.   Promoting livestock or forage projects in northern Afghanistan may have unintended consequences (lower the value of their combined cash and livestock assets) for certain households due to the additional costs associated and the relative ability of the household to support livestock through crops produced on farm.

The results show that small-scale milk collection schemes may have the most positive impact on lower-endowment households because they are further from the market and incur transactions costs higher than those of milk traders. As long the assumed trader price is paid to farmers, the reduction in transaction costs for selling milk will allow these lower-endowment households to substantially increase cash balance.

Perhaps the most important policy implication is that the simulations show that information that is unavailable to development practitioners or policy-makers is needed to predict the outcome of certain interventions to prevent unintended consequences. Key pieces of information, such as the market position of the household (and how it may change over time), can be a key determinant of the adoption or efficacy of an intervention. These data should be collected prior to implementation of development interventions.

Extensions

One of the most logical next steps is further testing and assessment of the simulation model with comprehensive farm-level data. This model provides a strong outline for identifying uncertain parameters and relevant variables when considering one of the simulated interventions but is still only a model. More specifically, it would be beneficial to have research data on the costs and returns of alfalfa production, particularly improved varieties. More detailed household consumption data will also be very important for model verification and future modeling given the results of sensitivity analyses reported in Chapter 5.

Relevant extensions to the model include development of a more detailed decision-making structure based on survey findings. Additional behavioral assessment may improve the realism of the current model and possibly predict patterns of behavior that are excluded from the current structure. Further development of dynamic and endogenous animal feeding strategies may also improve model prediction.

Additional analyses (such as those referred to herein but omitted) to more comprehensively select the best outcomes should be conducted, including incorporation of empirical forage data. Consideration of risk aversion preferences and the probability of shocks and thus ranking of interventions in terms of stochastic dominance may be useful in determining the best intervention for each household.

APPENDIX 1

Table A1.1 MODEL PARAMETER ESTIMATES AND SOURCES FOR DATA

Model Parameters by View (initial conditions for Sherabad)			
Parameter Name	**Units**	**Initial Value**	**Source**
		Herd Structure[129]	
Maturation Delay	months	12	There is no Afghan term for this period. The term heifer is used in the model to distinguish different feeding practices after 1 year of age.
Heifer Parturition Delay	months	27	FAO 2006 survey, Mazar-i-Sharif, amount of time an animal is a heifer, post maturation (estrus) to age of first calving (1st calving =2.29 years or 27.48 months).
Lactation Length	months	10	FAO 2002 survey, Mazar-i-Sharif. This appears to range quite a bit in other areas of Afghanistan from as much as 6-10.
Calving Interval	months	31.8	FAO 2006 survey, Mazar-i-Sharif. (including lactation length and gestation delay)
Cow Average Productive Lifetime	months	108	Focus group estimate. Corroborated by Fitzherbert (2005)
Gestation Time Delay	months	9.4	9.4 months or 283 days.
Ox Maturation Time	months	20	This is based on focus group information. Age when oxen are used for plowing.
Oxen Average Productive Lifetime	months	120	Focus group estimate. 10 years for oxen.
Minimum Feed Consumption	dmnl[130]	1	When feed intake falls below the level of maintenance requirements for animals, they are sold.

[129] Note that many of the monthly figures for animal rates are round (24 months, 30 months) because farmers were reported in years even though questions were asked in terms of months. Not based on recorded reproduction rates.
[130] dmnl= demensionless. This is used for ratios, where units cross eachother out.

Model Parameters by View (initial conditions for Sherabad)			
Effect of ME Ratio on Heifer Parturition	dmnl	(0,1.33), (1,1.33), (1.98,1), (3,0.79)	Function is calibrated based on ratio of intake to maintenance returning Average Heifer parturition delay. Upper bound is reference ME level. The delay is variable based on whether the input is above or below this figure
Effect of ME Ratio on Open Dry Parturition	dmnl	(0,1.32), (1,1.32), (1.43,1), (3,0.61)	Same as above
Smooth Time	month	1	This smoothes the intake to maintenance ratio by
Livestock Inputs[131]			
Reference Feed Per Animal per Day [animals]	kg/animal/ day	Table A3.1	FAO 2006 survey, interviews, expert opinion in Mazar-i-Sharif. For Calf, Heifer, Lactating Open, Dry Bred, Open Dry, Oxen respectively.
Priority of Animals for Feeding	dmnl	(1)Lactating animals, (2) open dry abd dry bred, (3) all others	Based on focus group and expert opinion, Mazar-i-Sharif.
ME per kg Fed [Wheat Straw]	Mcals/kg	1.47	Estimates from CNCPS for the type of feed in the quantity of the base diet.
ME per kg Fed [Alfalfa]	Mcals/kg	2.48	Same as above
ME per kg Fed [Cottonseed Meal]	Mcals/kg	2.14	Same as above
ME per kg Fed [Grass]	Mcals/kg	2.36	Same as above
Replenished Tissue per ME	kg/Mcal	0.08	CLASSES estimate (Stephens et al., 2008).
Mobilized Tissue per Mcal	kg/Mcal	0.13	CLASSES estimate (Stephens et al., 2008)

[131] Much of the data regarding livestock parameters was collected by household survey not by more empirical methods such as weighing feeds and measuring lactation yields. Therefore, in the model averages are rounded and median figures are chosen when a discrete integer is desired. After a working model was completed sensitivty of these parameters within the ranges reported is tested and results are given.

Model Parameters by View (initial conditions for Sherabad)			
Maximum Fractional Mobilization Rate	1/month	0.5	CLASSES estimate (Stephens et al., 2008)
Percent Minimum Body Fat	kg/animal	0.05	CLASSES estimate (Stephens et al., 2008)
Initial Body Fat	kg/animal	40 kg MBW	CLASSES estimate (Stephens et al., 2008).
Daily ME Maintenance Requirements per Animal [Calf]	Mcals/animals/days	1	CNCPS output based on average diets from FAO 2006 survey.
Daily ME Maintenance Requirements per Animal [Heifer]	Mcals/animals/days	7.9	CNCPS output based on average diets from FAO 2006 survey.
Daily ME Maintenance Requirements per Animal [Lactating Open]	Mcals/animals/days	9.3	CNCPS output based on average diets from FAO 2006 survey.
Daily ME Maintenance Requirements per Animal [Open Dry]	Mcals/animals/days	6	CNCPS output based on average diets from FAO 2006 survey.
Daily ME Maintenance Requirements per Animal [Dry Bred]	Mcals/animals/days	8.3	CNCPS output based on average diets from FAO 2006 survey.
Daily ME Maintenance Requirements per Animal [Bull]	Mcals/animals/days	5	CNCPS output based on average diets from FAO 2006 survey.
Livestock Outputs			
Milk Constant	dmnl	0.361	This is a constant taken from CLASSES (Stephens et al., 2008) Also in Fox (2004).
Mcal per kg Fat	Mcals/kg	0.097	This is a constant taken from CLASSES (Stephens et al., 2008) Also in Fox (2004).
Fat Content of Milk	dmnl	3.3	This is the average fat content reported by Balkh Dairy, who collects, tests, and sells milk for Sherabad.
ME to NEm Efficiency	dmnl	0.63	This is a constant taken from CLASSES (Stephens et al., 2008) which is taken from CNCPS.
Average Daily Milk Production	kg	6.91	This is the average production of milk recorded in Mazar from FAO 2006 survey data.

Model Parameters by View (initial conditions for Sherabad)			
Average Milk Market Transactions Costs	$/day	0.67	30 afs/trip from Mazar to Sherabad.
Slope of Transportation Costs	$/day/month	0.0085	Estimate is from the transportation price index compiled by the (FAAHM) ministry of agriculture (average monthly slope from 2005-present).
Market Price of Milk	$/kg	0.34	Price for a liter of milk in Mazar was 17 afg which is about $.34/kg with a 1/50 currency exchange (or $340/T). June 2006. Land of Lakes Data.
Daily Feeding Labor Required per Head	hour/animal/day	0.5	Focus group data. Mazar-i-Sharif. Corroborated with survey data.
Daily Grazing Labor Required per Herd	hours/day	2	Focus group data. Mazar-i-Sharif
Daily Lactation Labor Required per Head	hour/animal/day	0.5	Focus group data. Mazar-i-Sharif
Daily Feed Collection Labor per Head	hour/animal/day	0.5	Focus group data. Mazar-i-Sharif
Days per Month	days/month	30	Conversion constant from days to months
Proportion of Manure Applied to Crops [staples]	dmnl	0.25	Focus group data, Mazar-i-Sharif.
Proportion of Manure Applied to Crops [cash]	dmnl	0.25	Focus group data, Mazar-i-Sharif.
Average Monthly Fixed Costs per TLU	$/animal	0.22	Sherabad is an average of $0.22/head/month from survey data.
Crop Inputs			
Initial land in Crops [staples]	jeribs	6	(FAO, 2006) household survey data
Initial land in Crops [forage]	jeribs	3	(FAO, 2006) household survey data
Initial land in Crops [cash crops]	jeribs	6	(FAO, 2006) household survey data
Reference Forage Labor Use	hours/jerib/month	40	Reported gross margins, FAO.

Model Parameters by View (initial conditions for Sherabad)			
Maximum Crop Yield per Jerib[crops]	kg/month /jerib	800	Compilation of gross margins from various sources including discussion with expert in the field and data from FAO, Mercy Corps, and Chabot.
Maximum Crop Yield per Jerib[crops]	kg/month /jerib	1200	Same as above
Maximum Crop Yield per Jerib[crops]	kg/month /jerib	1385	Same as above. Metric= (6925kg/month/ hectare)
Effect of Rainfall on Staple Production	dmnl	(0,5), (0.5,16), (1,18), (3,25)	The effect of irrigation is calibrated like other parts of the model with average water set at average yield, with max and mins.
Effect of Rainfall on Forage Production	dmnl	(0,1),(1,18), (10,60)	Same as above.
Effect of Rainfall on Cash Crop Production	dmnl	(0,0), (0.4,110), (1,200), (3,300)	Same as above.
Reference Rainfall for Crop Production[staple]	Mm/month /jerib	44	Based on NOAA rainfall data.
Reference Rainfall for Crop Production[forage]	Mm/month /jerib	45	Based on NOAA rainfall data.
Reference Rainfall for Crop Production[cash]	Mm/month /jerib	10	Based on NOAA rainfall data.
Reference N for Crop Production [staples]	kg N/jerib	100	Calibration for equilibrium based on Nitrogen levels and other parameters.
Reference N for Crop Production [forage]	kg N/jerib	40	Calibration for equilibrium based on Nitrogen levels and other parameters.
Reference N for Crop Production [cash crop]	kg N/jerib	40	Calibration for equilibrium based on Nitrogen levels and other parameters.
Effect of N on Efficiency	dmnl	(0,0), (1,0.5), (2.5,1), (5,2)	Calibrated based on what the average yields look like and given the reported fertilizer levels and soil dynamics for those yields.
Crop Outputs			
Average Seed Reserved for Next Harvest	kg/month	35	Mercy Corps (2004)

Model Parameters by View (initial conditions for Sherabad)			
Fraction of Grain Payment to Thresher	1/month	0.1	Mercy Corps (2004); Chabot (2004), also corroborated in own field interviews) that 1/10 of the grain harvest is retained by the owner of the thresher.
Staple Grain Buffer	kg/month	5	Notion of buffer is based on focus groups and discussion with expert. Farmers were unable to report specific monthly amount.
Residue to Grain Ratio	dmnl	0.4	Euan Thomson, Afghan Livestock Specialist (60:40).
Minimum Grain Storage Time	month	0.25	Wheat is dried for at least one week (focus groups/experts).
Average Price per kg Staple Grain	$/kg	0.288	FAAHM. Ministry of agriculture price data. 2006 price.
Slope of Wheat Price	$/kg/Month	0.0079	FAAHM. Ministry of agriculture website.
Fractional Storage Loss Rate for Feed	1/month	0.05	Focus groups. Many farmers claim that up to 15% is lost during storage.
Time Between Crop Harvests	months	12	Annual crops.
Market Price per kg Forage	$/kg	0.029	Mazar market price: 10 afs/kg.
Minimum Forage Storage Time	months	0.25	1 week assuming the forage is produced and dried for storage.
Crop Sale Transportation Price	$/month	5	This is the cost of paying a truck to drive a load from Sherabad to Mazar: 250 afs. Balkh Dairy.
Slope of Crop Sale Transportation Price	$/month/month	0.0085	From transportation price index from FAAHM.
Market Price per kg Staple Residue	$/kg	0.04	Maletta (2006), Mercy Corps (2004)
Initial Forage Stored Value	kg	3000	This is the average amount stored based on other parameters in the model or calibration of model.

Model Parameters by View (initial conditions for Sherabad)			
Initial Staple Residue Stored Value	kg	1000	For calibration of model.
Initial Staple for HH stored value	kg	2000	For calibration of model.
Soil and Nutrient Flows			
Average Urea Fertilizer Applied to Crops [staple]	kg/jerib/Month	75	Coke (2004), Mercy Corps (2004)
Average Urea Fertilizer Applied to Crops [forage]	kg/jerib/Month	0	Coke (2004), Mercy Corps (2004)
Average Urea Fertilizer Applied to Crops [cash]	kg/jerib/Month	75	Coke (2004), Mercy Corps (2004)
Fraction N in Urea	kg N/kg	0.46	From CLASSES (Stephens et al., 2008)
Fraction N in Residues [staples]	kg N/kg	0.1	Estimate from literature, expert opinons
Fraction N in Residues [forage]	kg N/kg	0.3	Same as above.
Fraction N in Residues [cash]	kg N/kg	0.01	Same as above.
Residual N Fixed [forage]	kg N/jerib/Month	.01	No source. Since N is not used to determine crop yields I am not going to explore this variable.
Proportion of Urea in Manure	dmnl	0.01	Taken from CLASSES model (Stephens et al., 2008), CNCPS Output.
Proportion Yield Returned to Soil as Residue [staples]	dmnl	0.2	Personal communication with Emal Jafar.
Proportion Yield Returned to Soil as Residue [forage]	dmnl	0.15	Same as above
Proportion Yield Returned to Soil as Residue [cash]	dmnl	0.15	Same as above
Fraction N in DAP	kg N/kg	0.2	Estimate is from CLASSES model (Stephens et al., 2008).
Dentrification Constant	1/month	0.2	Estimated based on information in CLASSES (Stephens et al., 2008). This is a value that is not well known in the literature.
Average DAP Fertilizer Applied to Crops [staples]	kg/jerib/Month	25	Gross Margins. AREU Baseline Data 2006, Coke 2004

Model Parameters by View (initial conditions for Sherabad)			
Average DAP Fertilizer Applied to Crops [forage]	kg/jerib/Month	25	Gross Margins. AREU Baseline Data 2006, Coke 2004
Average DAP Fertilizer Applied to Crops [cash]	kg/jerib/Month	50	Gross Margins. AREU Baseline Data 2006, Coke 2004
Nitrate Leaching Constant	1/month	0.1538	Estimate is from CLASSES model. (Stephens et al., 2008)
Protein Content of Crop[staples]	kg N/jerib/month	0.07	From Dairy One Forage Analysis Laboratory for wheat, alfalfa, and cabbage. Description of procedure:http://www.dairyone.com/Forage/Procedures/default.htm
Protein Content of Crop[forage]	kg N/jerib/month	0.0287	From Dairy One Forage Analysis Laboratory for wheat, alfalfa, and cabbage.
Protein Content of Crop[cash]	kg N/jerib/month	0.278	From Dairy One Forage Analysis Laboratory for wheat, alfalfa, and cabbage.
Fraction N in Protein	kg N/jerib	6.25	From David Parsons, Personal Communication.
Initial Soluble N in Soil [annual]	kg N/jerib	25	For calibration of model based on average amounts given other parameters.
Initial Soluble N in Soil [perennial]	kg N/jerib	18	For calibration of model based on average amounts given other parameters.
Household Inputs and Outputs			
Staple Consumption Norms	kg/month/person	16.67	Staple Consumption Norms
Milk Consumption Norms	kg/month/person	3.75	This is from survey data. This is approximately 1 kg/day/household.
Other Food Consumption Norms	kg/month/person	5.56	Consumption Data, World Bank (2004).
Average Cost of Other Food Consumption	$.kg	0.338	Consumption Data, World Bank (2004).
Average Fraction of HH Working Age	dmnl	0.5	From survey data in Mazar. FAO 2006.
Average Work Days per Month per Person	days/month/person	20	Estimate based on personal field observations.

Model Parameters by View (initial conditions for Sherabad)			
Labor Required for Crop Establishment [staples]	hours/jerib/ Month	56	Gross margin estimates various sources. Mercy Corps, FAO, RAMP
Labor Required for Crop Establishment [forage]	hours/jerib/ Month	50	Same as above
Labor Required for Crop Establishment [cash crop]	hours/jerib/ Month	56	Same as above
Labor Required for Crop Irrigation [staples]	hours/jerib/ Month	18	Same as above
Labor Required for Crop Irrigation [forage]	hours/jerib/ Month	21	Same as above
Labor Required for Crop Irrigation [cash crop]	hours/jerib/ Month	18	Same as above
Labor Required for Crop Harvesting [staples]	hours/jerib/ Month	40	Same as above
Labor Required for Crop Harvesting [forage]	hours/jerib/ Month	48	Same as above
Labor Required for Crop Harvesting [cash crop]	hours/jerib/ Month	40	Same as above
Labor Required for Crop Weeding [staples]	hours/jerib/ Month	24	Same as above
Labor Required for Crop Weeding [forage]	hours/jerib/ Month	20	Same as above
Labor Required for Crop Weeding [cash crop]	hours/jerib/ Month	18	Same as above
Initial Household Population	person	8	Average number of people per household. FAO 2006 survey, Mazar-i-Sharif
Cash Balance Sheet			
Average Market Price Livestock by Class [Calf]	$/animal	150	Mazar-i-Sharif livestock market, Thomson et al (2005).
Average Market Price Livestock [Heifer]	$/animal	250	Mazar-i-Sharif livestock market, Thomson et al (2005).
Average Market Price Livestock [Lactating Open]	$/animal	750	Mazar-i-Sharif livestock market, Thomson et al (2005).
Average Market Price Livestock [Open Dry]	$/animal	600	Mazar-i-Sharif livestock market, Thomson et al (2005).
Average Market Price Livestock [Dry Bred]	$/animal	600	Mazar-i-Sharif livestock market, Thomson et al (2005).
Average Market Price Livestock [Bull]	$/animal	550	Mazar-i-Sharif livestock market, Thomson et al (2005).

Model Parameters by View (initial conditions for Sherabad)			
Average Transportation Price per Animal Sale	$/animal	9.7	Thomson et al 2005.
Average Market Price Cash Crop	$/kg	0.2	Based on RAMP, CRS estimates for various vegetable crops
Off Farm Labor Wage	$/day	3	Reported to be 150 afs/day in market Mazar in July 2006 which is about $3. Corroborated by FAAHM estimates.
Initial Cash Available	$	500	For calibration of model based on other parameters.
Market Price per kg DAP	$/kg	0.5	Maletta. (also FAO) I could graph this and have a lookup like the rainfall.
Market Price per kg Urea	$/kg	0.5	Maletta. (also FAO) I could graph this and have a lookup like the rainfall.
Pesticide Price	$/kg	1	This is a 50afs estimate for pesticide/herbicide costs/jerib from Engineer estimates in Kunduz.
Quantity Pesticide Applied[staples]	kg/Month/ jerib	1	Mercy Corps, RAMP data.
Quantity Pesticide Applied[forage]	kg/Month/ jerib	0	Mercy Corps, RAMP data.
Quantity Pesticide Applied[cash]	kg/Month/ jerib	4	Mercy Corps, RAMP data.
Seed Price[staples]	$/Month/ jerib	5	Estimated rate of 5 seer per jerib at a 2006 costs of 50 afs per seer is approximately $5/jerib. (Mercy Corps, 2004)
Seed Price[forage]	$/Month/ jerib	16	10 kg of seed average at approx 80 afs/kg in 2006 is 800 afs or $16. (FAO, 2006)
Seed Price[cash]	$/Month/ jerib	0.85	RAMP data on vegetables.
Average Agricultural Daily Wage Rate	$/day	2	(Maletta, 2006), Charbolak data.
Labor Market Transaction Price	$/Month	0.4	This is an estimate of the cost from Sherabad to Mazar for work.

Model Parameters by View (initial conditions for Sherabad)			
Average Feed Price [staples]	$/kg	0.04	Market in Mazar-i-Sharif, July 2006.
Average Feed Price [forage]	$/kg	0.029	Market in Mazar-i-Sharif, July 2006.
Average Feed Price [Cotton Seed]	$/kg	0.2	Market in Mazar-i-Sharif, July 2006.
Market Transaction Cost for Feed	$/Month	0.8	Estimate based on Mazar Prices in 2006.
Average Cost of Irrigation per Jerib	$/jerib	3.33	FAO estimate includes 6 irrigations per season at a cost of 250 afs per irrigation per jerib for an average of 3.33/month. Mercy Corps calculates about $2 for irrigation plus 7 days of labor.

APPENDIX 2

Table A2.1 COMPREHENSIVE TABLE OF MODEL ASSUMPTIONS

Key Model Assumptions (by view)
A. Herd Structure View
(1) Calf gender is randomly assigned. Maturity is based on fixed rates (lactation length, gestation time, etc) and variable rates (parturition) endogenously affected by ME levels.
(2) Female animal sales take place when an animal reaches the end of the average productive lifetime, the ratio of daily ME intake is less than animal maintenance requirements or actual to required labor for livestock is low.
(3) Household maintains oxen for draft and sells oxen if a mature calf is available to replace an older one.
B. Livestock Inputs View
(1) A reference diet is constructed and available produced and collected feed is allocated by priority to the herd. This diet varies seasonally. Wheat stubble is not included.
(2) The reference diet does not endogenously change during the simulation.
(3) The HH will purchase feeds to make up for nutrient deficits from own production.
(4) MP is ignored because ME is assumed to be most limiting given overall lack of DM in diets.
(5) ME from milk to calves is excluded because calf ME ratios are not used in the model.
C. Livestock Outputs View
(1) ME available is determined by the ME balance less requirements.
(2) Milk yield is calculated as an average over the length of the lactation.
(3) A fixed amount of milk is consumed per person in the household and per calf, whereas, the rest is sold if exceeds costs of transaction. Calves have priority, then household, then sales.
(4) Manure is not commonly used as fertilizer.
D. Crop Inputs and Production View

Key Model Assumptions (by view)
(1) Land allocation is exogenously determined for a given simulation. Forage is grown on one piece of land (perennial land) while staples and cash crops are rotated on a second land type (annual land). There is no rotation between the land types.
(2) Crop Production is a function of labor, water, and nitrogen.
(3) The variable which most limits production is the determinant of yield. Labor limiting yield is calculated with a multiplicative effect while water and nitrogen limiting yields are calibrated based on average and possible range of yields.
(4) Rainfall is simulated using historical rainfall data and irrigation can make up for the deficit in some instances.
(5) Nitrogen is considered the most limiting nutrient (phosphorus is excluded).
(6) The difference between input and output prices is transactions costs.
E. Crop Outputs and Allocation View
(1) Grain is allocated to satisfy household consumption requirements given grain losses and reserved quantities. Any remainder is sold based on estimated needs until next harvest.
(2) Staple residues and forage are allocated by priority to animals, excess is sold monthly.
(3) A constant fractional rate of feed stored is lost due to storage conditions.
(4) If transactions costs exceed value of quantity of crop output being sold, transaction will not occur.
F. Soil and Nutrient Flows View
(1) Staples and cash crops are rotated on annual land while forage crops are grown separately on another perennial land with no crop rotation between annuals and perennials.
(2) Fertilizer application is based on average rates, if cash is available.
(3) Soil organic matter dynamics are excluded because agronomic practices are not the focus of the model and given time scale of model.
(4) Soluble N in soil is used as the principal nutrient constraint for crop yields. Ammonium N is omitted because it changes to Soluble N quickly and it is assumed the plant is flexible in taking up either in the form of soluble N.

Key Model Assumptions (by view)
(5) Crop residues can be returned to soil and manure can be applied. However, neither of these is commonly practices in the study region.
G. Household Inputs and Outputs View
(1) Households have constant minimum requirements of staples and other food.
(2) Crop labor requirements are a function of land size and average unit labor by activity. Livestock labor is a linear function based on specific labor activates and the number of livestock maintained.
(3) Labor is allocated giving priority to staple production, then forage and livestock labor activities, and lastly to cash crop activities.
(4) Labor is not hired-in but the off farm labor will take place if there is excess household labor.
H. Cash Balance Sheet
(1) Cash available is modeled as a simple balance sheet with no ranking of allocation of cash to needs when cash is limited.
(2) Household cannot make cash investments in agriculture if there is not enough cash in the current cash balance stock for a purchase.
(3) Cash balance can go negative (assuming access to costless credit).
(4) The household cannot reinvest in livestock or change proportion of enterprise activities unless exogenously imposed through an intervention.

APPENDIX 3
FEED INTAKE AND OUTPUT TABLES

Table A3.1 Lactating Cattle Inputs Used in CNCPS Diet Simulation

CNCPS Inputs (by Animal Type)	Lactating Dairy Cow (Sherabad)	Lactating Dairy Cow (Charbolak)	Heifer (Replacement Heifer)	Dry Bred (Dry Cow)
Days in Cycle	365	365	365	365
Age (months)	60	60	9	60
Days Pregnant	0	0	0	270
Days since Calving	80	80	--	--
Calving Interval	24	24	24	24
Lactation Number	2	2	--	--
Calf Birth Weight (kg)	20	20	20	20
Age at First Calving (mo)	36	36	36	36
Milk Production (kg/day)	6.9	5.1	--	--
Milk Fat (%)	3.3	3.3	--	--
Milk True Protein	3.1	3.1	--	--
Milk Crude Protein	3.33	3.33	--	--
Milk Lactose	4.78	4.78	--	--
BCS (1-5)	2	2	3	2
Target BCS	3	3	--	3
Days to reach BCS	100	100	--	100
Breed Type	Dairy	Dairy	Dairy	Dairy
Breeding System	Straightbred	Straightbred	Straightbred	Straightbred
Primary Breed	Brahman	Brahman	Brahman	Brahman
Mean SBW (kg)	288	288	288	288
Mean FBW (kg)	300	300	300	300
Mature SBW (kg)	336	336	336	336
Mature FBW (kg)	350	350	350	350

Table A3.2 Sherabad Lactating Cow Diet Inputs and ME Outputs from CNCPS (DM Basis)

CNCPS runs for model calibration	Sherabad Low Diet	Sherabad Base Diet	Sherabad High Diet
Wheat Straw (kg/d)	4.0	5.0	5.0
Alfalfa Hay (kg/d)	4.0	5.0	8.0
Local Grass (kg/d)	0	0	0
Cottonseed Meal (kg/d)	0	0.5	1.8
Total DM diet (kg/d)	8.0	10.5	14.8
ME Supply (Mcal/d)	15.6	20.1	29.1
ME Maintenance (Mcal/d)	10.1	10.5	11.0
ME Lactation (Mcal/d)	7.3	7.3	7.3
ME Balance (Mcal/d)	-1.8	2.4	10.7
Allowable Milk (kg/d)	2.9	6.8	14.8
Manure, fecal (kg/d)	17.0	23.0	32.0
Manure, urine (kg/d)	9.0	12.0	20.0
Total Wet Manure (kg/d)	27.0	36.0	52.0

Table A3.3 Charbolak Lactating Cow Diet Inputs and ME Outputs from CNCPS (DM Basis)

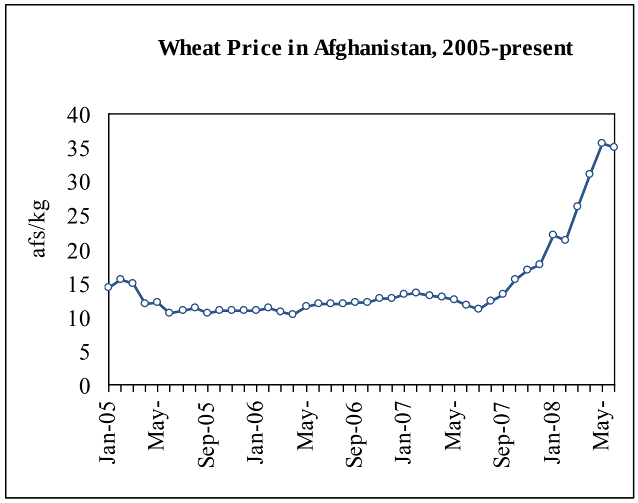
CNCPS runs for model calibration	Charbolak Low Diet	Charbolak Base Diet	Charbolak High Diet
Wheat Straw (kg/d)	3.0	2.0	6.0
Alfalfa Hay (kg/d)	1.0	2.0	2.0
Local Grass (kg/d)	3.0	4.0	5.0
Cottonseed Meal (kg/d)	0	0	0
Total DM diet (kg/d)	6.0	8.0	13.0
ME Supply (Mcal/d)	13.6	16.8	24.6
ME Maintenance (Mcal/d)	10.0	9.6	10.4
ME Lactation (Mcal/d)	5.4	5.4	5.4
ME Balance (Mcal/d)	-1.8	1.8	8.8
Allowable Milk (kg/d)	1.1	4.5	11.2
Manure, fecal (kg/d)	15.0	16.0	30.0
Manure, urine (kg/d)	7.0	9.0	12.0
Total Wet Manure (kg/d)	22.0	25.0	42.0

Table A3.4 Heifer and Dry Bred Cow Diet Inputs and ME Outputs from CNCPS

CNCPS runs for model calibration	Sherabad Heifer (Ref Diet)	Charbolak Heifer (Ref Diet)	Sherabad Dry Bred (Ref Diet)	Charbolak Dry Bred (Ref Diet)
Wheat Straw (kg/d)	4.0	2.0	4.0	1.5
Alfalfa Hay (kg/d)	3.0	1.0	3.0	1.0
Local Grass (kg/d)	0	3.0	0	3.5
Cottonseed Meal (kg/d)	0	0	0	0
Total DM diet (kg/d)	7.0	6.0	7.0	6.0
ME Supply (Mcal/d)	13.3	12.2	13.2	12.5
ME Maintenance (Mcal/d)	10.3	10.2	9.4	8.8
ME Lactation (Mcal/d)	16.3	14.1	3.8	3.2
ME Balance (Mcal/d)	0	0	2.6	2.6
Allowable Milk (kg/d)	-13.3	-12.2	-2.6	-2.1
Manure, fecal (kg/d)	0.2	0.1	0.1	0.1
Manure, urine (kg/d)	15.0	12.0	15.0	12.0
Total Wet Manure (kg/d)	10.0	8.0	10.0	8.0

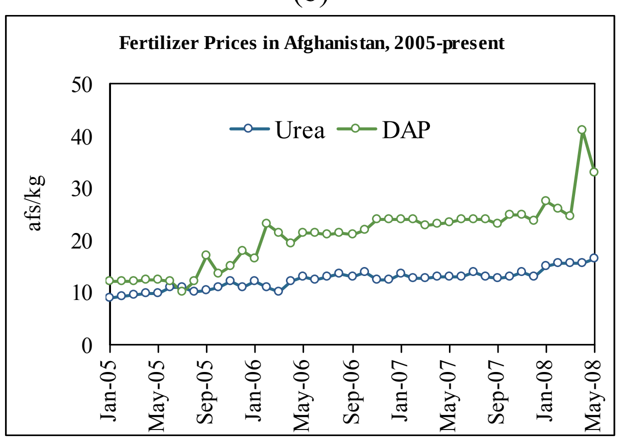
APPENDIX 4

Figure A4.1 GRAPHS OF SELECTED MONTHLY PRICES, 2005-2008



(a)

(b)



(c)

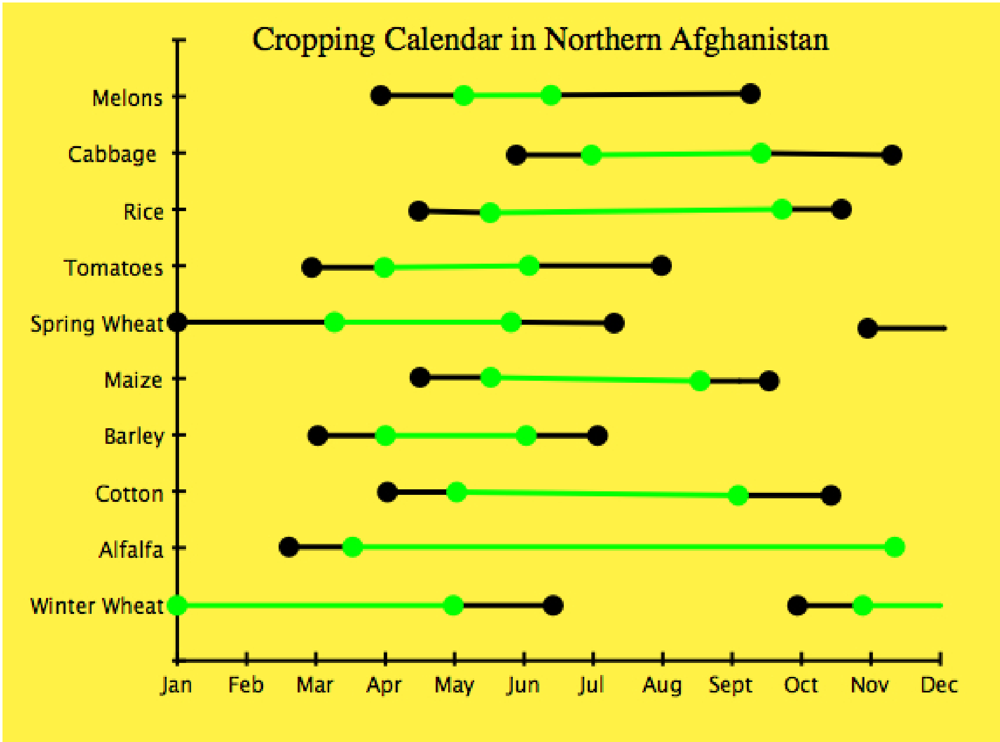
(Source for all price graphs: FAAHM, 2005-8)

Table A4.1 Prices of Small, Medium and Large Animals

Prices	Small	Medium	Large
Kabul	253	460	734
Kandarhar	459	993	1781
Kunduz	148	255	410

Source: Thomson et al. (2005)

APPENDIX 5
CALENDAR OF HARVESTING AND GROWING SEASONS[132]



*segments in (dark) black are the range of planting and harvesting times estimated, while (light) green segments delineate growing seasons of crops

[132] This calendar draws on a collection of sources from the literature, focus groups with farmers, and discussion with local horticulture experts.

APPENDIX 6
MAPS OF REPRESENTATIVE COMMUNTIES

Figure A6.1. Map of Sherabad in Dehdahdi District

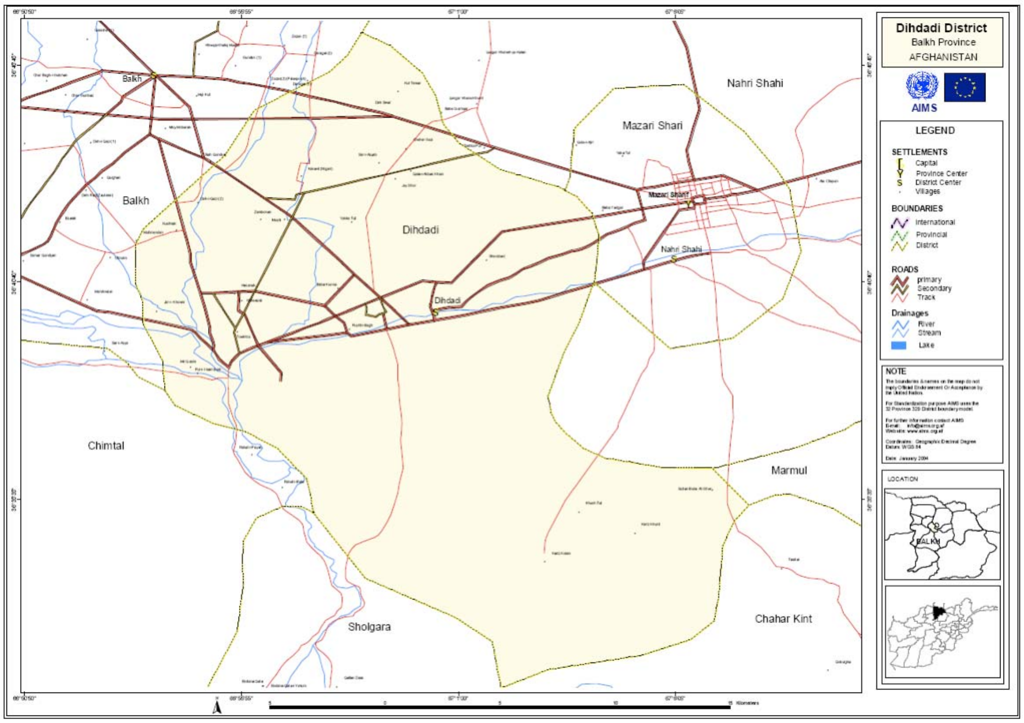
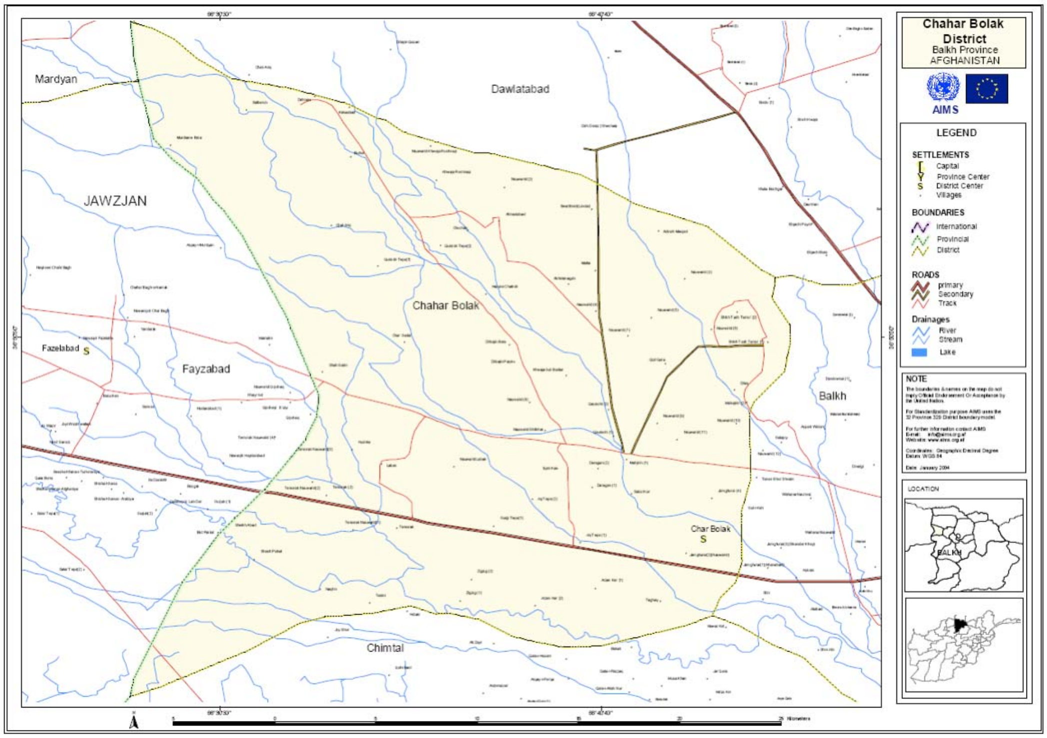


Figure A6.2 Map of Charbolak District



APPENDIX 7
HOUSEHOLD SURVEY INSTRUMENT

CODEBOOK: Cornell University-FAO Mazar Household Survey August 2006

Survey Location: _____location_________MCC# _mcc
Date of Interview: ______date____________
Household Head Name ______name__ **Male/Female sex=**m/f Name of Interviewer:___enum_____
Father's Name __father__

1.1 Livestock Ownership

How many of the following do you have?

	Calves	Heifers	Cows	Young Males	Bulls
Local	L_calf	L_heifer	L_cow	L_male	L_Bull
Crossl	C_calf	C_heifer	C_cow	C_male	C_Bull
Total	T_calf	T_heifer	T_cow	T_male	T_Bull

Goats	Sheep	Horse	Poultry	Donkey	Camel
	L_sheep				
	C_sheep				
T_goat	T_sheep	T_horse	T_poultr	T_donke	T_camel

*use only numbers here **not** checks or x.*

1.2 Herd Structure

Were there any changes in the herd in the last 2 years?

		Calves	Heifers	Cows	Young Males	Bulls
add	Birth	B_calf	B_heifer	B_cow	B_male	B_Bull
	Purchased	P_calf	P_heifer	P_cow	P_male	P_Bull
minus	Slaughter	S_calf	S_heifer	S_cow	S_male	S_Bull
	Disease	D_calf	D_heifer	D_cow	D_male	D_Bull
sell	No feed	F_calf	F_heifer	F_cow	F_male	F_Bull
	Good price	G_calf	G_heifer	G_cow	G_male	G_Bull

Goats	Sheep	Horse	Poultry	Donkey	Camel
B_goat	B_sheep	B_hors	B_poultry	B_donkey	B_camel
P_goat	P_sheep	P_hors	P_poul	P_donkey	P_camel
S_goat	S_sheep	S_horse	S_poul	S_donkey	S_camel
D_goat	D_sheep	D_hors	D_poul	D_donkey	D_camel
F_goat	F_sheep	F_hors	F_poul	F_donkey	F_camel
G_goat	G_sheep	G_horse	G_poultry	G_donkey	G_camel

**after p_calf, column for QP_calf (quantity paid). After F_calf, QF_calf,*

1.3 Individual cows

Please answer the following questions for each cow.

ID	Breed	Age	First Calf (#years)	Calving Interval (months)
01	Breed_1	Age_1	First_1	Interval_1
02	Breed_2	Age_2	First_2	Interval_2
03	Breed_3	Age_3	First_3	Interval_3
04	Breed_4	Age_4	First_4	Interval_4

*no=0, yes=1

Now is cow Lactating?	Is Cow pregnant	Days pregnant	Last Pregnant?	Now calf Suckling?
Lactate_1*	Preg_1*	Days_1	Last_1	Suck_1
Lactate_2	Preg_2	Days_2	Last_2	Suck_2
Lactate_3	Preg_3	Days_3	Last_3	Suck_3
Lactate_4	Preg_4	Days_4	Last_4	Suck_4

1.4 Livestock Products Consumption/Income

How many liters did your cow produce yesterday morning?
How many liters did your cow produce yesterday evening?
How many liters does your household consume each day in the summer?
How many liters does your household give to MCC each day in the summer?
How many liters does your household consume each day in the winter?
How many liters does your household give to MCC each day in the winter?

1.5 Have you treated your animals with any veterinary medicines or vaccines in the last 2 years? Vet, *no=0, yes=1
About how much did you spend on medicines or vaccines in the last 2 years? vet_p

2. LIVESTOCK FEEDING

2.1 Grazing

Do you have access to rangelands? Rang *no=0, yes=1
What seasons do you take your animals to the pasture?
S_rang Summer=1, spring=2, fall=3, winter=4
How far is the pasture (in kilometers)? D_range
How far is your house from the MCC? D_mcc
What hours do you graze your animals?

morning: graz_am1 to graz_am2 afternoon graz_pm1 to graz_pm2
Do your cows graze crop residue? Resid *no=0, yes=1
In what seasons? S_resid Summer=1, spring=2, fall=3, winter=4
How many hours per day are your animals grazed on crop residue? H_resid

2.2 Feeding

What do you feed your cows? *use feed code for feed source column.

	List	Feed Source	Kg/day	Produce (yes/no)	Buy (price/yr)	winter storage
cows	1	CFeed_1	CKg_1	CProd_1*	CBuy_1	CStor_1*
	2	CFeed_2	CKg_2	CProd_2*	CBuy_2	CStor_2*
	3	CFeed_3	CKg_3	CProd_3*	CBuy_3	CStor_3*
	4	CFeed_4	CKg_4	CProd_4*	CBuy_4	CStor_4*
	5	CFeed_5	CKg_5	CProd_5*	CBuy_5	CStor_5*
sheep	1	SFeed_1	SKg_1	SProd_1*	SBuy_1	SStor_1*
	2	SFeed_2	SKg_2	SProd_2*	SBuy_2	SStor_2*
	3	SFeed_3	SKg_3	SProd_3*	SBuy_3	SStor_3*
	4	SFeed_4	SKg_4	SProd_4*	SBuy_4	SStor_4*
	5	SFeed_5	SKg_5	SProd_5*	SBuy_5	SStor_5*

2.3 Winter Storage of Feed: Was the quantity stored sufficient last year?
Suff *no=0, yes=1

3. RESOURCES

3.1 Land *no=0, yes=1
How many *jeribs* do you own? own
How many do you rent? rent
How many jeribs do you sharecrop? share
What percent profit do you get? prof
How many of these are irrigated? irr
How many are rainfed? rain

How much land is planted for livestock? *Use feed code for Land_x

	What Feed?	How many Jeribs planted	Is this different than last year	Year first planted this crop
Feed 01	Land_1	Jerib_1	Last_1	When_1
Feed 02	Land_2	Jerib_2	Last_2	When_2
Feed 03	Land_3	Jerib_3	Last_3	When_3

3.2 Labor

How many people live in this house now? HH
Do you own a tractor? T_own
Do you rent a tractor? T_rent
How much for one hour? T_P
Do you use your own oxen for plowing? Ox_own
Do you rent an oxen for plowing? Ox_rent

3.3 Water: How many times a day do you provide water to your cow?
River=1, ditch =2, spring=3, deep=4, shallow=5

	river	ditch	Spring	Deep well	Shallow well
What is your main source of water irrigation?	Main				
What other (secondary) sources?	Sec				
What is your main source of water drinking?	drink				

3.3.1 What is the position of your land on the village irrigation canals?
*0=upstream, 1=down

	Upstream	Downstream
Major parcel (most jeribs)	major	
Minor parcel	minor	

APPENDIX 8
GRAPHICS OF MODEL VIEWS

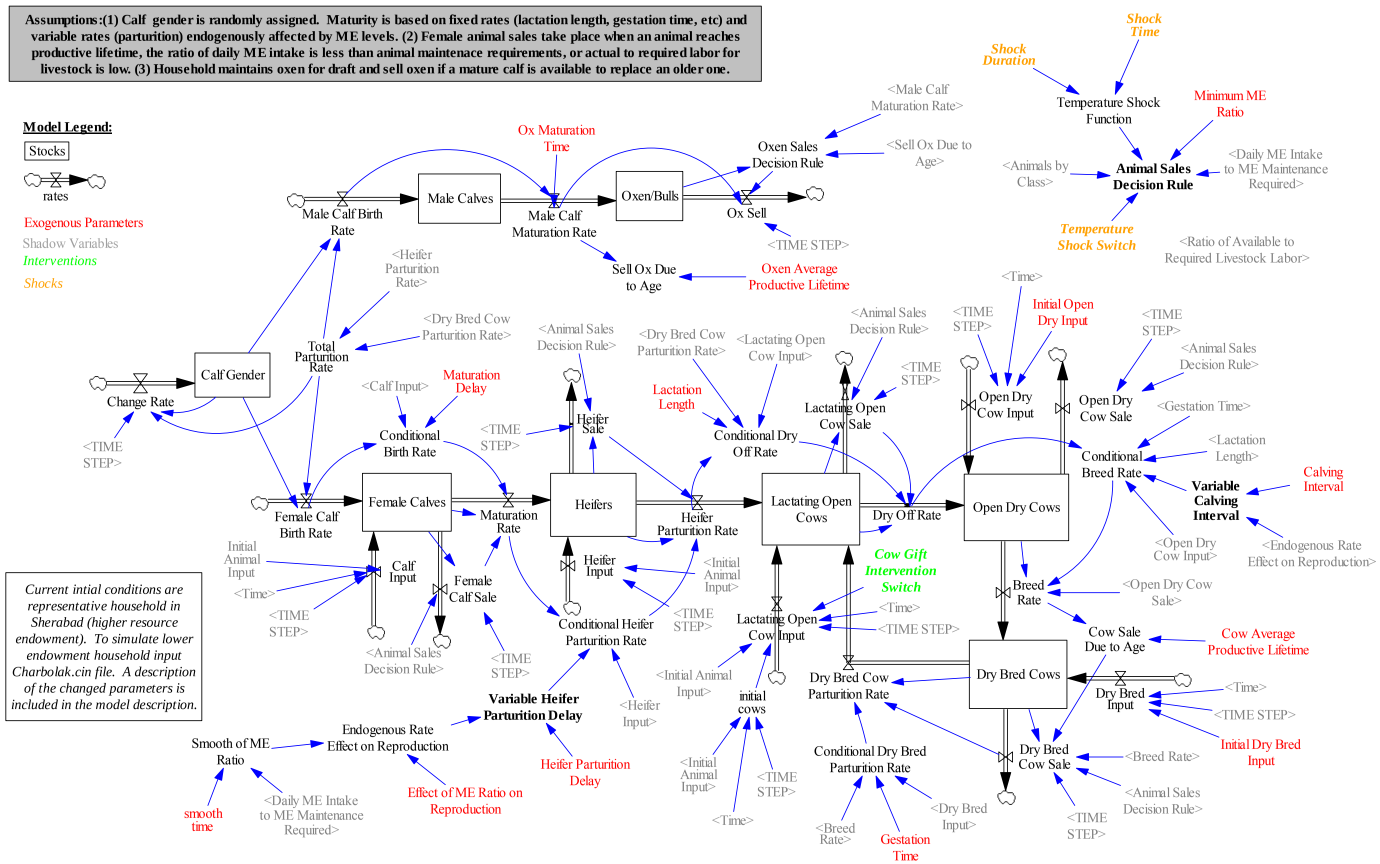


Figure A9.1 Herd Structure View

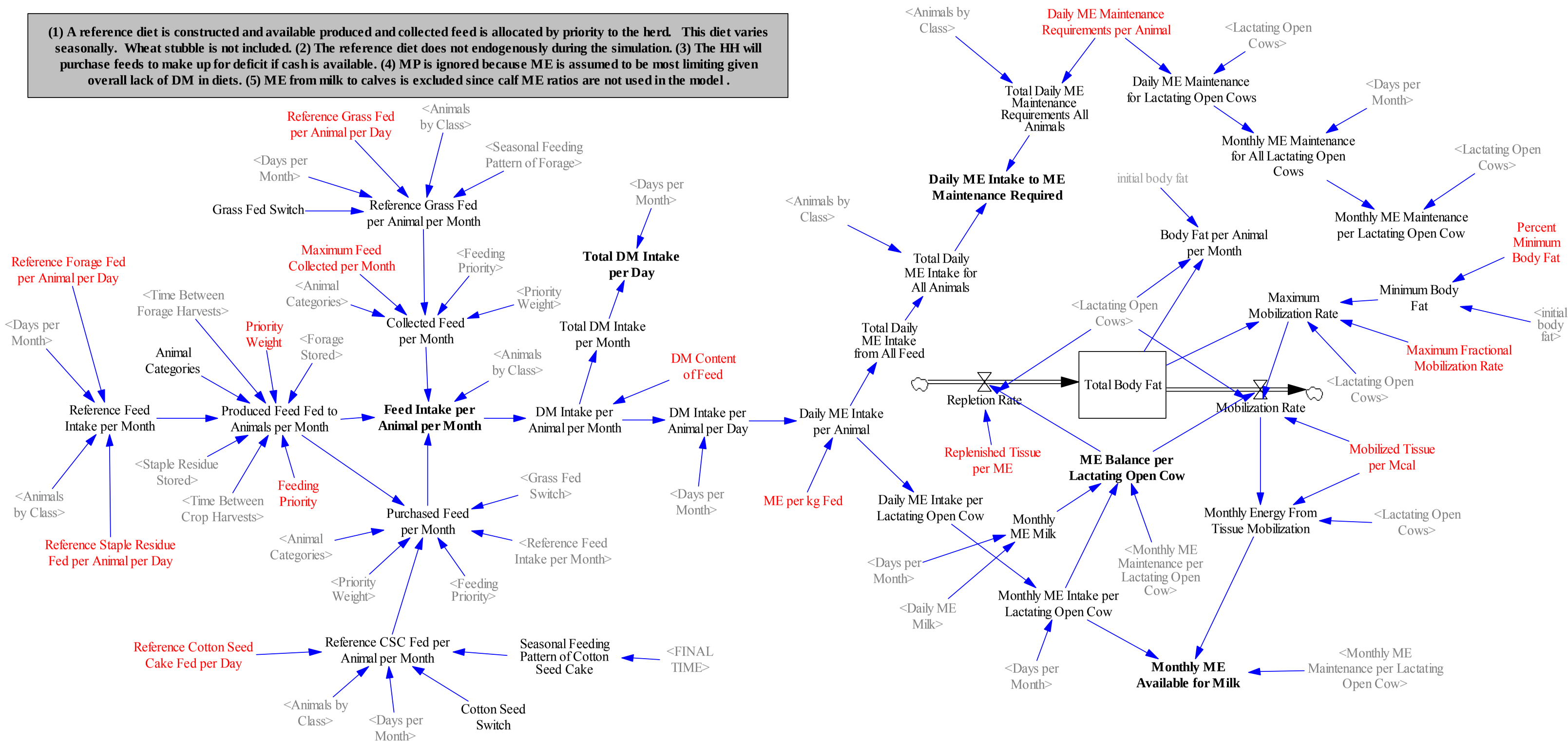


Figure A9.2 Livestock Inputs View

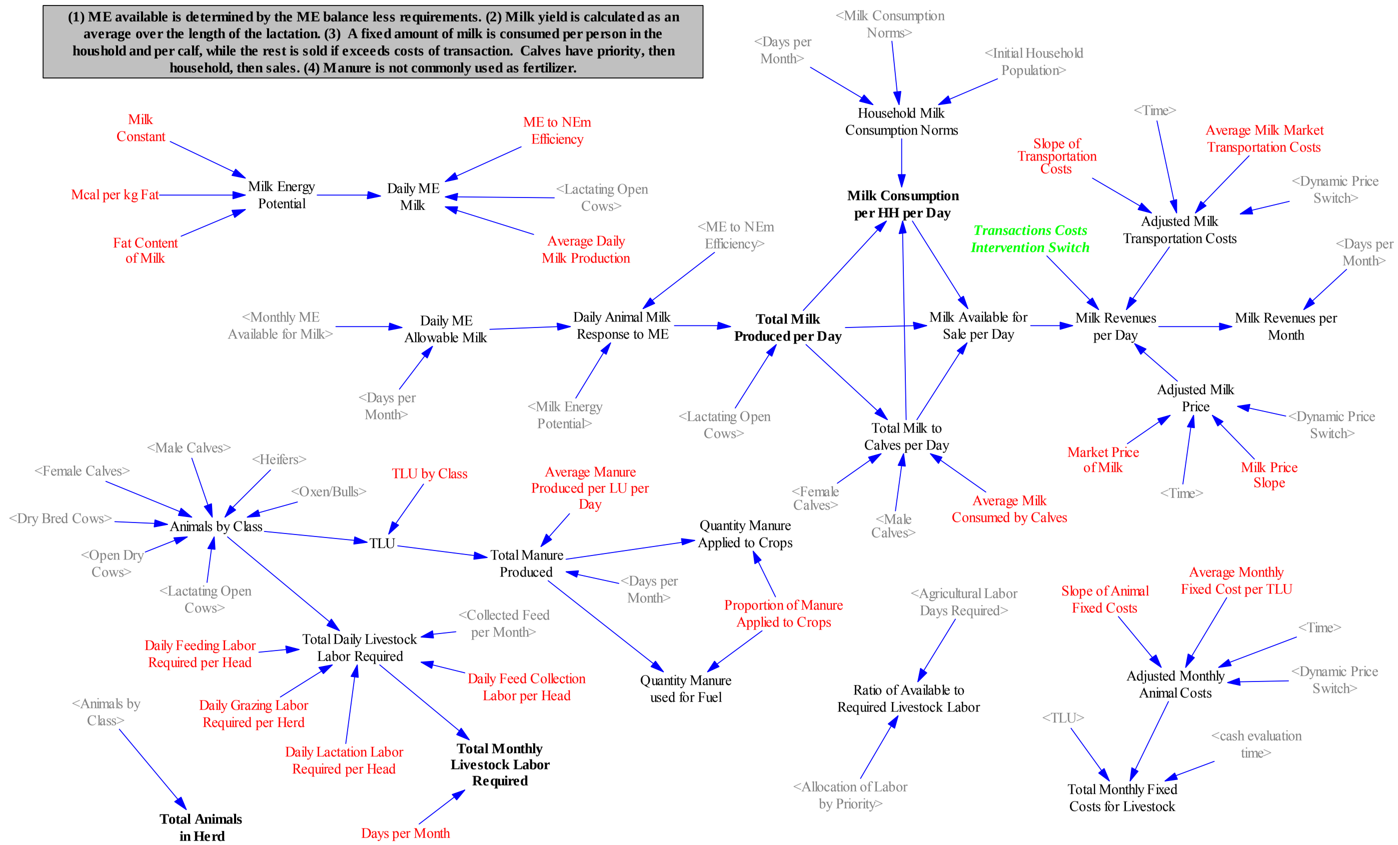


Figure A9.3 Livestock Outputs View

(1) Land allocation is fixed. Forage is grown on one piece of land (perennial land) while staples and cash crops are rotated on a second land type (annual land). There is no rotation between the land types. (2) Crop Production is a function of labor, water, and nitrogen. (3) The variable which most limits production is the determinant of yield. Labor limiting yield is calculated with a multiplicative effect while water and nitrogen limiting yields are calibrated based on average, range of yields.

(4) Rainfall is simulated using historical rainfall data and irrigation can make up for the deficit in some instances. (5) Nitrogen is considerd the most limiting nutrient (phosphorus is excluded). (6) The difference between input and output prices is only transactions costs.

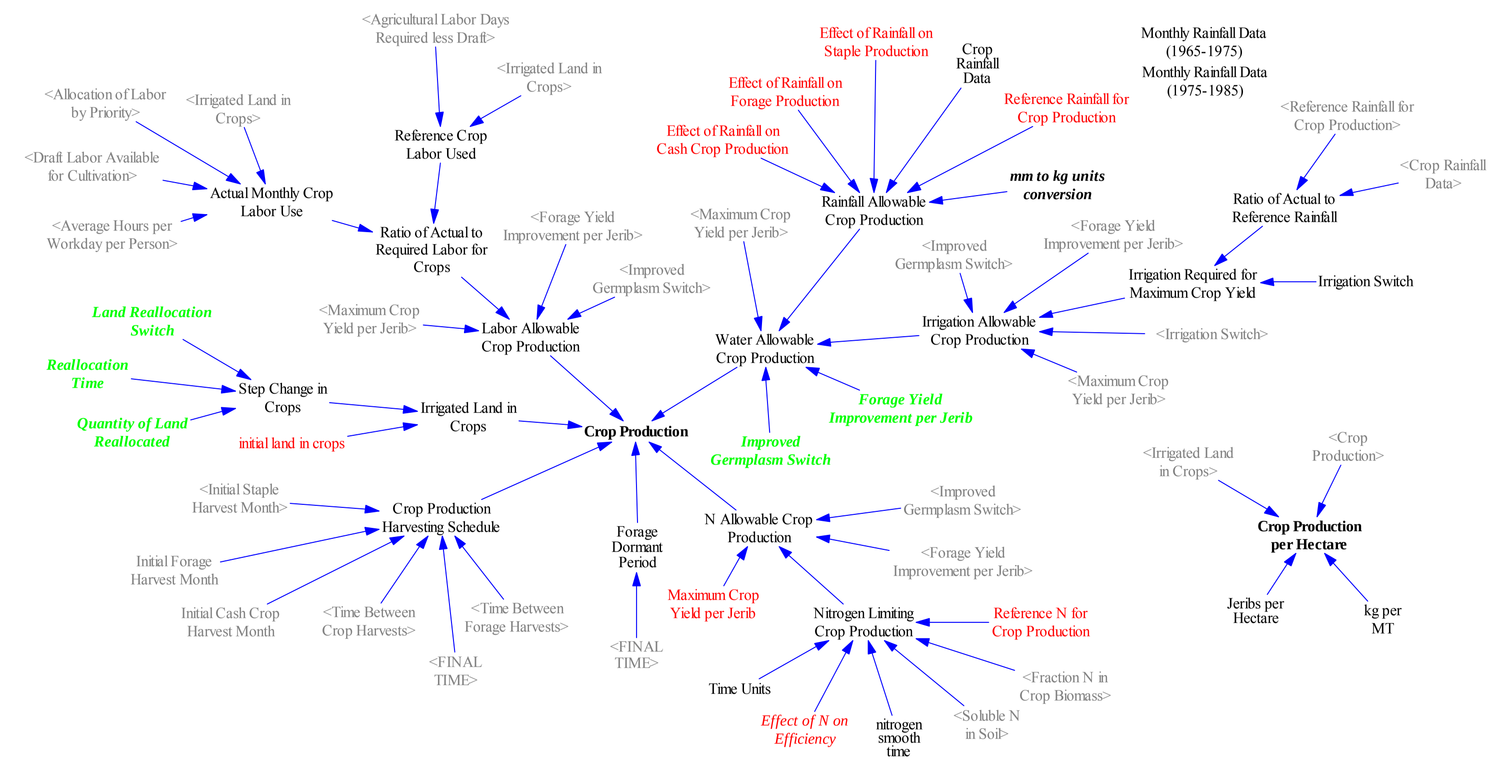


Figure A9.4 Crop Inputs View

(1) Grain is allocated to satisfy household consumption requirements given grain losses and reserved quantities then sold the remainder is sold based on estimated needs until next harvest. (2) Staple residues and forage are allocated by priority to animals, then excess is sold monthly. (3) A fractional rate of feed stored is lost due to storage conditions. (4) If transactions costs exceed value of quantity of crop output being sold, transaction will not occur.

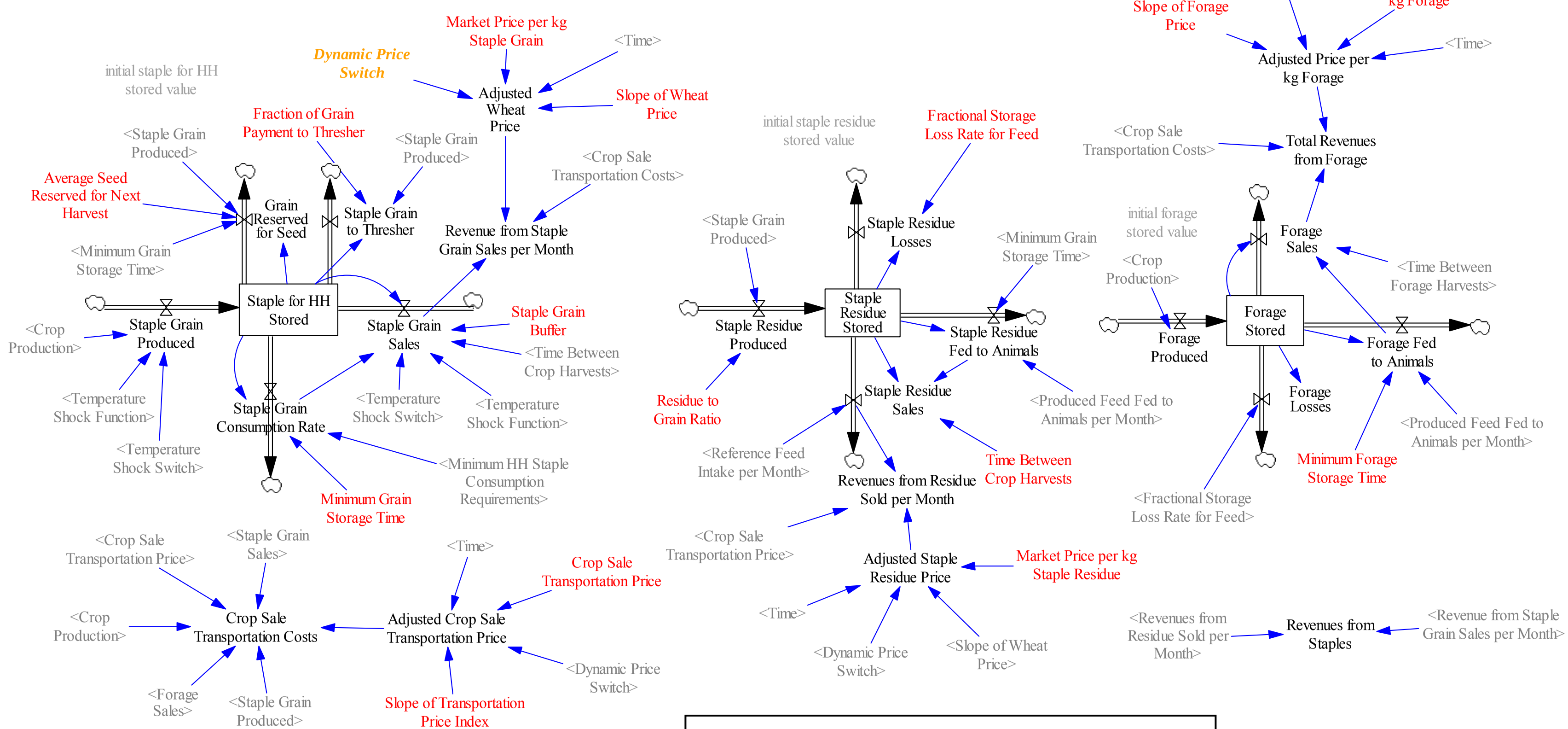


Figure A9.5 Crop Outputs View

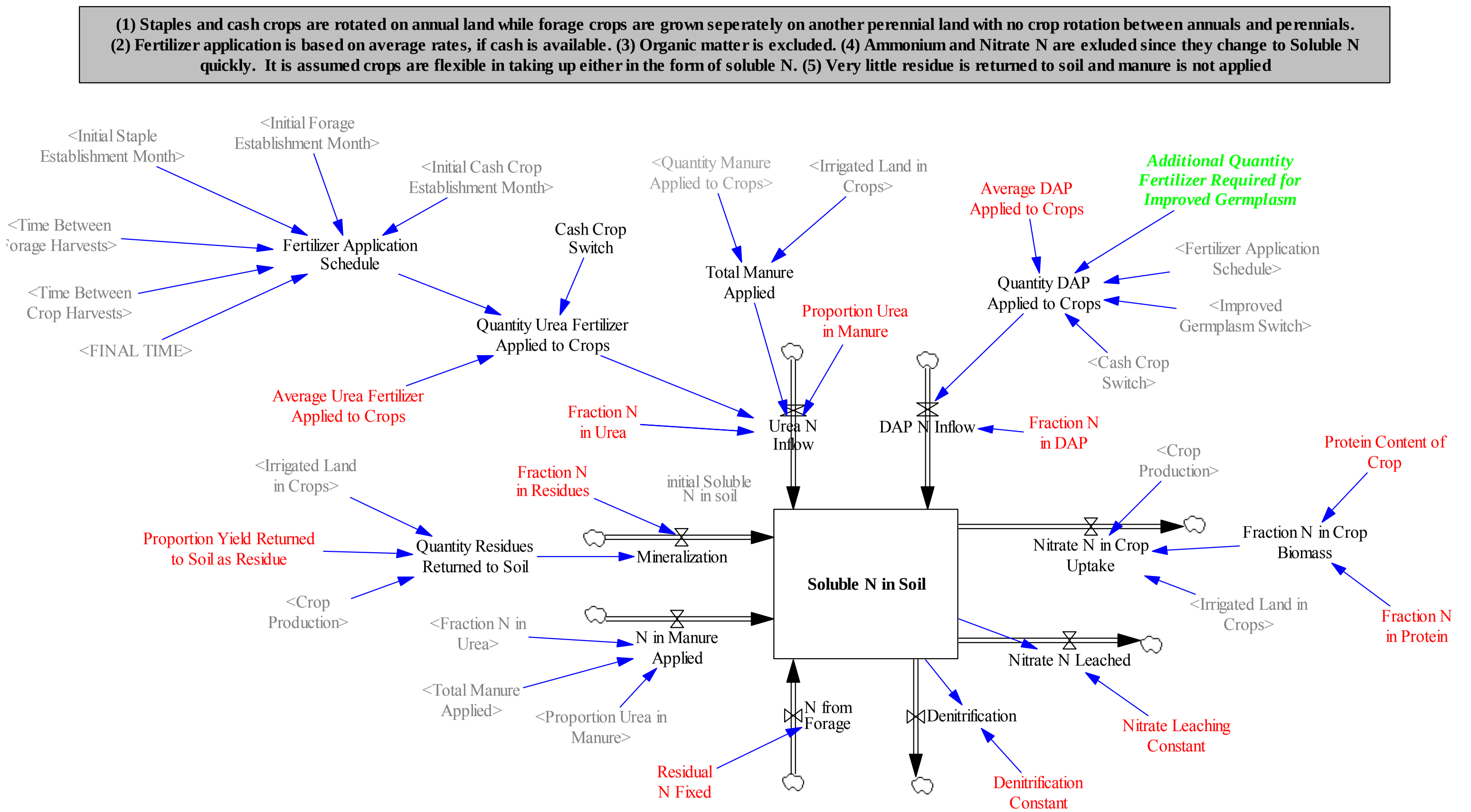


Figure A9.6 Soil and Nitrogen Flows

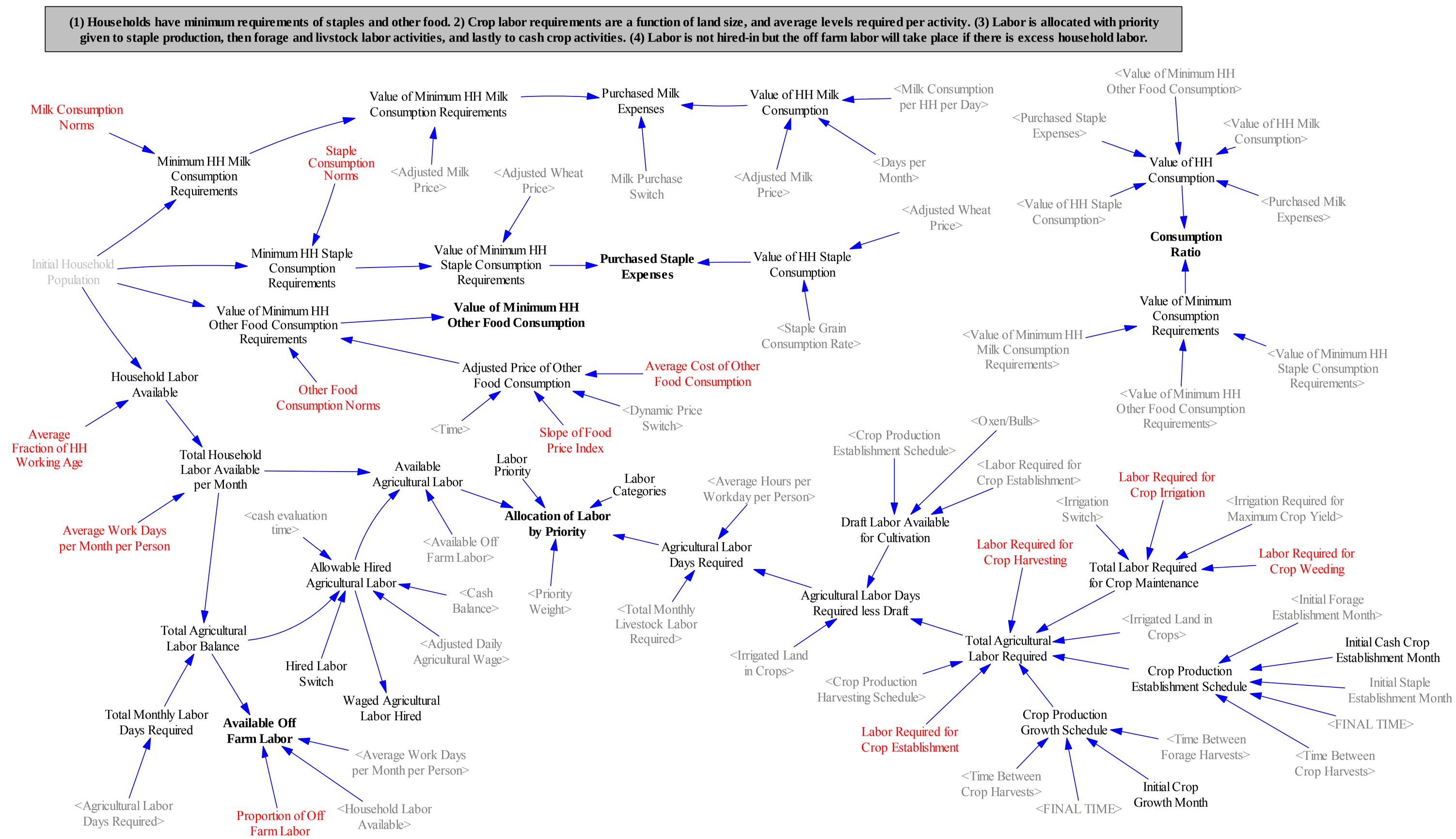


Figure A9.7 Household Inputs and Outputs View

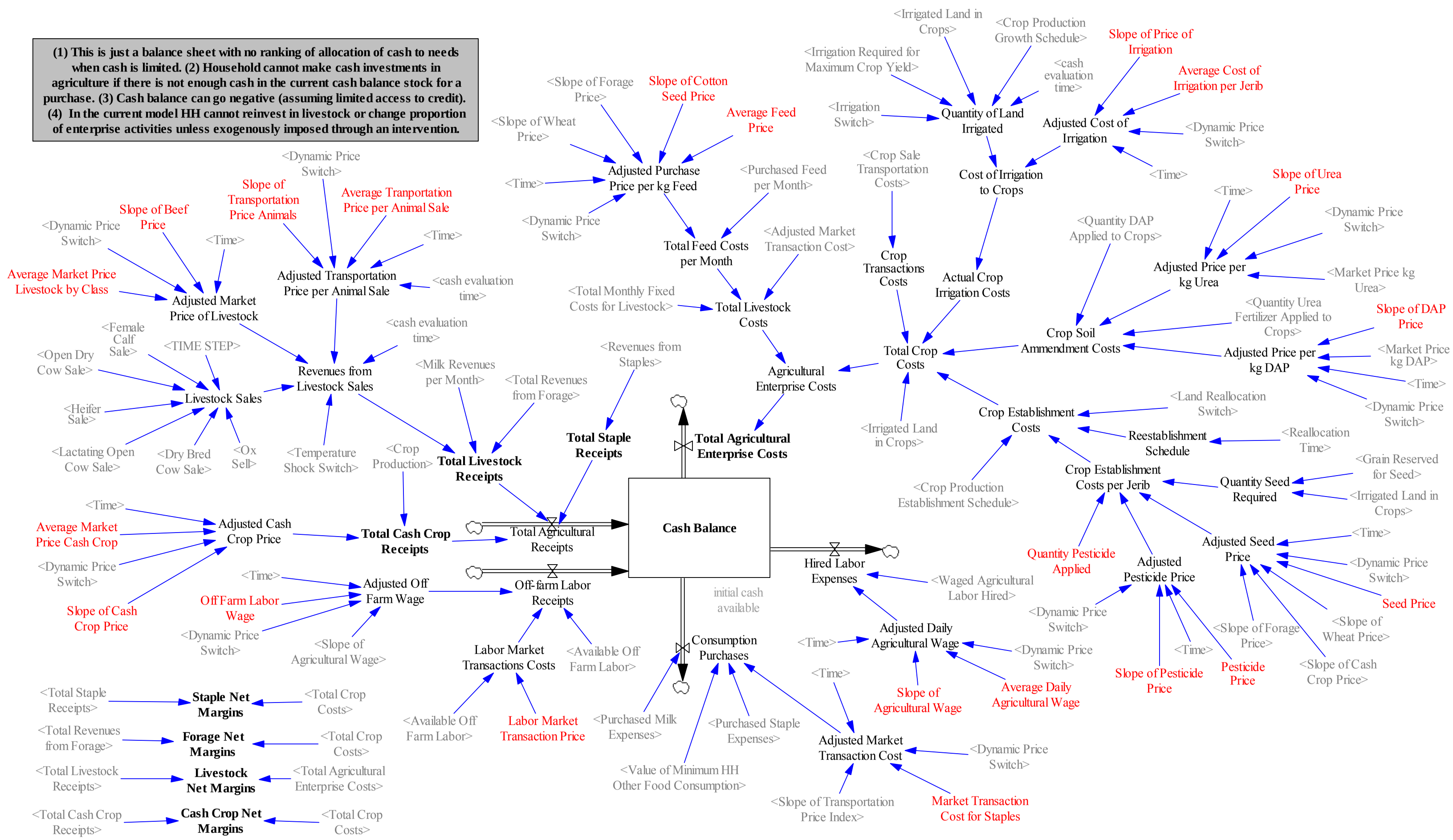


Figure A9.7 Cash Balance View

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