Available online at www.sciencedirect.com
SCIENCE DIRECT®
Agricultural Systems 86 (2005) 207–222
AGRICULTURAL SYSTEMS
www.elsevier.com/locate/agsy

Modelling the effect of household composition on the welfare of limited-resource farmers in Coastal Cañete, Peru

V.E. Cabrera [a,*], P.E. Hildebrand [b], J.W. Jones [c]

[a] University of Miami, 256 Frazier- Rogers Hall, PO Box 110570, Gainesville, FL 32611-0570, USA
[b] Food and Resources Economics, University of Florida, G155E, McCarty Hall, PO Box 110240, Gainesville, FL 32611-0240, USA
[c] Agricultural and Biological Engineering, University of Florida, 288 Frazier-Rogers Hall, PO Box 110570, Gainesville, FL 32611-0570, USA

Received 18 June 2002; received in revised form 27 August 2004; accepted 27 August 2004

Abstract

Family composition and its changes over time are believed to have a major impact on the welfare and sustainability of small-scale, limited resource farm households. In order to understand and test the effects of household composition on overall farm household well-being, a simulation model was developed based on information from 60 small farms from the Coastal Cañete Valley, Peru. The model accounts dynamically for the birth, age and death of household members and for crop, livestock, and economic activities. A representative farm with ten scenarios representing the range of household composition was simulated. Results in 10, 20 and 40-year runs showed that family composition has a large influence on economic stress. Families with fewer members were economically better off after 10, 20, and even 40 years. With more young or very old members, the expenses and consumption requirements exceeded the benefits from the additional labor, and debt was greater and of longer duration. Changing prices and yields across their observed ranged of variability influenced simulated financial position, but not the ranking of results among household composition scenarios.

* Corresponding author. Tel.: +1 352 392 1864x256; fax: +1 352 392 4092.
E-mail address: vcabrera@ufl.edu (V.E. Cabrera).

0308-521X/$ - see front matter
doi:10.1016/j.agsy.2004.08.009

Keywords: Sustainability; Simulation; Small farm households; Model; Household characteristics; Household composition

1. Introduction

The study was conducted in the lower (50–150 m.a.s.l.) coastal part of the Cañete Valley, which is located in the central western coast of Peru, 140 km south of Lima (Fig. 1). This zone has about 32,000 ha in total, of which 24,000 are cultivable land (Mayer and Fonseca, 1979). Representative crops in this agro-ecological zone are

Fig. 1. Location of Coastal Cañete, the study area.

cotton, potato, maize, and sweet potato. In this article, this zone will be referred to simply as Coastal Cañete. The land in Coastal Cañete is highly parceled. There are about 6,000 farms; 80% of them are in the hands of small landholders (10 ha or less). Coastal Cañete is one of the driest deserts in the world. Even though it has fairly good soils, abundant water for irrigation, and good roads, the Coastal Cañete community desperately needs development work and improvement in quality of life. This is especially true for small farm households.

The Peruvian population has been growing at different rates. According to Gonzales de Olarte (1994) it grew at a rate of 1.3% between 1876 and 1940, but during the following 21 years (1940–1961) this rate increased to 2.3% and in 1972 it was 2.9%. Since 1980, growth rate has decreased. Although this population increase occurred mostly in urban areas, because farmers decreased as a percentage of total population, farmers also grew considerably in total numbers. Most of this rural population has been in low altitude regions like Coastal Cañete. This accelerated demographic growth affected the agriculture sector because demand for food grew rapidly as well.

In Coastal Cañete, the number of agricultural units has increased rapidly in the last 30 years. Alarcón and Rubio (1982) found 1850 small farms (less than 10 ha) in 1972. The *Valle Grande Rural Institute* (www.irvg.org) of Coastal Cañete indicated that around 4800 small farmers were present in 2002, with an average of seven members per household.

Smallholder households combine a variety of activities to satisfy as many of their consumption needs as possible, and integrate cash-generating and household activities into livelihood strategies (Norman, 1983; Weismantel, 1987). Households are engaged in production, distribution, reproduction, social interaction, and networking (Wilk and Netting, 1984). The household unit is composed of individuals who both contribute to and consume household production and income, some of which may come from individuals engaged in off-farm work (Wilk and Netting, 1984). In smallholder agriculture, the family household is the major social unit for mobilizing agricultural labor, managing productive resources, and organizing consumption (Netting, 1993).

Few studies were found in the literature to assess the impact of changes in household composition over time. Sullivan (2000), studying data from Senegalese communities over a period of 40 years, found that household composition drives the decision-making process by determining needs and the capacity of a household to meet these needs. She also found that households characterized by few adults and many young children were under relatively high stress. In this study, stress was indicated by the level and duration of debt required for family survival. As children became adolescents, or other adults joined the household, requirements and available resources changed. Growing children and newly assimilated adults contributed to the labor pool, but also increased total household consumption.

Alwang and Siegel (1999) did not directly study the impact of family composition and its impact over time, but they analyzed the scarcity of family labor on the farm and its effect on food insecurity in Malawi. They presented the paradox of a vicious cycle of poverty in which small landholders neglect their own farm because they need to work in low-paid jobs to obtain cash and food. The Alwang and Siegel (1999) paradox implies that family labor in subsistence farms in the long run might have financially less worth than the value of its maintenance. This would result in impoverishment, even though labor is available.

A survey study in Kenya (Yamano and Jayne, 2004) found important differences in farm financial status related to changes in family composition caused by mortality of family members having different genders and roles. They found that the death of adults reduced net value of the household's crop production, reduced off-farm income, increased the chance of selling farm assets (i.e., animals), and there was little evidence of household recovery within 3 years after an adult death. The Yamano and Jayne results are relevant because they indicated that adult members provided financially more than they demanded from the farm. Therefore, households with more adults might have less financial stress.

The purpose of this study was to test the hypothesis that financial stress imposed by many children could be overcome as the family matures. The objectives were: (a) analyze debt and cash accumulation as a function of family composition through time in small farms in Coastal Cañete, and (b) assess the potential of households with different compositions to operate in a sustainable manner.

2. Materials and methods

In order to understand and test the effects of different household compositions on farm household behavior, a simulation model was developed. The model accounts dynamically for the birth, aging and death of family members, and for crop, livestock, and financial activities. As a base model, a representative small farm household from Coastal Cañete was simulated using data from a survey of 60 randomly-chosen households (Cabrera, 1999). Using this base model, ten variable family compositions were analyzed over 10, 20 and 40 years.

2.1. Data collection

Data from a survey carried out in Coastal Cañete (Cabrera, 1999) were used as a baseline for this system simulation. The survey was arranged to cover a geographically-stratified random sample of 60 farm households distributed across the entire study region. Data were collected from a broad cross-section of Coastal Cañete (Cabrera, 1999). The survey employed a questionnaire covering household characteristics, resource endowment, production practices, and economics of production. These data were updated and, in a few cases recalculated, using information from the *Valle Grande Rural Institute*, a local non-government agency with 40 years of experience in the community.

2.2. Model description

2.2.1. Representative farm system characteristics

Three main components interact in the model to represent a Coastal Cañete household: the family, the farm, and the financial decisions. The family component keeps track of the number of household members in different age classes, controls all events, provides labor, consumes maize, sweet potatoes and chickens, and demands cash for living expenses. The farm component deals with production and storage activities (crops and chickens). The two crops (maize and sweet potato) considered in the model required land, labor and cash. After they were produced, the commodities flowed to a virtual storage compartment from where they were distributed for family consumption and sale. Chickens were consumed, sold and bought.

The simulated representative farm had 5 ha of cultivable land divided into two fields, field 1 of 3 ha and field 2 of 2 ha. Maize and sweet potatoes, the two most common crops in the community, were raised in these two fields. Maize was grown between September and December in field 1 and between February and June in field 2. Similarly, sweet potato was grown between August and December in field 2 and between March and July in field 1. Chickens were raised all year long. The family home, storage compartments, and chicken house did not use crop land. Cash was required for all events and all events could return cash. If there was not enough cash, the family could obtain credit.

2.2.2. Family, labor, consumption and expenses

The family module keeps account of the number of members and the age of each person at any given time. Then it classifies the members into 16 categories according to the age of each member: class 1 to class 16 (every 5 years, between 0 and 80 years of age).

The representative family had 5 members initially (and increased to 8 in the 5th simulation year) and there were no family member deaths during the simulation except for one person who reached 80 years of age. At the start of the simulation, the family was composed of the father (age 31) the mother (age 26) the grandmother (age 61), and two infants (age 2 and 1). There were newborns in subsequent years 2, 3 and 5.

Labor in the small farms of Coastal Cañete is determined by the number, gender, and age of the household members. Based on information collected in the survey (Cabrera, 1999), each child younger than five years required adult labor of 0.75 day-labor per day, each child between 5 and 14 years contributed 0.5 day-labor per day, the same amount as males older than 65 years and females older than 75 years. Males between 14 and 65 and females between 14 and 75 years contributed 1.00 day-labor per day to the household (Table 1). The female labor for crop production was more limited than the male because they take care of the children, the house, and most of the livestock.

The household had the opportunity to hire people in labor-intensive seasons (labor for hiring is available in the community). It is also common that household members work for others (off-farm labor) to supplement household income. The cost to hire someone or work off-farm was US$ 3.50 day^{-1}. In this small farm livelihood system, at least 50% of the total household labor was provided by its members. House and livestock activities did not use hired labor. Available labor, estimated in days per month, determined the selling or buying of labor. Labor surplus or deficit

Table 1
Labor, consumption, expense rates, and average net financial contribution by family member class

Age classes	Age range (years)	Labor rate (days member^{-1} day^{-1})	Consumption rate (standard kg member^{-1} day^{-1})	Expense rate (US$ member^{-1} month^{-1})	Average net financial contribution (US$ member^{-1} month^{-1})
Class 1	0–5	−0.75	0.1	100	−178.76
Class 2	5–10	−0.5	0.2	70	−122.52
Class 3	11–15	0	0.5	50	−50.06
Class 4	16–20	0.4	1	50	−8.12
Class 5	21–25	0.8	1	50	33.88
Class 6	26–30	1	1	50	54.88
Class 7	31–35	1	1	50	54.88
Class 8	36–40	1	1	35	69.88
Class 9	41–45	1	1	35	69.88
Class 10	46–50	0.8	1	35	48.88
Class 11	51–55	0.7	0.8	50	23.40
Class 12	56–60	0.6	0.7	50	12.92
Class 13	61–65	0.5	0.6	50	2.43
Class 14	66–70	0.4	0.5	75	−33.06
Class 15	71–75	0	0.4	75	−75.05
Class 16	76–80	−0.5	0.3	100	−152.54

Sources: Cabrera (1999), *Valle Grande Rural Institute*.

(L_i), at any point in time, was estimated by Eq. (1). Labor could be sold (if $L_i > 0$) or bought (if $L_i < 0$) in any given month.

$$L_i = \sum_{i=1}^{16} l_i - \sum A_{ji} R_{ji}, \tag{1}$$

where l_i is the labor available of each member class i, A_{ji} represents the quantity of a activity j, and R_{ji} is the labor demand for that activity.

According to the survey, people in this area worked effectively 20 days in a month. Therefore, the labor available from each member class (l) in a month was estimated by multiplying the number of members in that class by their labor rate and by 20 days of effective labor.

Family crop consumption was determined by the consumption rates presented in Table 1 and the specific crop coefficients (CC). The consumption rate is the estimated fraction of food consumed by a member in a determined age class relative to the adult class consumption. The CC are unitless standardized crop values parameterized as food for the family based on survey data (4.00 for maize and 6.00 for sweet potato). The monthly family crop consumption is calculated as

$$F_j = \mathrm{CC}_j \times \sum_{i=1}^{16} \mathrm{MC}_i \times \mathrm{CR}_i, \tag{2}$$

where F_j is total family consumption of crop, subscript j for a month (kg month^{-1}), CC is the specific crop coefficient, MC_i is the number of members in class i, and CR_i is the consumption rate for that class (kg member^{-1} day^{-1}). Consumption follows the same pattern as labor, with mid age members consuming more than the young or very old.

Similarly, total family expenses were estimated as the sum of member classes (MC_i) by their expense rates (ER) from Table 1 in US\$ month^{-1}. The expense rate was the estimated expenditure by a member in a particular age class i. Mid-age members require less expenditure from the household.

The family also consumes chickens produced on the farm. The number consumed in a month was a function of the total number of family members, based on Eq. (3) in units per month. The family consumed an extra chicken in the festival months (December and July) and two extra chickens in February, when the head of the household celebrated his birthday. Chicken consumption was estimated based on information provided by the Health Department of Cañete, information from the survey, and from Valle Grande Rural Institute files.

$$F_h = \mathrm{Trunc}\left(0.2 \times \sum_{i=1}^{16} \mathrm{MC}_i\right). \tag{3}$$

F_h is the total family consumption of chickens per month, MC_i is the number of members in class i, and the trunc function rounds the expression to the lower integer.

2.2.3. Chickens

Chickens have a reproductive ratio of 0.23% per month. Their death rate was described by a 67% of chance that at most one chicken died in a particular month (Eqs. (4) and (5)), independent of the number of chickens, based on data from the *Valle Grande Rural Institute*.

$$A_c = A_c + \text{Trunc}(A_c \times 0.23), \tag{4}$$

$$A_c = A_c - \text{Trunc}(\text{RND} \times 1.5), \tag{5}$$

where A_c is the number of chickens and RND is a 0.1 uniform random variate.

Limits to the number of chickens on a farm mimic the farmers' practices. When at the beginning of the month, the number of chickens was lower than eight, the family bought another eight chickens; but, if the number of chickens was greater than 14, the family sold chickens to maintain only 14 units on the farm. At the end of any month, the number of chickens ranged between 6 and 16. The price of selling or buying a chicken averaged US$ 6.72 per unit.

The chicken activity demanded labor and consumed maize and sweet potato produced on the farm. Each month, each animal required 0.1 days of labor and US$ 0.3 (for feed supplement), and consumed 3.0 kg of maize and 1.5 kg of sweet potato.

2.2.4. Maize and sweet potato production

In order to produce maize and sweet potato, labor and cash are required in addition to land. The quantity of labor and cash varies according to crop physiological stages and production season. Table 2 contains information extracted from the annals of crop production costs from the *Valle Grande Rural Institute*.

Each crop has two harvests per year. Maize is harvested in December and June, and sweet potato in December and July. Average yields were 5120 kg ha^{-1} for

Table 2
Costs and labor required for production and area planted by crop

	Cost, US$ (ha^{-1} month^{-1})		Labor (days ha^{-1} month^{-1})		Area (ha)	
	Maize	Sweet potato	Maize	Sweet potato	Maize	Sweet potato
Aug	0	88	0	27	0	2
Sep	141.9	44	30	12	3	2
Oct	94.6	44	24	12	3	2
Nov	47.3	44	16	12	3	2
Dec	189.2	220	54	27	3	2
Jan	0	0	0	0	0	0
Feb	141.9	0	30	0	2	0
Mar	47.3	132	24	27	2	3
Apr	47.3	44	12	12	2	3
May	47.3	44	12	12	2	3
Jun	189.2	44	48	12	2	3
Jul	0	176	0	27	0	3

maize and 19,650 kg ha^{-1} for sweet potato. Total amounts of maize and sweet potato produced were estimated by multiplying the area planted by the yield in each season.

2.2.5. Maize and sweet potato storage

After crops are harvested, they are stored for consumption by family members and chickens, and for sale. For food security, the family stored maize and sweet potato for future consumption until the next harvest. They usually stored 600 kg of maize and 900 kg of sweet potato. The surplus was sold. Average prices found in the community (Cabrera, 1999) for maize and sweet potato were US$ 0.161 and 0.093 kg^{-1}, respectively.

2.2.6. Cash and debt

Cash flow was computed by tracking all farm activities that produce cash (selling crops, chickens, and labor, and borrowing money) or require cash (costs of production, buying chickens, family expenses, and payment of debts). Cash and debt are intimately linked. Money can flow from debt to cash following credit rules, and cash must pay the debts following specified payment rules. At the beginning of a month, if farm cash dropped below US$ 2000, the family borrowed US$ 1000 successively until it could cover all its expenses up to a maximum of US$ 6000 in a month.

The credit payment rules were estimated using economic data from the administrative office of the Valle Grande Rural Institute. Credit had a monthly interest rate of 1.5%. In any month, if the cash available was lower or equal to US$ 4,000, the family only paid 5% of the total debt. But, if the cash was greater than US$ 4,000, the family had to pay all the money owed in excess of US$ 4,000. If the debt payment was greater than the current debt, then the payment equaled the total debt. For initial conditions, the simulation started with the family having US$ 1,000 of cash available and a debt of US$ 1,000.

2.3. Scenarios

To explore the potential impact of family composition on farm sustainability, we simulated 10 household composition scenarios (Table 3). These scenarios were selected to encompass the existing range of variability of households in the Valley.

Table 3 shows ages of the members at the starting point of the simulation (initial conditions). Negative numbers indicate that new members will be born in subsequent years. Note that the original simulation (base model) was for scenario number 4. Table 4 shows the proportion of the population of each scenario in the Coastal Cañete.

The family of the first scenario started with 5 members, the parents, the grandmother and two children of 1 and 2 years. In the years 2, 3, 5, 7, 9 and 11, new members were born. Finally, the household totaled 11 members until the grandmother

Table 3
Initial household composition of scenarios

Scenarios	Number of members	Age of members (years)										
		61	31	26	2	1	−2	−3	−5	−7	−9	−11
1	11	X	X	X	X	X	X	X	X	X	X	X
2	10	X	X	X	X	X	X	X	X	X	X	
3	9	X	X	X	X	X	X	X	X	X		
4	8	X	X	X	X	X	X	X	X			
5	7	X	X	X	X	X	X	X				
6	6	X	X	X	X	X	X					
7	5	X	X	X	X	X						
8	4	X	X	X		X						
9	3	X	X	X								
10	2		X	X								

Negative age of members represent the number of years after the simulation starts in which new members are born and are added to the family composition.

Table 4
Number of family members and frequency of occurrence in the community by scenario

Scenario	Number of members	Frequency	Percent (%)
1	11	1	1.7
2	10	3	5.0
3	9	2	3.3
4	8	11	18.3
5	7	9	15.0
6	6	6	10.0
7	5	6	10.0
8	4	7	11.7
9	3	11	18.3
10	2	4	6.7

died in year 19, when the total number became 10. In the following scenarios, there was one less member born, until scenario 7 when the family did not have any new births after the simulation started. In the last 3 scenarios there was only one child, none at all, or neither children nor the grandmother. In this last scenario, the couple started the simulation, they did not have children, and no other relative lived with them.

There are families in scenarios 4 or 5 than in any of the others. Scenario 9, with only 3 family members, is also common. The representative family would have 5 children and usually hosts a relative in the farm household (8 members in total, scenario 4). The extreme scenarios, even though not very common, help test the sensitivity of the overall family composition to farm outputs and sustainability.

For analysis purposes, the observed outputs: cash, debt, and the difference between them (net income), were accumulated at different points in time (at 10, 20 and 40 years).

3. Results and discussion

3.1. Base farm (scenario 4)

Family size increased dynamically with time from the initial five members to 8 in the fifth simulation year. It remained at eight members until the 19th year when the oldest female died. From that point to the end, there were seven members. The crops, chickens, and storage activities had a predictable pattern throughout the seasons of the year, except for random chicken deaths.

Fig. 2 displays the interaction of the financial variables (cash and debt) with the family composition through time. At the beginning, the household with three adults and two children faced moderate indebtedness that increased when more children were born. By year 10 there were five children, one elderly woman, and two adults that caused high financial stress: debt was near its peak.

Maximum financial stress, as indicated by the highest debt (more than US$ 16,000), was reached between years 12 and 13 when children still did not contribute substantially to the labor pool. In subsequent years, children progressively provided more labor, which decreased the debt and consequently the financial stress on the family. In the 19th year the grandmother died, which decreased stress on the family's finances. By year 20 the family had 7 members: 2 were adults and 5 were grown

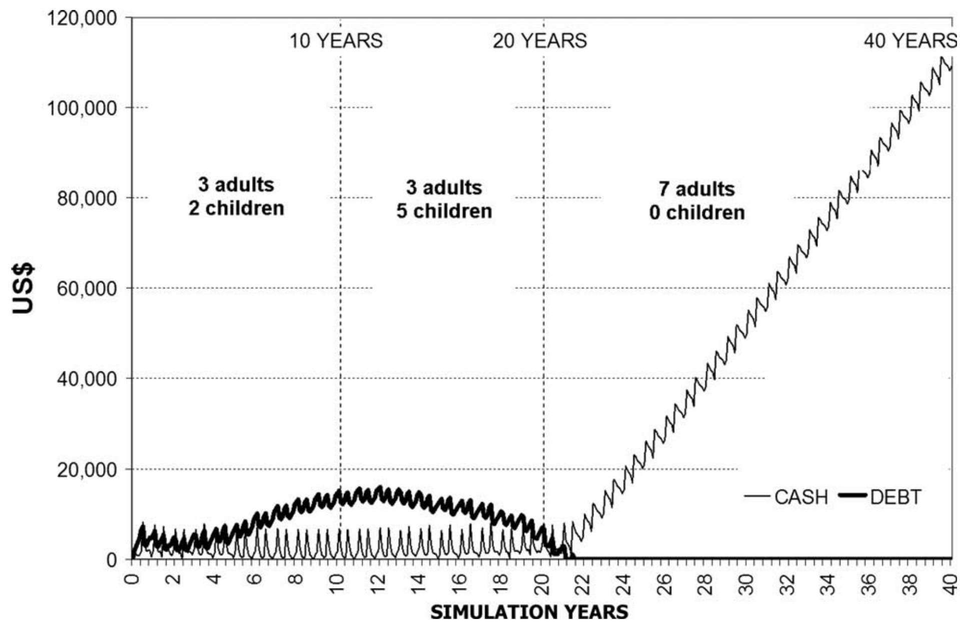

Fig. 2. Simulated cash, debt and approximate family composition of a representative household (scenario 4).

adolescents. All provided labor. In simulation year 20 the family had paid almost all its debt.

The family became free from debt in the 22nd simulation year. From then on, the household started accumulating cash because children grew older and provided more labor to the household. At the end of the 40th year, the family had accumulated about US$ 107,000. In year 40, the family still had seven members: the father and the mother who were 71 and 66 years old, and the sons and daughters who were between 35 and 42 years old (and assumed to be unmarried).

3.2. Other family compositions

Similar to the base farm, all families in the scenarios with children passed through a cycle in which a maximum financial stress was reached. The duration and intensity of this stress depended on the number of children. Families with 4 or more children (scenarios 1–5) still had debt after 10 years, and families with 5 or more children (scenarios 1–4) still had debt after 20 years (Table 5). However, all scenario families were free of debt and had different amounts of accumulated cash after 40 years. Mature families were always better off than young families. Families with 3, 2 or 1 children (scenarios 6–8) passed this maximum stress before year ten. Families without children (scenario 9) or families composed only of the couple (scenario 10) did not have this stress period, and started to accumulate cash in the first year. Table 5 shows the number of years that each family had debt. Larger families had debt for up to 32 years, while a family with three children (scenario 5) remained in debt for 16 years and families without children (scenarios 9 and 10) did not have debt for more than a few months.

Simulated farms were able to obtain credit based on the value of their farm land of 5 ha, valued at US$ 40,000. If farm households maintained debts of more than 25% of their capital asset for prolonged periods, they risked not being able to comply with the credit rules, and were at risk of losing their land. Families that had debts of

Table 5
Net income of different family scenarios

Scenarios	Number of members	Net income (Cash–Debt)			Years until debt free
		10 years	20 years	40 years	
1	11	−16,063	−37,194	50,638	32
2	10	−16,107	−26,664	68,976	29
3	9	−15,026	−11,817	97,026	24
4	8	−12,975	−4365	108,730	22
5	7	−6,902	15,048	127,032	16
6	6	1352	33,648	142,380	10
7	5	17,698	55,516	161,708	4
8	4	31,460	73,033	173,964	2
9	3	46,188	91,489	187,603	1
10	2	50,907	109,013	204,958	1

more than US$10,000 after 10 or 20 years would face this risk (as in the case of families with 5, 6, 7 or 8 children in scenarios 1–4) (Table 5).

It was hypothesized that larger families would be better off than smaller families after the stress period because more productive members would be present. However that was not the case in this study. The simulation of different household compositions (Table 5) demonstrated that smaller families were economically always better off than larger families. The availability of labor and its low cost, with the option to hire labor for most on-farm tasks, greatly affected this situation. In the long-run, living expenses for each family member were higher than the value of their labor contribution. Hired labor was more economical for the household, but Coastal Cañete's families will only hire extra labor if their family members are not able to do all jobs. For reproduction tasks, such as child care and house keeping, there was no option to hire labor. Therefore when there were more members who required care, the stress increased.

3.3. Sensitivity analysis

Two main variables (price and yield) of the principal production activities (maize and sweet potato) could change drastically, unexpectedly, and without control from the household. Prices for maize and sweet potato are determined by the rules of supply and demand in the market. Coastal Cañete is located very close to Lima, the largest market in Peru. Lima receives these commodities from different parts of the country and even though the aggregated amount produced in Coastal Cañete would have some impact, there are other factors that drive prices. As one farmer stated, "it is a lottery, you never know how much you are going to receive for your product". During interviews, Cabrera (1999) found that prices (US$ kg^{-1}) received for maize could vary from 0.15 to 0.18 (mean = 0.161) and for sweet potato could vary from 0.04 to 1.40 (mean = 0.93).

Yields of maize and sweet potato are also quite variable primarily due to climate variability. For example the El Niño climate year in 1997–1998 caused yield reductions of up to 50% of the main crops due to a higher incidence of pests and a higher demand for water because of much higher than normal temperatures (Valle Grande Rural Institute). In La Niña years, lower than normal temperatures are expected and with them, slower growth and lower yields. Additionally, climatic conditions in the mountains also have an indirect effect because this determines water availability for irrigation in Coastal Cañete. La Niña years are drought years for the Andes. Consequently in these years the Cañete River flow is low and there could be a lack of water for crops. Cabrera (1999) found yields ($kg\ ha^{-1}$) for maize could vary from 4500 to 6000 (mean = 5120) and for sweet potato from 15,000 to 25,000 (mean = 19,650).

A sensitivity analysis was performed by combining these different extreme and average prices and yields and holding them constant for simulations on the representative farm household (scenario 4). This was done to assess the impact of these prices and yields on overall household financial status at the 40-year end point. Results in Fig. 3 show the ending debt and cash for the minimum, mean, and maximum prices

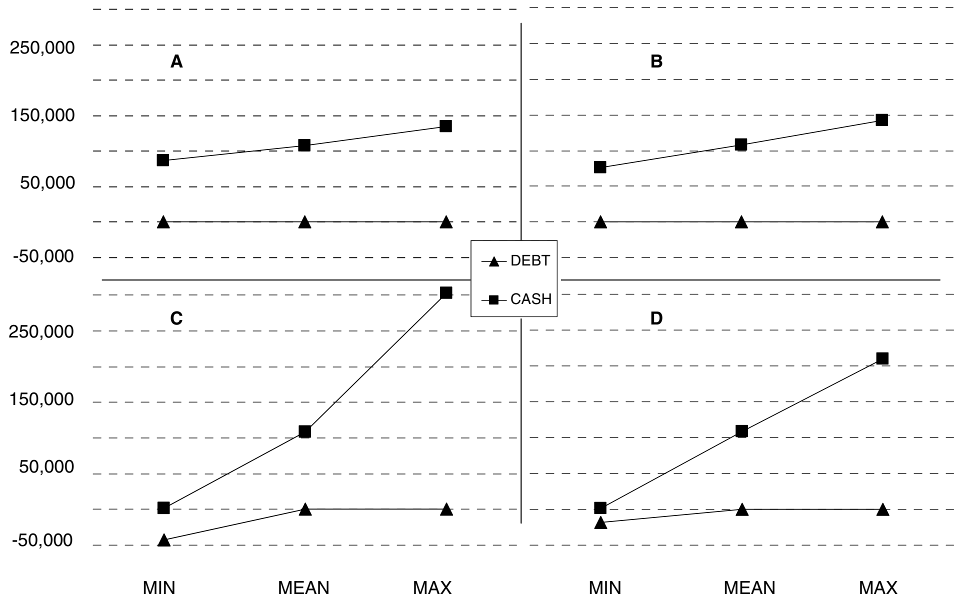

Fig. 3. Sensitivity analysis of prices and yields for base family (scenario 4) for forty-year runs. (A) Maize price changes. (B) Maize yield changes. (C) Sweet potato price changes. (D) Sweet potato yield changes.

of maize (Fig. 3(A)) and sweet potato (Fig. 3(C)); and for the minimum, mean, and maximum yields of maize (Fig. 3(B)) and sweet potato (Fig. 3(D)).

This sensitivity analysis indicated that sweet potato had a greater impact in the farm financial status than maize. When sweet potato price and yield remained constant, changes in the prices and yields of maize (Figs. 3(A) and (B)) had less impact than changes in prices and yields of sweet potato when maize prices and yields were held constant (Fig. 3(C) and (D)).

By comparing the sole effects of these commodity prices on the finances of the farm (Figs. 3(A) and (C)), it was clear that changes in sweet potato prices had a greater impact on farm financial status than changes in maize prices. When sweet potato price was at its minimum value, the farm ended with accumulated cash of US$ 1,100 and a debt of US$ 42,000; and when the sweet potato price was the maximum, the farm ended with more than US$ 300,000 accumulated cash. When these changes were explored for maize, the accumulated cash varied substantially less; the farm ended with US$ 87,000 (minimum maize price) and with US$ 135,000 (maximum maize price).

Similarly, the sensitivity to yield levels was studied by comparing graphs B and D in Fig. 3. Evidently, changes in sweet potato yield had more impact on the farm financial status; the farm ended with only US$ 1,300 accumulated cash and a debt of US$19,000 when yield was minimum, and with US$ 210,000 when yield was maximum. Conversely, the effect of varying maize yields was to change the accumulated cash at the end from US$ 76,000 to US$ 142,000.

Notice that the debt at the end of the 40 years only existed (indicated by a negative value) in cases of either minimum price or minimum yield of sweet potatoes. In all other cases the debt was 0. The farm net income, determined by the difference between cash accumulated in 40 years and the debt at the end of this period of time, was negative only in the cases of minimum sweet potato price (US$ -41,000) and yield (US$ -17,000).

The financial impact of price changes compared to yield changes was different for each crop. For maize, a change from minimum to maximum yield had a greater impact than similar changes in prices (Figs. 3(A) and (B)). However, for sweet potato, changes in prices had a greater impact than changes in yield (Figs. 3(C) and (D)).

These different prices and yields were also tested with all the other family composition scenarios (Table 3). Results were similar to the representative household. The main driver was sweet potato price, followed by sweet potato yield, and then maize yield and maize price. In all cases there were families with debt after 40 years when the prices and yields were the minimum. However, smaller families resulted in fewer cases with debt and higher amounts of accumulated cash at the end of the 40-year period when compared with larger families. Additional runs for all family compositions were performed with different prices and yields (different than extreme and averages) and results confirmed previous results. Smaller households were always better off, having either lower debt or higher cash.

4. Conclusions

Families with fewer members were economically better off after 10, 20 and 40 years in all cases. With more young or old members, the expenses and consumption requirements exceeded the benefits from additional labor, and debt was greater and of longer duration. It appears that debt began to decrease as the total household labor rate approached 0.5 labor day^{-1}. The total labor rate is the weighted average of the individual labor rates of household members. The labor rate is the estimated fraction of labor contributed by a member in a determined age class with respect to the adult class labor contribution, which equals 1.0. The ability of households to hire inexpensive labor is a big factor in explaining the above results. Labor in the community is not a limiting factor.

Further research should look carefully at other options for labor as children grow older. Projecting household composition is conjectural at best. In this study none of the children died or married and all remained in the household. Gender of the children was also not considered. Future studies should take into account gender variations and older children leaving the household when they marry, or bringing the spouse into the household. Also, future research could look at uncertainty via stochastic modeling.

References

Alarcón, J., Rubio, A., 1982. Un método estadístico de selección y evaluación de muestras para encuestas agrícolas. Con aplicación a productores de papa en el valle de Cañete. Centro Internacional de la Papa, Lima.

Alwang, J., Siegel, P.B., 1999. Labor shortages on small landholdings in Malawi: implications for policy reforms. World Development 27, 1461–1475.

Cabrera, V.E., 1999. Farm problems, solutions, and extension programs for small farmers in Cañete, Lima, Peru. Thesis (MS). University of Florida, Gainesville, FL. Available at: <http://etd.fcla.edu/etd/uf/1999/amj9816/cabrera.pdf>.

Gonzales de Olarte, E., 1994. En las fronteras del Mercado, economía política del campesinado del Perú. Instituto de Estudios Peruanos, Lima.

Mayer, E., Fonseca, C., 1979. Sistemas agrarios en la cuenca del río Cañete. ONERN, Lima.

Netting, R.McC., 1993. Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable, Agriculture. Stanford University Press, Stanford, CA.

Norman, D.W., 1983. The farming systems approach to research. In: Butler-Flora C. (Ed.), Proceedings of Kansas State University's 1982 Farming Systems Research Symposium: Paper No. 5. Farming systems in the field. Kansas State University, Manhattan, Kansas, pp. 7–19.

Sullivan, A.J., 2000. Decoding diversity: strategies to mitigate household stress, Thesis M.S. University of Florida, Gainesville, FL.

Yamano, T., Jayne, T.S., 2004. Measuring the impacts of working-age adult mortality on small-scale farm households in Kenya. World Development 32, 91–119.

Weismantel, M.J., 1987. Making breakfast and raising babies: The Zumbagua household as constituted process. In: Wilk, R.R. (Ed.), The Household Economy: Reconsidering the Domestic Mode of Production. Westview Press, Boulder, CO, pp. 56–72.

Wilk, R., Netting, R., 1984. Households: Changing forms and functions. In: Netting, R., Wilk, R., Arnould, E. (Eds.), Households: Comparative and Historical Studies of the Domestic Group. University of California Press, Berkeley, pp. 1–28.