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MODELING THE EFFECT OF HOUSEHOLD COMPOSITION ON THE WELFARE OF LIMITED-RESOURCE FARMERS IN CAÑETE, PERU

by

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

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Abstract

Family composition and its changes over time are believed to have a major impact on the welfare of small scale, limited-resource farm households and their sustainability. 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 Cañete valley, Peru. The model accounts dynamically for the birth, age and death of household members and for crop, livestock, and economic activities. Ten typical Cañete households were simulated. Results in 10, 20 and 40-year runs showed that family composition has a great influence on economic stress. Smaller families were always better off than larger families. Prices and yields are expected to greatly vary, and even though they would have the greatest impact over the household sustainability, we can always foresee that the smaller families will be better off than the larger ones.

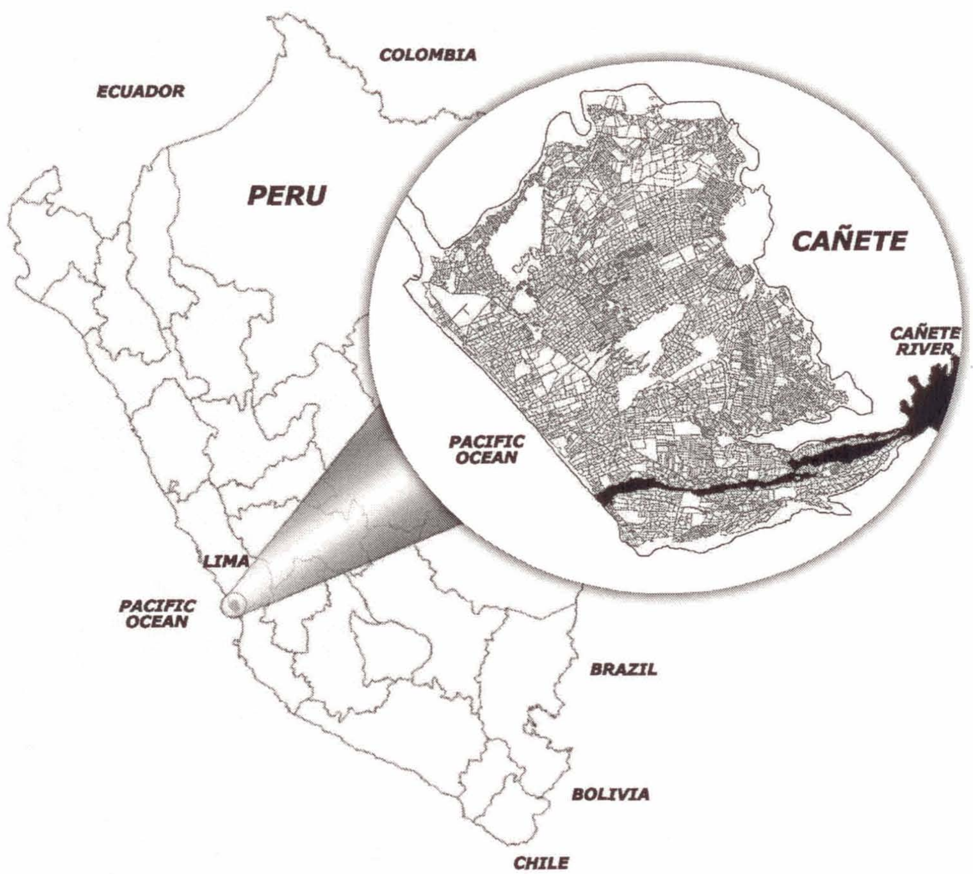
Key words: sustainability, simulation, small farm households, Peru, model, household characteristics.

1. Introduction

The study was conducted in the lower coastal part of the Cañete valley, which is located in the central western coast of Peru, 140 km south of Lima (Figure 1). This zone has about 32,000 ha in total, of which 24,000 are cultivable land. Mayer and Fonseca (1979) distinguished 10 production zones in the Cañete river Basin, each of them with an ecological floor (altitude) and characteristic crops. This study focuses on the lowest agro-ecological zone at elevations from 50 to 150 m.a.s.l. where the typical crops are cotton, potato, maize, and sweet potato. In this article, this zone will be referred to simply as Cañete.

The land in Cañete is highly parceled; there are about 6,000 farms; 80% of them (4,800) are in hands of small landholders (10 ha or less). Cañete is one of the driest deserts in the world and. Even though it has fairly good soils, plenty of water for irrigation, and good roads, the Cañete community desperately needs development work and improvement in quality of life. This is especially true for small farm households.

Figure 1. Cañete location



The Peruvian population has grown at different rhythms. Growth rhythms are measured by annual percentage rates that express the new population as a percentage of the initial population. 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 to 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 as is the case of Cañete. This accelerated demographic growth affected the agriculture sector because the demand for food grew rapidly as well.

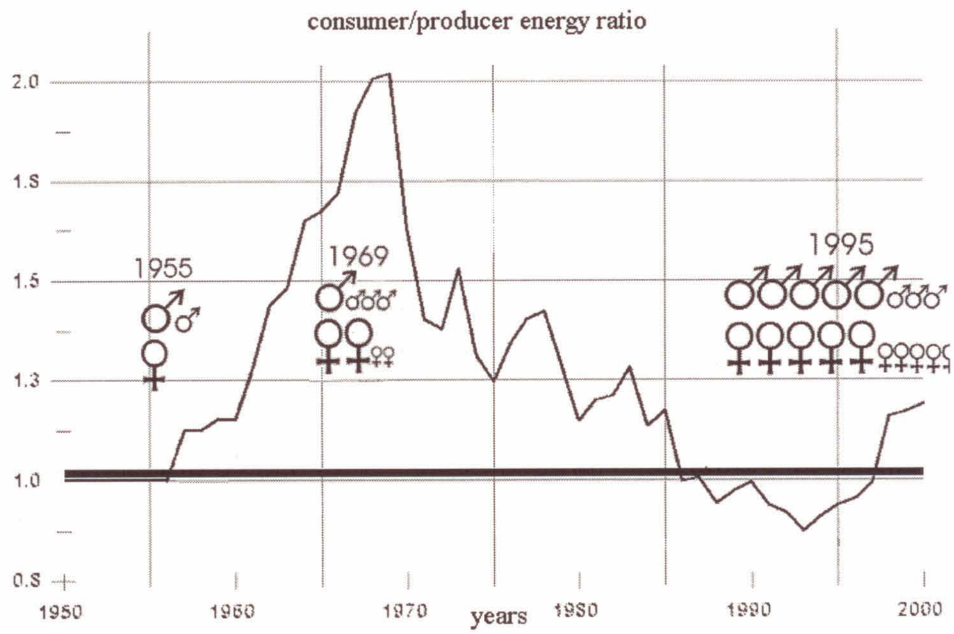
In Cañete, the number of agricultural units has been increasing rapidly in the last 30 years. Alarcón and Rubio (1982) found 1,850 small farms (less than 10 ha) in 1972. The *Valle Grande Rural Institute* (www.irvg.org) of Cañete has a database that indicates around 4,800 small farmers were present in 2002, with an average of seven members per household.

According to Wharton (1963) the life of subsistence farmers is a complex system. The subsistence farming systems involve production and reproduction activities. They are not only complex and diverse, but also rational (Chambers, 1997). The household members manipulate their primary resource, labor, to meet consumption needs (Chayanov, 1966) as these needs change over time (Wharton, 1963).

Smallholder households combine a variety of production activities in order to satisfy as many of their consumption needs as possible, including the integration of cash generating and reproduction activities into livelihood strategies (Norman, 1983; Weismantel, 1987). Households are engaged in production, distribution, biological and social reproduction, and co-residence (Wilk and Netting, 1984). The household unit is at the same time composed of individuals who contribute to and consume from pooled 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 corporate 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 overtime. Sullivan (2000) studying data from Senegal 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 would be under relatively high stress; as children become adolescents or other adults join the household, requirements and available resources change yet again, Figure 2. Grown children, as well as newly assimilated adults, contribute to the labor pool but also increase total household consumption.

Figure 2. Household energy stress curve



Source: Sullivan (2000)

In Figure 2, the male married his first wife in 1953 and within two years their first son was born. In 1960 he took a second wife. In 1969, the peak of food production stress, his household consisted of one man, two women and five children under the age of 15. As the children entered the workforce the stress on the household began to decrease. By 1986, "there were nine adults producing for this household, two of whom were employed off farm, remitting cash" (Sullivan 2000).

The purpose of this study was to test the hypothesis that family stress imposed by the existence of many children could overcome and could even be advantageous as the family matures. Stress is indicated by the level and duration of debt required for family survival. The objectives were: a) analyze the behavior of debt and cash accumulation versus different family composition over time for typical representative small farms in Cañete; and b) assess the potential associated with different household composition to achieve sustainable operation.

Farm scale simulation models are developed for different objectives. These models are usually divided into biological, ecological, and socio-economic modules. Biological processes include crop and livestock production and other biophysical variables related to production such as the soil-water balance. Ecological processes summarize the relationships of the farm with the environment; and the Socio-Economic processes include variables that are related to consumption, survival and/or sustainability. Authors use them for assessing sustainability (Hervé et al., 2002; Sullivan, 2000; Shepherd et al., 1998; Hansen and Jones, 1996); estimating disruptions from policy changes (Ruben and van Ruijven, 2001; Kaya et al., 2000; Kruseman and Bade, 1998; Ruben et al., 1998; Dent et al., 1995); or testing new technologies to be diffused (Mudhara et al., 2003; McGregor et al., 2001; Cabrera, 1999; Dalsgaard and Oficial, 1997; Nyangito et al., 1996). Many recent models aim to produce expert systems or to develop decision support systems (Castelán-Ortega et al., 2001; Attonaty et al., 1999); several combined above approaches (Shaffer et al., 2000; Neil et al. 1999; Keating and McCown, 2001; Herrero et al., 1999).

2. Materials and Methods

In order to understand and test the effects of different household composition on limited resource farm household behavior, a simulation model combining several of the approaches cited above was developed. The model accounts dynamically for the birth, age and death of family members and for crop, livestock, and financial activities.

As a base model, a typical representative small farm household from Cañete was simulated using data from a survey of 60 randomly chosen households (Cabrera, 1999). The activities were arranged to represent reality as closely as possible. Using this base model, ten variable family compositions were tested over 10, 20, and 40 years for different scenario analyses.

2.1. Data collection

Data from a survey carried out in 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. Survey data were collected from a broad cross section of Cañete households and the study area was completely covered. For more details, see Cabrera at URL: http://etd.fcla.edu/etd/uf/1999/amj9816/cabrera.pdf.

The questionnaire consisted of structured questions of 70 items contained in three sections. The first section had three subsections: (1) household information, (2) agricultural factors, and (3) economic information. The second section consisted of seven open-ended needs assessment questions. And the final section included 13 open-ended questions regarding farm problems and concerns.

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. Description of a representative household and the simulation model

2.2.1. Representative household components

Three main components interact in the model of a typical 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 and controls all events, provides labor, and consumes maize, sweet potatoes and chickens, as well as demands cash for living expenses.

The farm component deals with production and storage activities (crops and chickens). The two crops (only maize and sweet potatoes are considered in the model) require land, labor and cash. After they are produced, the commodities flow to a virtual storage compartment from where they are distributed for family consumption, selling, and chicken consumption. Chickens are 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, are raised in these two fields; maize is grown between September and December in field 1 and between February and June in field 2. Similarly, sweet potato is grown between August and December in field 2 and between March and July in field 1. Chickens are raised all year long. The family home, storage compartments, and chicken house do not use crop land.

Cash is required for all events and all events can return cash. If there is not enough cash, the family can obtain credit.

2.2.2. Family, labor, consumption, and expenses

The family module runs in yearly steps and keeps account of the number of members and the age of each one 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).

The representative or base family had five members at the beginning 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 base family is composed of the father (31) the mother (26) the grandmother (61), and two infants (2 and 1). There are newborns in subsequent years 2, 3, and 5. This is a typical family observed in the Cañete community.

Labor is a limited resource on the small farms of Cañete and 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 requires adult labor of 0.75 day-labor per day, each child between 5 to 14 years contributes 0.5 day-labor per day, the same amount as the males older than 65 years and the females older than 75 years, and the males between 14 and 65 and the females between 14 and 75 years contribute 1.00 day-labor per day to the household (including production and reproduction activities, Table 1). The female labor for crop production is more limited than the male because they take care of the children, the house, and most of the livestock.

The household has the opportunity to hire people in labor intensive-seasons (labor for hiring is available in the community). It is also common that the household members work for others (off-farm labor) to supplement household income. The cost to hire someone or work off farm is the same, as found in the survey, US$ 3.5 day^{-1}. In this small farm livelihood system, at least 50% of the total household labor is provided by its members and house and livestock activities do not use hired labor. Available labor, estimated in days per month, determines the selling/buying of labor. Total labor available for the farm at any point in time is stated in Equation [1]. Labor can be sold (if extra labor is available) or bought (if overall family labor is not enough) in any given month.

$$L_i = \sum l_i - \sum A_{ji} R_{ji} \qquad [1]$$

Where L is the total available labor, l_i is the labor available of each member class, A_j represent the activities, and R_j is the labor demand for each activity.

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

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

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

Family crop consumption is determined by the coefficients presented in Table 1 and the specific crop coefficients (CC). The CC are standardize crop values as a food for the family; it is 4.00 for maize and 6.00 for sweet potato. The monthly family crop consumption is calculated by the Equation [2] as kg $month^{-1}$. Consumption follows the same pattern as labor, mid age members consume more.

$$F_j = CC_j \times \sum_{i=1}^{16} MC_i \times CR_i \qquad [2]$$

Where F is total family consumption of crop $_j$ for a month (kg month^{-1}), CC is the specific crop coefficient, MC is the number of members in each class, and CR is the consumption rate (kg member^{-1} day^{-1}).

Similarly, total family expenses were estimated as the sum of member classes (MC) by their expenses rates (ER) from Table 1 in US$ month^{-1}. Expense rates are inverse to the labor and consumption rates: mid-age members demand less expenses from the household.

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

$$F_h = Integer\left(0.2 \times \sum_{i=1}^{16} MC_i\right)$$

$$F_h = F_h + 1, \text{ if Month = December or July} \qquad [3]$$

or

$$F_h = F_h + 2, \text{ if Month = February}$$

F_h is the total family consumption of chickens per month, MC is the number of members in each class, and *Integer* means truncation.

2.2.3. Chickens

Chickens have a reproductive ratio of 0.23% per month and a death rate described by a 67% of chance that at most one chicken dies in a particular month (Equations [4] and [5]). The death rate is completely independent of the total number of chickens. This particular death rate function was built and verified using data from the Extension office from the *Valle Grande Rural Institute*.

$$A_c = A_c + Integer(A_c \times 0.23) \qquad [4]$$

$$A_c = A_c - Integer(RND \times 1.5) \qquad [5]$$

Where A_c is the number of chickens, *Integer* means truncation and *RND* is a random computer generated number between 0 and 1.

There are limits to the number of chickens on the farm, which was implemented to mimic the farmer's practices. When at the beginning of the month, the number of chickens reaches the minimum of eight (8) or maximum of fourteen (14), the family buys below 8 units or sells all above 14 units, respectively. At the end of any month, there is a common range of $6 \leq A_c \leq 16$. The price of selling or buying a chicken averages US$ 6.72 per unit.

The chicken activity demands labor and consumes maize and sweet potato produced on farm. Each month each animal requires 0.1 days of labor and US$ 0.3, and consumes 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 the crop physiological stages and the production season. Table 2 contains the information extracted from the annals of crop production costs from the *Valle Grande Rural Institute*.

	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

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

Each crop has two harvests in a year. Maize is harvested in December and June, and Sweet Potato in December and July. Average yields are 5,120 kg ha^{-1} for 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 the crops are harvested, the commodities flow to a virtual storage facility. From this pool, these products support family and chicken consumption, and income from sales. For food security, the family maintains certain amounts of crops in the storage facility at all times to be consumed in subsequent months, until the next harvest. They usually store 600 kg of maize and 900 kg of sweet potato. Therefore, the differences of the harvested quantities less the stored quantities are the amounts sold. Average prices found in the community (Cabrera, 1999) for the maize and sweet potato were US$ 0.161 and 0.093 kg^{-1}, respectively.

2.2.6. Cash and debt

Cash flow is estimated 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 the cash in the farm goes below US$ 2,000, the family obtains a credit of US$ 1,000. If, after this loan, the family will not be able to cover all its expenses, it obtains another credit of US$ 1,000, if it still is not enough, it obtains another US$ 1,000 credit successively up to a maximum of US$ 6,000 in a month.

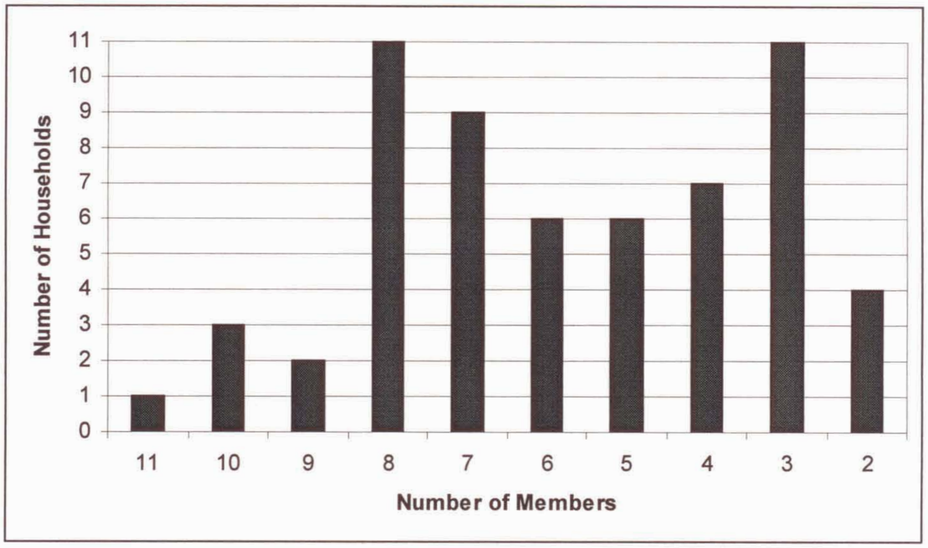
The credit payment rules were estimated using economic data from the administrative office of the *Valle Grande Rural Institute*. Credit has a cumulative monthly interest rate of 1.5%. In any month, if the cash available is lower or equal to US$ 4,000, the family only pays 5% of the total debt. But, if the cash is greater than US$ 4,000, the family must pay all the money above US$ 4,000. If the Debt Payment is greater than the current debt, then the payment must only equal the total debt and pay it in full. If the credit is paid in full, the family is freed from debt and starts accumulating cash.

For the initial conditions, the simulation starts in a situation where the family has US$ 1,000 of cash available and at the same time a debt of US$ 1,000.

2.3. Scenarios

Based upon number of family members and family compositions found in the 60-household interviews, complemented by information provided by the *Valle Grande Rural Institute*, different initial family compositions were tested as different scenarios (Figure 3, Table 3).

Figure 3. Frequency of family sizes



These scenarios were used because of the importance in understanding the potential of different family compositions to achieve sustainable performance.

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								

Table 3. Age and number of family members for starting simulation

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 (-11 means that there will be a new member in year 11). Note that the original simulation (base model) was for scenario number 4 that initially had eight members in total. Table 4 shows the proportion in the Cañete population of each scenario.

The family of the first (1) scenario starts with five 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 are born. Finally, the household totals 11 members until the grandmother dies in year 20, when the total number becomes 10. In the following scenarios, there is one less member born, until scenario seven (7) when the family does not have any new born after the simulation starts. Scenarios eight (8), nine (9), and ten (10) change the family structure before starting. In these last three scenarios it is assumed that there is only one child (scenario 8) or none at all (scenario 9) or neither children, nor the grandmother (scenario 10). In this last scenario, only the couple starts the simulation and they do not have children, nor do they live with any other relative.

		Number of Members	Frequency	Percent (%)
SCENARIOS	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

Table 4. Number of family members and frequency of occurrence by scenarios

It is more common to find families in scenarios 4 or 5. Scenario 9 with only three family members is also common. The representative family would have five sons and/or daughters and usually hosts some relative in the farm household (8 members in total, scenario 4). The extreme scenarios, even though not very common, help to test the sensitivity of the overall family composition related to farm outputs and sustainability.

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

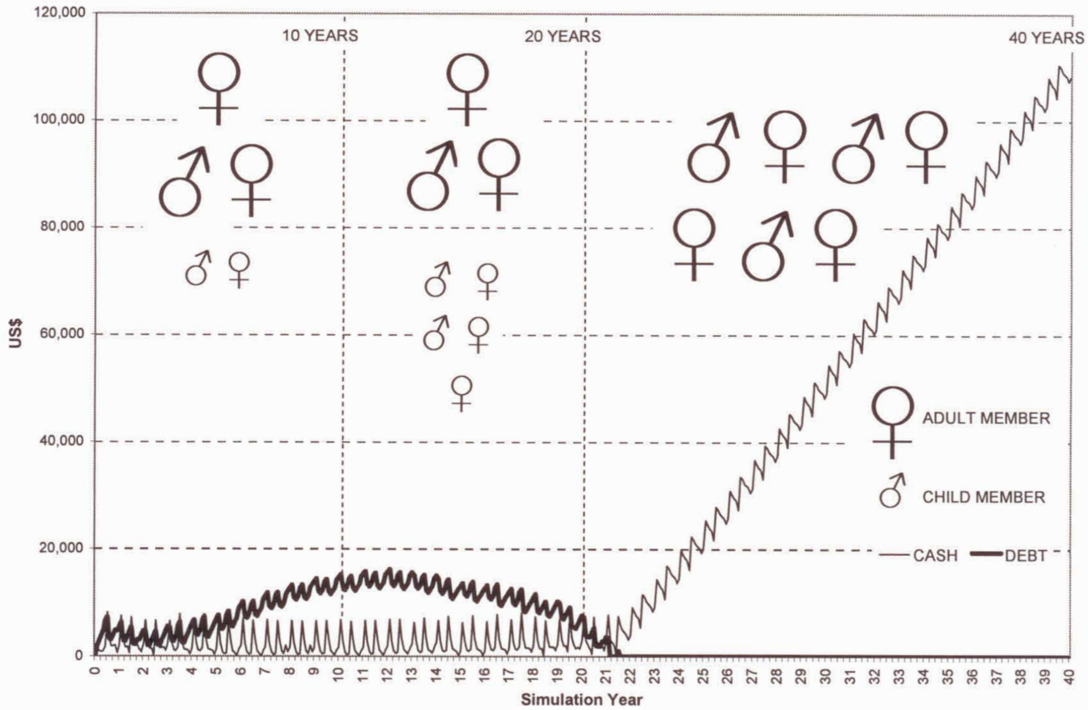
3. Results and discussion

3.1. Base farm (scenario 4)

Family size increases dynamically with the simulation from the initial 5 members to 8 in the fifth simulation year. It remains at 8 members until the 19th simulation year when the oldest female dies. From that point to the end, there are 7 members. The crops, chickens, and storage activities have a predictable pattern throughout the seasons of the year, except for random chicken deaths.

Figure 4 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 faces moderate stress that increases when more and more children are born. By year ten there are five children, an old woman, and two adults that determine a very high stress on the household impacting greatly the financial variables. Debt is high and near to reach its peak.

Figure 4. Simulated cash, debt and approximate family composition of representative household (Scenario 4)



Maximum stress indicated by the highest debt (more than US$ 16,000) is reached between years 12 and 13, when children still do not contribute substantially to the labor pool. In subsequent years, children progressively provide more and more labor, which decreases the debt and consequently the stress on the family. Additionally, in the 19th year the grandmother dies and decreases stress on the family's finances. By year 20 the family has seven members: two are adults and five grown adolescents. All provide labor to decrease stress. In simulation year 20 the family is close to paying all its debts.

The family becomes "free" from debt by the 22nd simulation year. From then on, the household starts accumulating cash because children grow older and provide more and more labor to the household. At the end of the 40th simulation year the representative family accumulates about US$ 107,000. In year 40, the family still has seven members: the father and the mother, who are 71 and 66 years old, and the sons and daughters who are between 35 and 42 years old.

3.2. Other family compositions

As in the case of the base farm, all families with children pass through a cycle in which a maximum stress is reached. The duration and intensity of this stress depends on the number of children. Families with four or more children (scenarios 1 to 5) would still have debt after 10 years, and families with five or more children (scenarios 1 to 4) would still have debt after 20 years, Table 5. However, all family scenarios would be free of debt and with different amounts of accumulated cash after 40 years of simulation, mature families are always better off than young families. Families with three, two or one children (scenarios 6, 7, and 8) would pass this maximum stress before year ten, and families without children (scenario 9) or families composed only of the couple (scenario 10) would not have this stress period. They start to accumulate cash the first year. Table 5 shows the number of years that each family faces debt; larger families with many children have debt for up to 32 years, while a family with three children (scenario 5) will remain in debt for 16 years and families without children (scenarios 9 and 10) would not have debt for more than a few months.

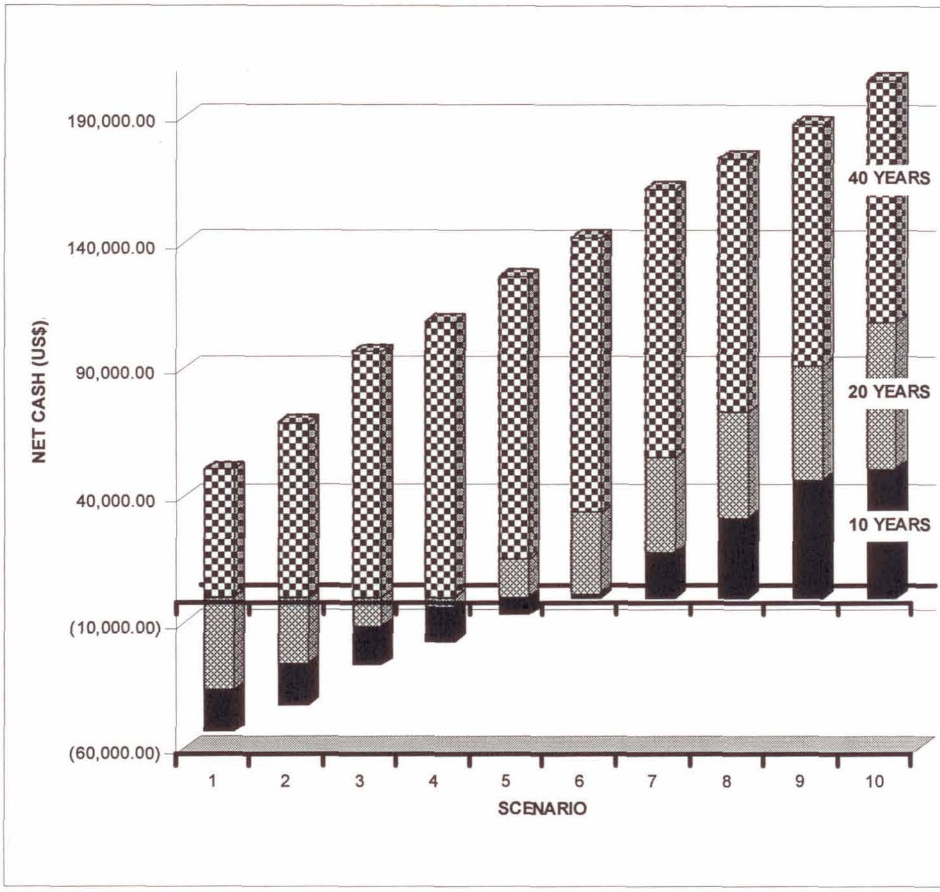
		NUMBER OF MEMBERS	NET INCOME (CASH-DEBT) 10 YEARS	20 YEARS	40 YEARS	YEAR FREE FROM DEBT
SCENARIOS	1	11	(16,063.21)	(37,194.22)	50,637.79	32
	2	10	(16,107.33)	(26,663.83)	68,976.02	29
	3	9	(15,025.60)	(11,817.38)	97,025.53	24
	4	8	(12,975.27)	(4,364.86)	108,730.17	22
	5	7	(6,902.17)	15,048.35	127,032.49	16
	6	6	1,351.74	33,648.41	142,380.13	10
	7	5	17,698.42	55,515.57	161,707.72	4
	8	4	31,459.97	73,032.91	173,963.96	2
	9	3	46,188.39	91,489.08	187,603.35	1
	10	2	50,906.72	109,013.05	204,958.31	1

Table 5. Net income of different family scenarios

Simulated farms have as their main capital asset their farm land of 5 ha valued at US$ 40,000.00 (US$ 8,000.00 ha^{-1}) and based on it they are able to obtain credit. If farm households maintain debts of more than 25% of their capital asset for prolonged periods, it is very dangerous because they risk not being able to comply with the credit rules and may lose their land. This happens in the community. From Table 5, families that have debts of more than US$ 10,000.00 after 10 or 20 years would face this risk (as in the case of families with 5, 6, 7, or 8 children or scenarios 1 to 4).

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 (Figure 5) demonstrated that smaller families are 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 affects this situation. Overall, the living expenses (consumption and miscellaneous expenses) for each family member are higher than his/her contribution as labor to the farm. Hired labor would be more economical for the household, but Cañete´s families will only hire extra people if their members are not able to do all jobs by themselves. For reproduction tasks such as child care and house keeping there is no option to hire labor, therefore when there are more members who require care, the stress in household increases.

Figure 5. Net income of family scenarios at 10, 20 and 40 years



3.3. Sensitivity analysis

Two main variables (prices and yields) of the principal production activities (maize and sweet potato crops) could change drastically, unexpectedly, and without control from the household. Prices for maize and sweet potatoes are determined by the rules of supply and demand in the market. Cañete is located very close to the largest market in Peru, Lima. Lima receives these commodities from different parts of the country and even though the aggregated amount produced in Cañete would have some impact on it, there are larger factors that drive prices. As farmers mentioned, "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 greatly variable. Even though Cañete is a desert where it never rains (average precipitation is lower than 1 mm $year^{-1}$) and all agricultural activities are irrigation dependent (so is farmer controlled and managed), the overall climate has a great impact on production. For example the El Niño climate year in 1997/1998 caused a reduction of up to 50% in yields 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 the water available for irrigation in Cañete. La Niña years are drought years for the Andes, consequently in these years the Cañete river brings much less water and there could be lack of water for crops. Cabrera (1999) found yields (kg ha^{-1}) for maize could vary from 4,500 to 6,000 (mean = 5,120) and for sweet potato from 15,000 to 25,000 (mean = 19,650).

A sensitivity analysis was performed using these extreme and average values of prices and yields (3 x 3 x 3 x 3 = 81 runs) with all the previous family composition scenarios in order to assess the impact of these potential events on overall household sustainability. All household compositions were evaluated at the 40 year end point.

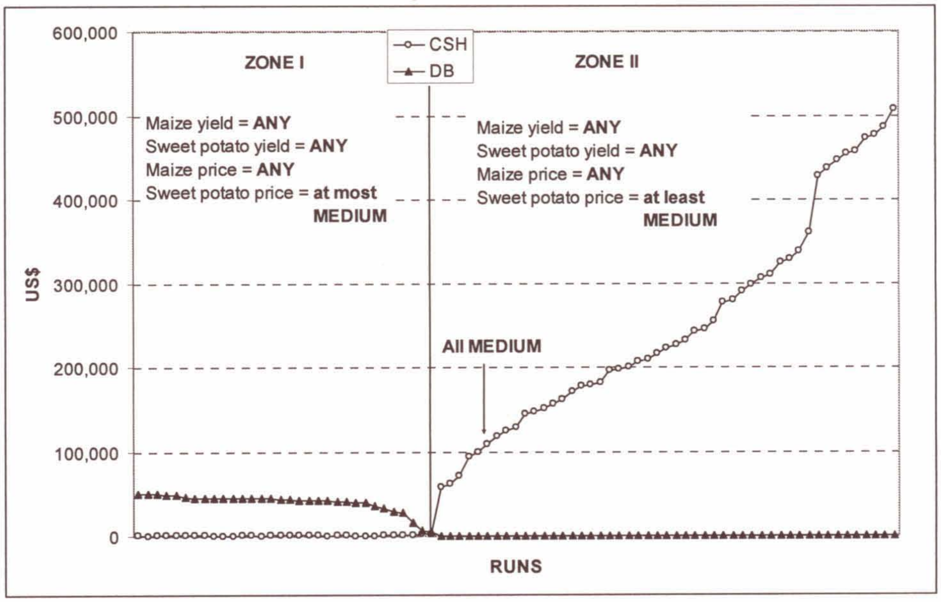
Figure 6 shows the overall picture for the base family (scenario 4) with all possible options of prices and yields. In Figure 6 the arrow points to the solution when prices and yields are average (as is seen in detail in previous Figure 4). Figure 6 is divided in two main parts. The Zone I where the family is still in debt after 40 years and Zone II where the family is accumulating cash after 40 years.

In Zone I the price of sweet potato is at most 0.093 US$ kg^{-1}, but the price of maize, and the yields of the two crops could be any of the extremes or the averages. In this Zone, of the five cases in which the price of sweet potato was the average (0.093 US$ kg^{-1}), they were combined with low, medium (one case), and high (one case) maize prices, low or at most medium (one case) maize yields, and low sweet potato yields. For low sweet potato prices, all possible combinations of the other factors were found. The worst case scenario is when all factors are the lowest and the accumulated debt in 40 years is about US$ 50,000. Thirty out of the 81 runs (37%) ended with debts between US$ 22,000 and 50,000.

In Zone II, where the net balance is positive after 40 years, as in the previous case, the main driver is the sweet potato price, that is at least medium (0.093 US$ kg^{-1}), but never low; all the other factors are in all combinations. However if the sweet potato yield is low, the price of the maize has to be at least medium, and its yield at least medium, or if one (price or yield of maize) is low the other has to be high. The highest amount of accumulated cash is when all factors are in high combinations, in which case the family would accumulate about US$ 500,000 in the forty years.

These different prices and yields were tested with all the family composition scenarios. Results were similar to the base family (scenario 4): the main driver was the sweet potato price, followed by the sweet potato yield, and then the maize price and maize yield. Also, in all scenarios there were families with debt after 40 years, even in the smaller ones, when the prices and yields were low (Table 6).

Figure 6. Sensitivity analysis of prices and yields for base family (scenario 4) for forty-year runs



		US$ DEBT	US$ CASH	RUNS ENDING WITH DEBT
SCENARIOS	1	50,321	467,030	39.51%
	2	49,716	480,266	39.51%
	3	49,605	494,678	38.27%
	4	49,554	507,883	37.04%
	5	49,344	521,073	35.80%
	6	49,266	534,269	34.57%
	7	49,208	547,434	33.33%
	8	49,083	547,440	33.33%
	9	48,559	547,440	32.10%
	10	47,465	547,444	30.86%

Table 6. Debt, cash, and percentage of runs ending with debt after 40-year simulation with lowest prices (0.04 and 0.15 US$ kg^{-1} for sweet potato and maize) and yields (15,000 and 4,500 kg ha^{-1} for sweet potato and maize)

–Place Table 6 here –

Table 6 indicates that prices and yields of sweet potato and maize have a greater impact than family composition over the outcomes of the household. Consequently, an analysis that isolates these effects would be advisable, as was the case of using average prices and yields, to test different family compositions.

Additionally, runs for all family compositions were performed with different prices and yields (different than averages) and results confirmed previous results: smaller households will always be better off showing either lower debt or higher cash accumulated. During the forty-year simulation period, prices and yields are expected to greatly vary, and even though they would have the greatest impact over the household sustainability, we can always foresee that the smaller families will be better off than the larger ones.

4. Conclusions

Families with fewer members were better off after 10, 20, and even 40 years. With more younger or very old members, the expenses and consumption requirements exceed the benefits from the additional labor, and debt is greater and of longer duration. It appears that debt begins to decrease as the total household labor rate approaches 0.5. The ability of households to hire inexpensive labor, is a big factor 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 nor 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.

It is also important to recommend further research that includes community feedback in the estimations, mostly if it is intended to aggregate and draw community based conclusions.

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