RETURNS TO THE INTRODUCTION OF NEW SORGHUM CULTIVARS INTO THE DAIRY INDUSTRY OF EL SALVADOR

Paper presented at CENTA conference:

“Cambio Climático e Impacto de los Sorgos Forrajeros”

December 7, 2011

San Salvador, El Salvador

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ACKNOWLEDGMENTS

We would like to express our gratitude to CENTA, PROLECHE, INTSORMIL and especially to our principal collaborator Rene Clara. Rene pushed to have this study done and helped us during the last two years while we performed this study. We have furthermore to thank our collaborators Mario Mazariego, Ricardo Estevez, Cecilia Landaverde, Moises Morales, Ricardo Araujo, Domingo Palacios, Jose Benitez, Carlos Molina, Alfonso Escobar and Mario Parada. They all supported us during this research work.

INTRODUCTION

The driver of agricultural development is the introduction of new technology. Sensitive[1] sorghums have long been a critical component of hillside Central American agriculture providing a reserve or insurance policy when the principal staple of maize falters. The insensitive sorghums have been more recently introduced since the '70s for planting in the valleys in the second season. In the last thirty years the introduction of new insensitive cultivars has accelerated initially for poultry and in the previous two decades for dairy production. This growth has been facilitated by strategic investments in research by CENTA and the Ministry of Agriculture.

As incomes grow the demand for high quality foods, meat, milk, cheese, fruits and vegetables, accelerates. Milk and products from milk are principal beneficiaries of these demand

[1] The sensitive sorghums are planted beneath the maize in the first season and wait for the light and rapid development until the maize is broken in the period between the two seasons ("canicula"). The sensitivity to light then insures that they will not compete with the maize but just wait their turn at the light. Insensitive sorghums are planted in monoculture in the second season. Photo-insensitive varieties are those whose flowering is not affected by the amount of daylight hours and flower regardless of the time they are planted. Photo-sensitive varieties (landraces) are those which flower only when days are short (November-December). Photo-insensitive sorghums need a greater amount of soil moisture for pollination and grain filling, compared with the photo-sensitive cultivars. In general, sorghum requires 550 mm of water throughout the growing season well distributed for optimum production (Clara, 2011).

shifts. To facilitate these consumption shifts agricultural research led by Rene Clara of CENTA focused on the development of a series of new cultivars. Since agricultural research and extension is expensive, we ask the returns on these public investments and who were the beneficiaries. Responding to these two questions is the objective of this paper. We will also make some recommendations for future research and policy.

DAIRY PRODUCERS IN EL SALVADOR

The dairy farms in El Salvador are concentrated in the middle and lower part of the country, areas that have been identified as "cuencas lecheras" (milk basins). Most dairy farms are located in the departments of San Miguel, La Union, Usulutan and Sonsonate (MAG, 2003, p. 14). Dairy farms in the western region are characterized by greater availability of irrigation and increased size of the herd while the ones in the eastern region have a more extensive system of livestock .Production systems for dairy farming in El Salvador are differentiated by their degree of technological adoption, herd size, and the farm size. We use the size of the herd in milk production to classify the production systems in El Salvador.

Small

Generally known as traditional producers; in this category are included producers owning less than 20 head of cattle in milk production. Here there is little or no adoption of technology, keeping the calf with the milking cow most of the day. The races are normally Brahman crosses with native cattle. Most of the milk produced by this group is used for home consumption and surpluses are sold locally to help with family finances. These farmers represent 15% of national milk production (Technoserve, 2009, p.14).

Medium

These farmers are called semi-technified. This group has from 20 to 50 cows in milk production. The reproduction system generally involves natural mating with Holstein and Brown Swiss bulls. This group employs accounting record systems, has stables and feeders with roofs for the cattle, and applies some technology in the milking including disinfecting udders with iodine solution and washing utensils and milking equipment with detergents, Their milk is higher quality than that of the small producers. These farmers represent 45% of national milk production (Technoserve, 2009, p.14).

Large

This group applies more sophisticated management system and has more than 50 cows in milk production. This includes artificial insemination, improved races and greater feed supplementation. They employ mechanized milking systems and perform hygienic milking practices such as washing and drying udders, udder dipping and prevention of mastitis. To control heat stress, sprinklers, fans, shades, or treatment rooms are common. They milk 2 or 3 times per day, placing the milk directly into cooling tanks of stainless steel. This maintains a better quality for the product reducing contamination. They also have access to bank loans and receive substantial technical assistance. These farmers often have annual contracts with processors for constant annual milk prices. These farmers represent 40% of national milk production (Technoserve, 2009, p.14).

STUDY REGION

The study was conducted in the four geographical areas in which the country is divided: Western, Central, Para-Central and Eastern, covering the fourteen departments of the country. All four have suitable agro-climatic conditions for the production of milk. In addition, improved sorghum technology development has been tested in these areas in on-farm trials and demonstrations.

A survey design with both qualitative and quantitative aspects was used. The sampling procedure was a combination of a two-stage stratified sampling technique used to select 180 farmers for this study. In the first stage, 30 sample farmers were selected from 4 of the 14 departments in El Salvador. In the second stage, 150 farm households were selected proportionally to the number of dairy farms per department of the sampling list. From these 150 farms, 90 farmers utilizing sorghum technologies and 60 farmers without the sorghum technologies were selected. This made a total of 120 dairy farmers who grew the improved sorghum varieties, and 60 who did not use sorghum (see A- 1). The sampling list was obtained from PROLECHE and CENTA extension agencies and was updated before sample selection (see Figure 1 below). Therefore there is a bias here from the selection procedure of these two agencies for their clients.

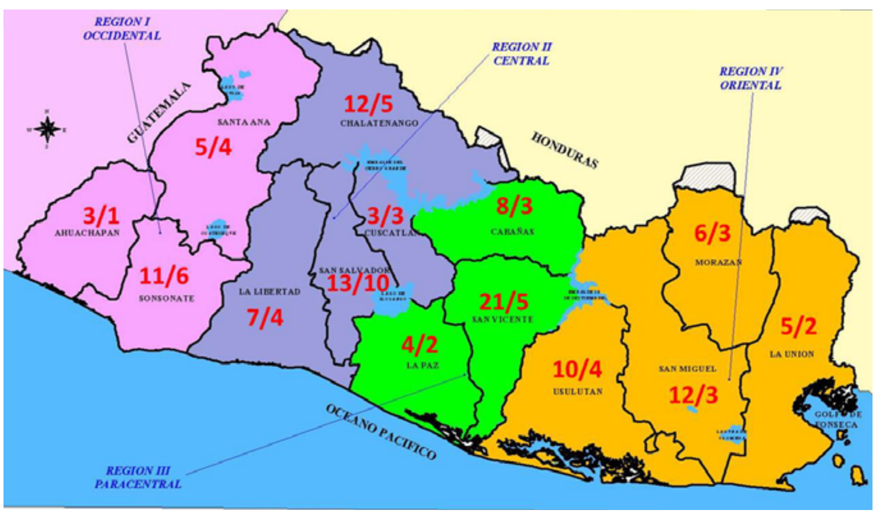

Figure 1. Distribution of Farmers Interviewed: With and Without Sorghum Technologies

Source: Villacís, 2011, survey data

Sample farmers were interviewed using a designed survey questionnaire. The interviews took place at the farmer's ranches or at central meeting places when villages were inaccessible. The principal author conducted the interviews. Extension agents from CENTA and PROLECHE assisted in arranging appointments with farmers and explaining local customs and practices. A typical interview took from one to two hours.

Both primary and secondary data were used. The primary data were collected from farm households using a structured questionnaire. Secondary data were collected from the agricultural and related organizations operating in the area of study, namely, Ministry of Agriculture and Livestock, National Center of Agricultural and Forest Technology (CENTA), National Association of Milk Producers (PROLECHE), Department of Statistics, Ministry of Economics and the Salvadorian Central Bank. In addition secondary data were collected from relevant national and international organizations such as the Food and Agriculture Organization (FAO). Both primary and secondary data were required to estimate the economic surplus model.

VARIETAL DEVELOPMENT OF THE INSENSITIVE CULTIVARS

Due to the interest in forage, caused by the increasing dairy production in the country, the Basic Grains Program of CENTA has devoted significant research to the testing for adaptation and the crossing[2] of photo-insensitive sorghum. This has resulted in the release of S2, S3, RCV and SS-44 that are now commonly grown throughout El Salvador (R. Clara, personal communication, May 30, 2010). The first three cultivars are used as either dual purpose[3] or silage while the hybrid SS-44 is grown for its multiple cuts for grazing, hay and silage.

Estimates of the total area planted over time with CENTA S-2, CENTA RCV, CENTA S-3 and CENTA SS-44, are compared with the data on certified seed production from the CENTA records of seed production of the four main sorghum seed companies of El Salvador, PROSELA, UPREX, VILLAVAR and CENTA (see Figure 2).

[2] The cultivar and hybrid breeding have used traditional pedigree approaches, with populations generated from American university and ICRISAT sorghum breeding programs. The best performing materials from these population trials were given to CENTA for evaluation and testing in El Salvador and other countries of Central America. When successful, these materials resulted in the release of improved, locally-adapted cultivars for grain and/or forage production.
[3] The grain can be sold and the rest of the plant used for forage.

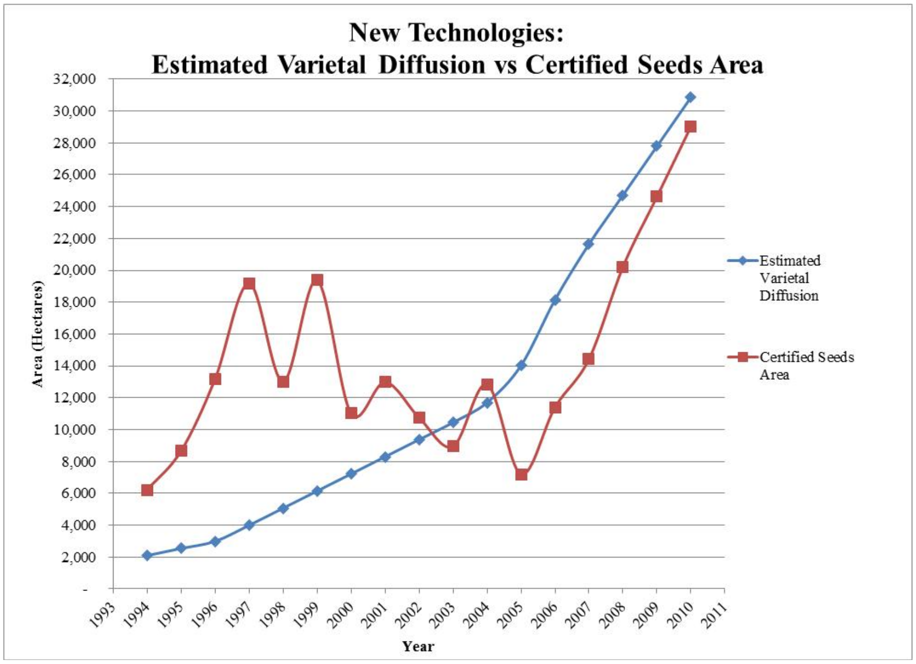

Figure 2. Comparison between Estimated Varietal Diffusion and Area Planted with Certified Seed.
Source: Villacís, 2011, survey data

One explanation for the initial higher area with certified seed than our estimates of diffusion over the period 1993 to 2003 is that the certified seed data reflect seed production rather than sales. Normally diffusion occurs with a gradual logistic curve as more and more producers see other producers using the cultivar. This is more consistent with our curve of the introduction than the data on certified seed production. After 2005 the gap between certified seed and our diffusion estimate may be due to farmer or other non-certified production of seed.

Not all of the area planted with the new technologies is used for dairy cattle feeding[4] but also for grain production for the poultry industry, especially CENTA-RCV. Hence, area estimates for the use of CENTA S-2, CENTA-RCV, CENTA S-3 and CENTA SS-44 for the production of forage and silage were obtained from experts in the field and were respectively 94%, 27%, 73% and 100% of the area (see Figure 3).

[4] Beef cattle production in El Salvador is very small and most beef consumed comes from Nicaragua.

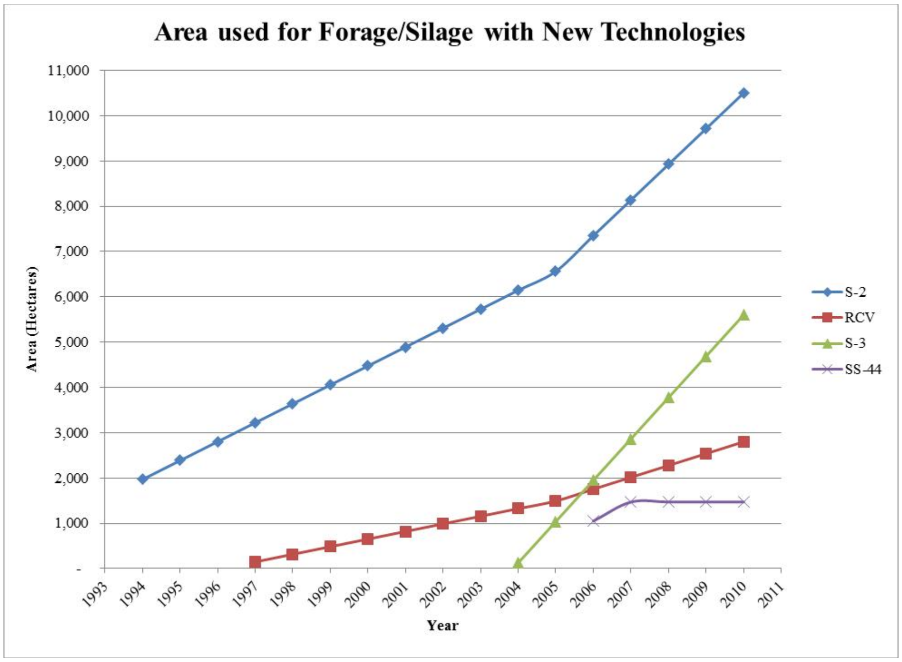

Figure 3. Area used for the production of forage and silage of the four sorghum cultivars under study.
Source: Villacís, 2011, survey data

S-2 is the most widespread variety for production of forage and silage due to its earlier introduction and because its seed is easier to find on the market in comparison with the other varieties. The hybrid SS-44[5] is just being introduced and is only produced by CENTA.

SILAGE INTRODUCTION AND DIFFUSION

The introduction of silage dates from the early 80's; however, during the civil war there was little diffusion. During the 90's with the support of the Salvadorian government and the assistance of the Israeli government the use of silage began to be widely disseminated among Salvadorian dairy farmers. By 2010 approximately 60% of the dairy farms in El Salvador used silage (Araujo, personal communication, June 10, 2011).

INSTITUTIONAL DEVELOPMENT AND EXTENSION IN THE DAIRY INDUSTRY

The Milk Producers Association of El Salvador (PROLECHE) was created in 1993. The objective was the rehabilitation of the dairy sector with the assistance of Israeli experts and funds

[5] All of the production of SS-44 is purchased by PROLECHE and sold to its members.

made available by USAID, following the agrarian reforms in 1980, and the termination of the civil war in 1989.

The project included training local instructors, the introduction of modem technologies, and the extensive rehabilitation of a number of ranches. Training was carried out on-site by an Israeli expert, in cooperation with 8 local instructors who received professional training, and participated in courses conducted in Israel. The project conducted field days in different dairy farms as well as courses delivered at the National School for Agriculture (The Israel Project, 2008). Salaries and transportation for the local instructors were provided by the Salvadorian Ministry of Agriculture.

This dairy project was mainly concerned with training farmers at all stages of production including conservation and marketing of milk. From 1993 to 2004 there was a transformation of dairy production.[6] By 2010 dairy productivity averaged 20 bottles[7] (15 liters) of milk per cow per day on PROLECHE farms (Morales, personal communication, June 30, 2011).

TECHNOLOGICAL CHANGE AND COST SAVINGS

Farm-level surveys were conducted to determine the differences in feeding costs among the different farm sizes. The survey indicates substantial differences in daily productivity per cow with productivity of large producers almost three times that of small producers (Table 1).

Table 1. Characteristic of Dairy Sorghum Farms in El Salvador

Characteristic	Farm Size		
	Small	Medium	Large
Hectares under sorghum	2.39	8.30	15.40
Herd Size Average	10.69	32.83	69.88
Milk Liter/Day/Cow	6.27	11.39	15.43
Milk mT/Year/Farm	24.14	134.60	388.28

Source: Villacís, 2011, survey data

[6] In addition, the Japanese International Cooperation Agency (JICA) ran various artificial insemination and embryo transplant programs to upgrade Salvadoran cattle genetics (USDA, 2001, p.4).
[7] The Salvadorian unit of milk production is the bottle which is equivalent to 0.75 liter.

Results also show that the productivity of the non-sorghum[8] producers is larger than those of the sorghum producers (see Table 2). One explanation for this is the slightly higher nutritional value and greater palatability of maize resulting in more consumption and increased milk production (Landaverde, personal communication, August 25, 2011).

Table 2. Characteristic of Dairy Non-Sorghum Farms in El Salvador

Characteristic	Farm Size		
	Small	Medium	Large
Herd Size Average	12.79	31.33	76.88
Milk Liter/Day/Cow	6.65	12.52	16.93
Milk mT/Year/Farm	30.61	141.14	468.69

Source: Villacís, 2011, survey data

Cost savings by size (small, medium, large)

The advantage of sorghum is that multiple cuts[9] reduce the costs of feed per unit of milk. These reductions are small indicating that the entire dairy sector is improving with and without sorghum but there are still small cost advantages for the farms which use sorghum as a feed (Table 3).

Table 3. Feed Cost Differences of Dairy Farms in El Salvador

Characteristic	Farm Size		
	Small	Medium	Large
Cost / mT of milk in Dairy Sorghum Farms	250.57	261.81	287.80
Cost / mT of milk in Dairy Non-Sorghum Farms	254.52	267.61	293.58
Change in cost per mT of milk	3.95	5.80	5.78

Source: Villacís, 2011, survey data

Results show medium size farmers are the principal beneficiaries from these cost savings technologies and then the large farmers.

[8] Non-sorghum farmers interviewed were maize users, which is along with sorghum one of the most important crops used for forage and silage.
[9] Sorghum producers can get up to 4 cuts for SS-44. The dual purpose cultivars generally give two cuts.

FROM COST SAVINGS PER FARM TO NATIONAL IMPACT

The model

Economic surplus analysis[10] compares a situation with and without the technology and can be used to quantify total increases in economic efficiency (total social benefits) as well as distribution of benefits between consumers and producers. Figure 4 is a conventional, comparative-static, partial-equilibrium model of supply and demand in a commodity market in a closed economy.[11] It shows the supply curve for milk under the original technology denoted by S_f and the demand for milk at the processor (D_f) and final consumer (D_r) levels. The original price for consumers is P_r and for producers is P_f, the quantity supplied and demanded is Q and the constant per unit margin of the milk processors is M. The consumer surplus from consumption of milk is equal to the triangular area FIP_r (the area beneath the demand curve for final consumers less the price of milk; similarly, the producer surplus is equal to the triangular area P_fKG (total revenue less total costs of production as measured by the area under the supply function). Total surplus is equal to the sum of producer and consumer surplus. Changes in producer, consumer, and total economic surplus are measured as changes in these areas (Alston, Norton & Pardey, 1998, p.41).

[10] Economic surplus analysis is the most common method used for analyzing the welfare effects of agricultural research in a partial-equilibrium framework.

[11] It is a partial-equilibrium model because it focuses on part of the economy and treats most other economic variables as being constant (exogenous) in the analysis. It is a comparative-static model in that two static (single period) equilibrium situations –with and without the technology- are compared. The dynamic issue of the process of reaching the new equilibrium is not considered. A closed economy refers to a situation where the commodity under study is not traded internationally and its price is determined inside the country (Alston et al, 1998, p.28).

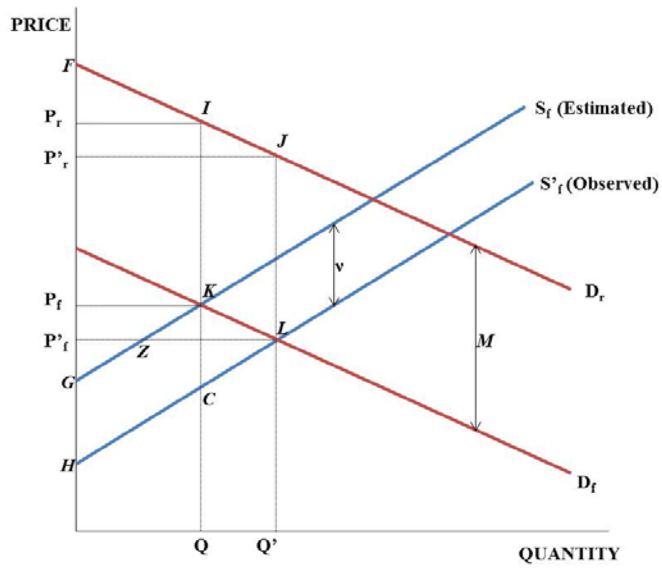

Figure 4. Demand and Supply of Milk with Technological Change.
Source: Adapted from Freebairn, Davis & Edwards, 1982, p. 40).

The shift of the supply curve[12] (from S_f to S'_f) indicates the technological change from the cost reduction by using the sorghum cultivars. New quantity (*Q'*) and prices (P'_f and P'_r) result from the interaction of the supply and the demand curves. The change in consumer welfare (surplus) due to the supply shift is represented by the area $P_rIJP'_r$ and the change in producer welfare (surplus) is represented by the area $HGZL - P'_fP_fKZ$. These terms give an aggregate social gain of area *HGKL.*[13]

Our analysis estimates the national benefits from this sorghum research.[14] Moreover, we estimate the distribution of benefits among groups, farmers and consumers. Consumers gain because they consume more milk at a lower price. In general, the net welfare effect on producers may be positive or negative depending on the supply and demand elasticities[15] and the nature of

[12] Supply represents producers' production costs and demand represents consumers' consumption values.
[13] This area can also be interpreted as the sum of the cost savings on the original quantity (area HGKC) plus the economic surplus due to the increment to production and consumption (the triangular area KLC).
[14] Research benefits refer to net annual private benefits (benefits to consumers and producers).Then we will take into account the public sector costs. The difference is the benefit to the society.
[15] The more elastic supply is relative to demand, the greater the consumers' share of total research benefits and vice versa. A perfectly elastic supply causes all the benefits to go to consumers and a perfectly elastic demand results in

the supply shift[16]. The national or total cost savings takes the farm level savings and adjusts it by the extent of the diffusion of this technology.

Calculation of Benefits for Consumers, Producers and Gross Benefits to the Society

This research conducts an ex-post study of technologies that have already been adopted and consequently the observed level of production is *Q'*. Based on this, mathematically:

The gain for consumers is (See Figure 5):

$$G_c(f) = P_r IJP'_r = \text{rectangle } P_r TJP'_r - \text{triangle } ITJ = (P_r - P'_r)Q' - \frac{1}{2}(P_r - P'_r)(Q' - Q)$$

$$G_c(f) = \frac{1}{2}(Q + Q')(P_r - P'_r)$$

The gain for producers is (See Figure 5):

$$G_p(f) = HGZL - P'_f P_f KZ = \text{ parallelogram HGXL} - \text{rectangle } P'_f P_f YL - \text{triangle } KXL + \text{triangle } KYL$$

$$G_p(f) = vQ' - (P_f - P'_f)Q' - \frac{1}{2}v(Q' - Q) + \frac{1}{2}(Q' - Q)(P_f - P'_f)$$

$$G_p(f) = \frac{1}{2}(Q + Q')[v - (P_f - P'_f)]$$

The aggregate gain for the society is (See Figure 5):

$$G_s(f) = G_c(f) + G_p(f) = HGKL = \text{parallelogram HGXL} - \text{triangle } KXL$$

$$G_s(f) = vQ' - \frac{1}{2}v(Q' - Q)$$

$$G_s(f) = \frac{1}{2}v(Q + Q')$$

all the benefits going to producers. When the elasticities are equal, the benefits are shared equally between producers and consumers.

[16] For this study supply and demand curves are assumed to be linear and to shift in parallel as a result of a technological change. Elsewhere we systematically evaluate the changes from different elasticities and utilize constant elasticities rather than constant slopes as in the above analysis (see Villacis, 2012).

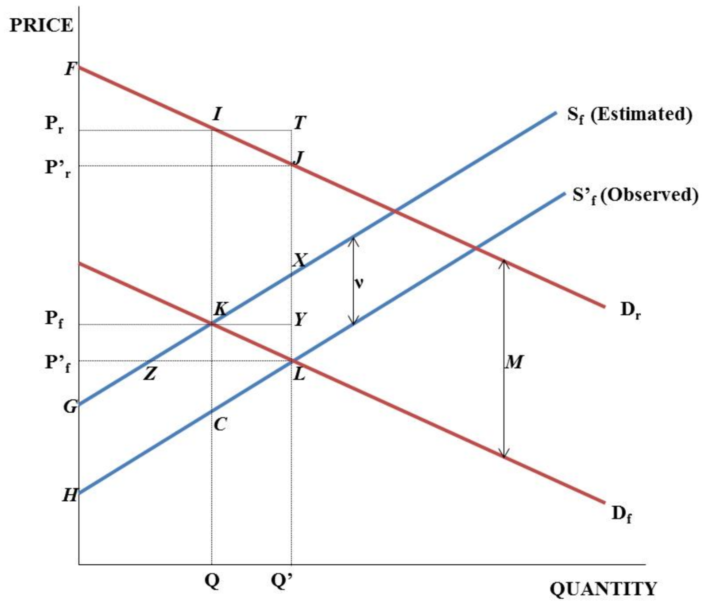

Figure 5. Demand and Supply of Milk with Technological Change when observed level of production is *Q'*.
Source: Adapted from Freebairn, Davis & Edwards, 1982, p. 40).

Defining the milk consumer demand as $Q_r = a - \alpha P_r$ and farm milk supply as $Q_f = b + \beta P_f$ we can calculate the benefits for consumers, producers and the society (Freebairn et al, 1982, p. 40), where α is the slope of the demand function and β is the slope of the supply function. To obtain these slope values we use elasticity estimates from other studies on the demand and supply of milk consumers and producers respectively. lasticities are defined as the percentage change in quantities consumed (demand) and produced (supply) in response to a one percent change in prices (consumer and producers), where the elasticity of supply is $\varepsilon = \beta P_f / Q$ and the elasticity of demand is $\eta = \alpha P_r / Q$. Values for elasticities used in this study were 0.2 and 0.1 respectively (FAPRI, 2011, sec. tools elasticities database).

The change in quantity resulting from the research ($\Delta Q = Q' - Q$) depends on the shift in the supply curve and the responsiveness of supply and demand. Recalling that the retail price equals the farm price plus the margin ($P_r = P_f + M$) the equilibrium situation without research would be that price and quantity, which satisfy both demand and supply:

$$Q_r = Q_f = Q$$
$$a - \alpha P_r = b + \beta P_f$$
$$a - \alpha\left(P_f + M\right) = b + \beta P_f$$
$$P_f = \frac{a - b - \alpha M}{\alpha + \beta}$$

And therefore:

$$P_r = \frac{a - b - \alpha M}{\alpha + \beta} + M$$

With research, the equilibrium now is on a new supply curve, where *v* is the shift down of supply caused by the effect of a reduction in farm production costs per unit of milk output resulting from the technological change:[17]

$$Q'_r = a - \alpha P'_r$$
$$Q'_f = b + \beta\left(P'_f + v\right)$$

Recalling again that $P'_r = P'_f + M$ the equilibrium situation with research would be:

$$Q'_r = Q'_f = Q'$$
$$a - \alpha P'_r = b + \beta\left(P'_f + v\right)$$
$$a - \alpha\left(P'_f + M\right) = b + \beta\left(P'_f + v\right)$$
$$P'_f = \frac{a - b - \alpha M - \beta v}{\alpha + \beta}$$

And therefore:

$$P'_r = \frac{a - b - \alpha M - \beta v}{\alpha + \beta} + M$$

The resulting change in producers' price is:

$$\Delta P_f = P_f - P'_f$$
$$\Delta P_f = \frac{\beta v}{\alpha + \beta}$$

[17] For this study the unit output we use is the metric ton which is equal to 1000 liters.

The resulting change in consumers' price is:

$$\Delta P_r = P_r - P'_r$$
$$\Delta P_r = \frac{\beta v}{\alpha + \beta}$$

And therefore the change in quantity is:

$$\Delta Q = Q' - Q = Q'_f - Q_f = Q'_r - Q_r$$
$$\Delta Q = \beta v - \frac{\beta^2 v}{\alpha + \beta}$$

After some algebra the gains for consumers can be expressed as:

$$G_c(f) = \frac{1}{2}(Q + Q')(P_r - P'_r) = \left(Q' - \frac{1}{2}\Delta Q\right)(\Delta P_r) = \left[Q' - \frac{1}{2}\left(\beta v - \frac{\beta^2 v}{\alpha + \beta}\right)\right]\left(\frac{\beta v}{\alpha + \beta}\right)$$
$$G_c(f) = \frac{Q' \beta v}{\alpha + \beta} - \frac{\alpha \beta^2 v^2}{2(\alpha + \beta)^2}$$

The gains for producers can be expressed as:

$$G_p(f) = \frac{1}{2}(Q + Q')\left[v - (P_f - P'_f)\right] = \left(Q' - \frac{1}{2}\Delta Q\right)(v - \Delta P_f) = \left[Q' - \frac{1}{2}\left(\beta v - \frac{\beta^2 v}{\alpha + \beta}\right)\right]\left(v - \frac{\beta v}{\alpha + \beta}\right)$$
$$G_p(f) = \frac{Q' \alpha v}{\alpha + \beta} - \frac{\alpha^2 \beta v^2}{2(\alpha + \beta)^2}$$

And the aggregate gains for the society can be expressed as:

$$G_s(f) = \frac{1}{2} v(Q + Q') = Q' v - \frac{1}{2} v \Delta Q = Q' v - \frac{1}{2} v\left(\beta v - \frac{\beta^2 v}{\alpha + \beta}\right)$$
$$G_s(f) = Q' v - \frac{\alpha \beta v^2}{2(\alpha + \beta)}$$

Quantitative Estimation of Economic Surplus

Yearly data from 1993 to 2010 were obtained from The General Directorate of Statistics and Census of the Ministry of Economy, CENTA, and The General Directorate of Agricultural

Economics (DGEA) of the Ministry of Agriculture and Livestock, on milk producer prices, milk retailer prices, the consumer price index,[18] quantities of milk produced, distribution of milk produced by farm size, and distribution of milk consumed by type of consumer, in order to calculate the benefits.

Beginning with the calculations of the national area planted with the new technologies of sorghum by each size of dairy farm (small, medium and large), and taking into account average areas of sorghum planted and milk yields, national quantities of milk produced with sorghum technologies were calculated for each size of farm. Then the effect of a reduction in production costs "ν" in each farm size was calculated (see A- 2- 4) as follows using the cost reductions of the different farm sizes with and without the technology:

- ν (Small Farmers) = (Cost reduction difference of small farms with and without the technology) x (Milk produced by small farmers using sorghum technologies) / (National Total Milk Production)

Afterwards an aggregate "ν" was calculated by adding up the "ν"s of each farm size group. Given total milk produced by farmers is distributed 58% to processors, 6% to self-consumption and 36% to final consumers (Ministry of Economy, 2007, p. 1), we adjusted the consumers' prices. Only for the processed milk were the official consumer price data used. For own production use the producers' price is the relevant price. For direct sale without processing we used the producers' price and added another 10% for transportation costs.

- Weighted Consumers' Price = (Retail Price X 0.58) + (Producer Price X 0.06) + (1.1 X Producer Price X 0.36)

Making the calculations for benefits we have (See Figure 6):

[18] All the prices were adjusted to 2010 prices using the Consumer Price Index (CPI) published by the Salvadorian Ministry of Economy.

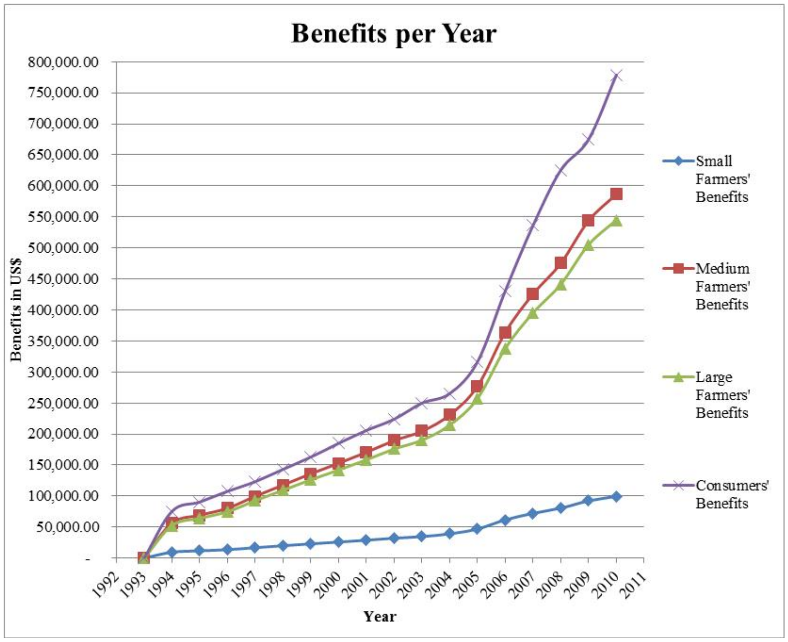

Figure 6. Private benefits per year for consumers and producers.
Source: Villacís, 2011.

The distribution per year of the gross benefits (private net benefits to consumers and producers) to society from this research is illustrated below reaching over 14 million dollars in 2010 (Figure 7). Note that we could have projected these benefits out another ten years because the pace of technology introduction was accelerating with the introduction of SS-44. So this is a conservative total estimate of benefits.

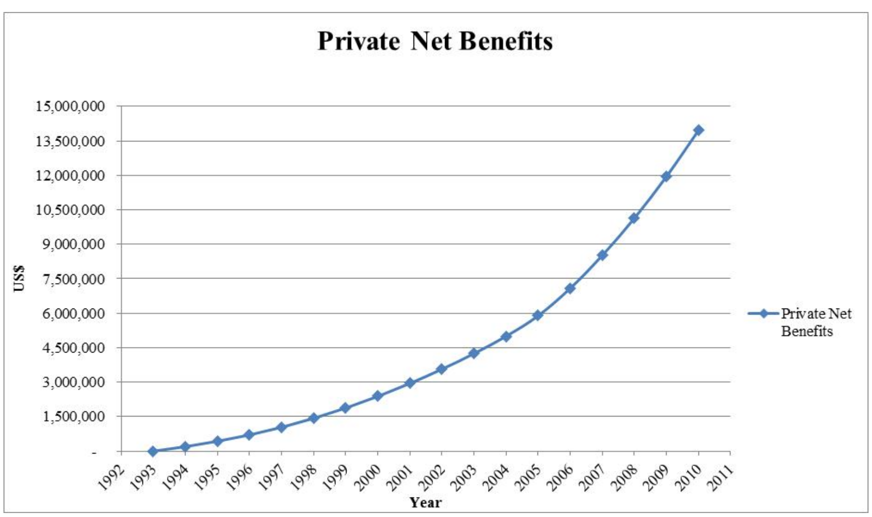

Figure 7. Cumulative Private Benefits to the society from the New Technology.
Source: Villacís, 2011.

Costs of Research and Extension

Data on the annual costs of research activities on sorghum incurred by CENTA, which included generation, evaluation and land and office rentals, were obtained for the period 1993-2010.[19] This information together with further discussions with specialists, senior scientists and administrators of CENTA led to the research cost estimates (A- 5).

Extension, transfer activities and associated expenses from 1993 until 2010 were estimated with the guidance of a senior extension officer from CENTA. Additionally, as mentioned earlier, there was extension service from the Israeli Cooperation over the period: 1993-2004 (A- 6).

Figure 8 summarizes the estimated research and extension service costs incurred on the improvement and diffusion of the sorghum varieties under study since 1993 (See also Appendix 7). Data on research costs in terms of total resource investment (equipment and personnel) and operating expenditures are included.

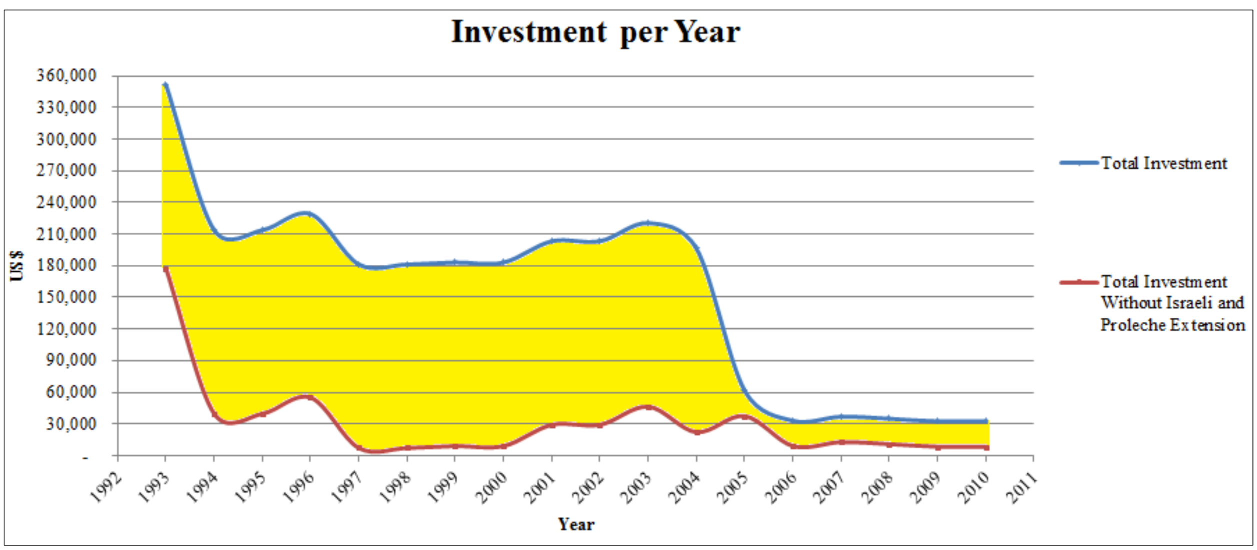

Figure 8. Annual Research Investment with and without Extension Costs for PROLECHE and the Israeli government.
Source: Villacís, 2011.

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[19] The high cost of generation and evaluation of variety CENTA-S2 in the year 1993 is the cumulative cost incurred from 1976 until 1992, years in which the variety was developed and introduced in the country (Clara, 2011).

The importance of the USAID investment in extension through supporting PROLECHE and of the Israeli investments in training and developing the technologies is clear from the above figure. These are treated as public costs to the government of El Salvador as they were an important component of extension that the government would have had to pay in the absence of the foreign assistance.

Net Benefits to the Society

In figure 9 we have the Net Benefits to Society after deducting the costs to the public sector discussed in the previous section (A-8).

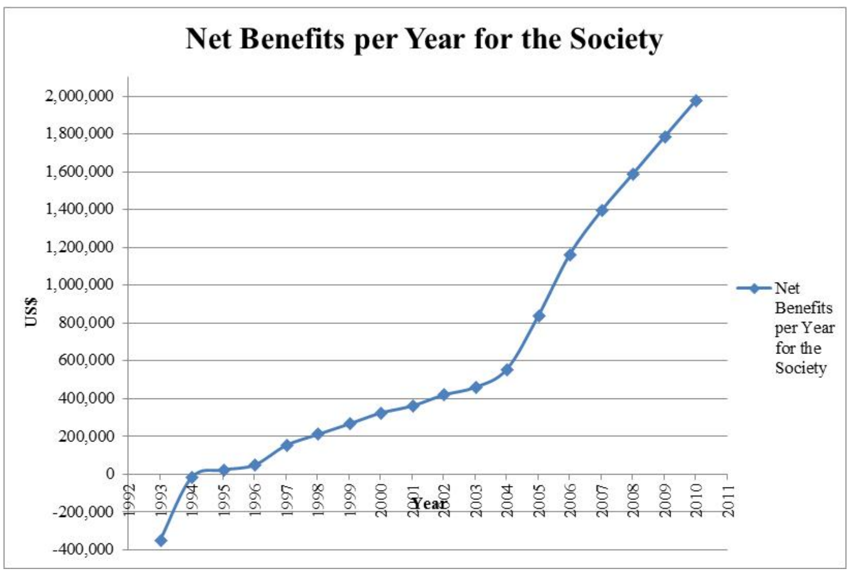

Figure 9. Net Public Benefits to the Country from the Investments in the Insensitive Sorghums
Source: Villacís, 2011.

Consumers' benefits from the lower prices of milk were over 5 million dollars during the period, 1993-2010. Producers' benefits from the lower costs of production hence increased profits were 8.8 million dollars. Large producers received almost \$3.9 million and medium sized producers earned another 4.2 million dollars. Note that consumers' gains were larger than the gains to large producers even with the technology focus on the large producers (see Table 4).

Table 4. Net Benefits for Consumers, Producers and Society

	Benefit (US$)
Consumer's Surplus	$ 5,195,411
Producer's Surplus	
Small Farmers	$ 709,330
Medium Farmers	$ 4,180,398
Large Farmers	$ 3,883,500
Total	$ 8,773,229
Gross Benefit to Society	$ 13,968,640
Total Research Cost	$ 2,790,917
Net Benefits to Society	$ 11,177,722
IRR	37%

Source: Villacís, 2011

The internal rate of return of 37% is a good return on the public investment. Average returns on investments in El Salvador are expected to be between 10 to 20% in real terms (net of inflation). So this was a better than average investment of public resources.

We assumed that there was perfect competition in the dairy sector. To evaluate market power of the processors we estimated the margins of consumer prices to producers' prices over time. Increasing margins can indicate higher market power, hence the lack of perfect competition. Margins decrease from 1993 to 2005, apparently indicating improvements in transportation and communication after the end of the civil war as El Salvador rebuilt (Figure 10). Then from 2006 to 2010 these margins increase so it is important in the future to study the market power of the processors. However, with the multiple production uses of milk there are many firms so the increased margins may reflect changes in consumption towards different qualitative uses of milk (shifts to ice cream, butter, cheese, different grades of milk) rather than increasing market power of the processors.

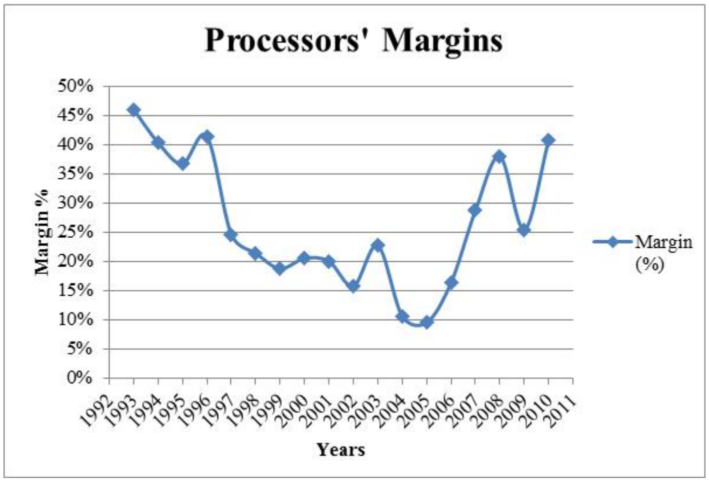

Figure 10. Processors Margins in the Dairy Industry of El Salvador.
Source: Villacís, 2011.

CONCLUSIONS

These are good returns on the research investment at 37%. The returns to producers are higher than those for consumers but the returns for consumers are greater than those for large producers. So from both an economic efficiency perspective and for the income distributional results of benefitting consumers more than large producers these public sector expenditures were very beneficial to El Salvador.

In the effort to design technology for small producers the public sector often forgets that the principal beneficiaries of agricultural technologies for domestic consumption are consumers. Hence for rapid growth sectors with changes in consumers habits such as the demands for milk, milk products, broilers, fruits and vegetables, there probably needs to be a focus on large (and medium) producers, who can rapidly adapt and expand production with new technologies so that relative prices do not increase as fast.

We understate benefits here by not including the value of the grains for the dual purpose case when the grain is sold and the rest used for forage. This would be especially the case for earlier years in the ‘90s and for the small farmers. Note that including these grain sales would shift our results in Figure 6 giving larger benefits to small farmers. Also this same technology is expected to continue generating benefits for another decade and the projected future benefits could also have been included in this analysis.

Questions and Answers from the Conference at San Salvador, El Salvador.

Q: Do you think the number of sample interviews is representative from the universe of the total agricultural zones in El Salvador?

A: We interviewed 30 farmers from the western zone, 57 from the central zone, 43 from the para-central zone and 45 from the eastern zone. These numbers represent proportionally the number of dairy farms per zone from lists of PROLECHE and CENTA and are not 100% representative of the distribution of total dairy farms per zone published in the 2007 yearbook of agricultural statistics by the Ministry of Agriculture and Livestock (MAG). Therefore, there is a bias given the majority of farmers interviewed were contacted through these lists. We tried to interview farmers outside of these lists but they were not willing to share specific information especially production costs, which made it difficult to us to include them in the study.

Q: How did you estimate the national sorghum production starting from a limited number of interviews?

A: We did not estimate the total national sorghum production. That is available from the national statistics. For this research we had to estimate the area in the new technologies. We estimated the areas planted only with the new sorghum technologies namely CENTA S-2, CENTA S-3, CENTA RCV and CENTA SS-44.These areas were calculated through discussions with the help and assistance of national sorghum breeders and specialists and then compared with data on certified seed production reported to CENTA by the seed producers Procela, Villavar and Uprex.

Q: Can you repeat what are the differences between private benefits and consumers' benefits?
A: Private benefits are the gains the society receives without taking in account research and extension costs and they include both the benefits to consumers and producers. Consumers' benefits refer only to the gains consumers receive due to the introduction of these cost savings technologies. They do not include the public research or extension costs. When we subtract research and extension costs from the total private benefits for consumers and producers, we get the net social gains.

Q: How does a monopoly in the milk processors industry affect the economy?
A: If it is not regulated by the government, the lack of perfect competition allows the monopoly to be a price maker and so the price of milk would be higher than in the pure competition case. The monopoly or oligopoly can impose barriers to entry and make it difficult for other competitors to enter the milk processing industry. The lack of competition would mean then that some of the benefits to producers (monopsony) and to consumers (monopoly) would be captured by the processors. Since market concentration could be in both the buying and selling and this would be oligopoly and oligopsony, market power is definitely worth studying. However, the multiple uses of milk and multiple number of firms imply that this is probably not a problem at the present time.
Q: Why does Soberano variety not appear on the study?

A: We used a two-stage stratified sampling technique to select farmers to be interviewed. In the first stage we found out that Soberano variety was not widely used as feed for the cattle but mainly for grain production in El Salvador. We still included Soberano in the questionnaire for the second stage. Of the 180 interviews only 5 dairy farmers used it but in a small proportion of their area planted with sorghum given they also planted the other varieties.

Q: For this study did you take in account the investment costs in machinery for the production of silage?

A: Yes. In the calculation of feed costs we included them as rental values. We included rental costs for transportation, the cutting machine and the use of tractors to compact the silage, all of them already included the cost of fuel. We estimated these costs for the production of one metric ton of silage and so forth. We did not include infrastructure costs.

Q: What was the total cost of the PROLECHE program? Why did it get cancelled?

A: We estimated a cost of $150,000 per year for the Israeli extension service from 1993 until 2004, which was the year it ended. Additionally we charged $24,000 per year from 1993 until 2010 as the salaries of the five extension agent collaborators. This adds up a total cost of $2,232,000 of the program from 1993 until 2010, which represents the 80% of the total costs incurred in research, transfer and extension taken in account by this study, hence its importance and impact in the dairy industry and economy of El Salvador.

On PROLECHE. We discussed the issue of the distribution of benefits of the technology in the paper. The public sector may have focused on the large benefits for large farmers. We think that they might relook at the gains to consumers. Gains to consumers tend to be small individual price savings, a few cents on the reduced costs of milk but when aggregated over the country, these are large gains

Q: What type of strategies can be implemented in order for the small farmers to improve their benefits?

A: One of the barriers of the adoption of these technologies by the small farmers is the cost of the seeds mainly due to small farmers buying them at intermediaries' stores who charge higher prices. If they can form cooperatives or associations, they could buy the seeds directly from seed producers at lower prices. Additionally on small farmers there is often a preference for dual purpose varieties with a sacrifice of feed quality.

Dairy processors prefer to buy milk in larger quantities than they can get from small farmers and to give more favorable prices to better quality milk, hence once again the importance of cooperatives or associations where the small farmers can place their milk into cooling tanks of stainless steel in order to maintain the quality of the product and thus reducing contamination while at the same time gaining market power for selling the milk in larger quantities.

Furthermore economies of scale in both dairy production and in silage production play an important role as well as access to information of new technologies.restoring a comparative advantage to small farmers would probably require beter farmers' associations and a large extension input.

Q: Were costs of concentrate feed included in the analysis?

A: Yes. Also costs of pastures, silage and hay were included. All these costs were calculated on a daily basis per cow in dollars per pound units. Additionally the feed costs were differentiated between the rainy season and the dry season since the use of concentrates has a considerable variation throughout the year.

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APPENDIX TABLES

A- 1. Distribution of Farmers Interviewed

Departments	Sorghum technology interviews	Other technology interviews
Ahuachapán	3	1
Cabañas	8	3
Chalatenango	12	5
Cuscatlán	3	3
La Libertad	7	4
La Paz	4	2
La Unión	5	2
Morazán	6	3
San Miguel	12	3
San Salvador	13	10
San Vicente	21	5
Santa Ana	5	4
Sonsonate	11	6
Usulután	10	4
Total	120	55

Source: Villacís, 2011, survey data

A- 2. Parameter ν for small farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by small farmers (Ha)	Number of small Farms using New Tech	Milk Produced under New Tech by small farms (mT)	Total Milk Produced by small farms	Total National Milk Production	ν (small Farmers)
1993	-	-	-	-	48,795	325,300	-
1994	1,969	394	165	3,974	47,880	319,200	0.05
1995	2,386	477	200	4,817	42,300	282,000	0.07
1996	2,804	561	234	5,660	47,618	317,451	0.07
1997	3,371	674	282	6,804	53,460	356,400	0.08
1998	3,957	791	331	7,986	49,721	331,470	0.10
1999	4,542	908	380	9,168	52,409	349,390	0.10
2000	5,128	1,026	429	10,350	57,016	380,106	0.11
2001	5,713	1,143	478	11,532	57,520	383,467	0.12
2002	6,299	1,260	527	12,714	59,892	399,280	0.13
2003	6,885	1,377	576	13,896	58,826	392,170	0.14
2004	7,597	1,519	635	15,335	59,729	398,191	0.15
2005	9,095	1,819	761	18,358	67,313	448,752	0.16
2006	12,106	2,421	1,012	24,435	65,312	435,413	0.22
2007	14,487	2,897	1,211	29,241	71,379	475,862	0.24
2008	16,448	3,290	1,375	33,199	74,111	494,071	0.27
2009	18,409	3,682	1,539	37,157	81,242	541,614	0.27
2010	20,370	4,074	1,703	41,115	81,242	541,614	0.30

Source: Villacís, 2011

A- 3. Parameter ν for medium farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by medium farmers (Ha)	Number of medium Farms using New Tech	Milk Produced under New Tech by medium farms (mT)	Total Milk Produced by medium farms	Total National Milk Production	ν (medium Farmers)
1993	-	-	-	-	146,385	325,300	-
1994	1,969	984	119	15,957	143,640	319,200	0.29
1995	2,386	1,193	144	19,341	126,900	282,000	0.40
1996	2,804	1,402	169	22,726	142,853	317,451	0.42
1997	3,371	1,685	203	27,321	160,380	356,400	0.44
1998	3,957	1,978	238	32,068	149,162	331,470	0.56
1999	4,542	2,271	274	36,814	157,226	349,390	0.61
2000	5,128	2,564	309	41,560	171,048	380,106	0.63
2001	5,713	2,857	344	46,307	172,560	383,467	0.70
2002	6,299	3,149	379	51,053	179,676	399,280	0.74
2003	6,885	3,442	415	55,799	176,477	392,170	0.83
2004	7,597	3,799	457	61,577	179,186	398,191	0.90
2005	9,095	4,548	548	73,716	201,938	448,752	0.95
2006	12,106	6,053	729	98,120	195,936	435,413	1.31
2007	14,487	7,244	872	117,418	214,138	475,862	1.43
2008	16,448	8,224	990	133,311	222,332	494,071	1.57
2009	18,409	9,205	1,108	149,204	243,726	541,614	1.60
2010	20,370	10,185	1,227	165,098	243,726	541,614	1.77

Source: Villacís, 2011

A- 4. Parameter ν for large farmers

Year	Total Area Planted under New Tech (Ha)	Area Planted under New Tech by large farmers (Ha)	Number of large Farms using New Tech	Milk Produced under New Tech by large farms (mT)	Total Milk Produced by large farms	Total National Milk Production	ν (large Farmers)
1993	-	-	-	-	130,120	325,300	-
1994	1,969	591	38	14,891	127,680	319,200	0.27
1995	2,386	716	46	18,050	112,800	282,000	0.37
1996	2,804	841	55	21,209	126,980	317,451	0.39
1997	3,371	1,011	66	25,497	142,560	356,400	0.41
1998	3,957	1,187	77	29,927	132,588	331,470	0.52
1999	4,542	1,363	88	34,356	139,756	349,390	0.57
2000	5,128	1,538	100	38,786	152,042	380,106	0.59
2001	5,713	1,714	111	43,215	153,387	383,467	0.65
2002	6,299	1,890	123	47,644	159,712	399,280	0.69
2003	6,885	2,065	134	52,074	156,868	392,170	0.77
2004	7,597	2,279	148	57,466	159,276	398,191	0.83
2005	9,095	2,729	177	68,795	179,501	448,752	0.89
2006	12,106	3,632	236	91,569	174,165	435,413	1.21
2007	14,487	4,346	282	109,578	190,345	475,862	1.33
2008	16,448	4,934	320	124,410	197,628	494,071	1.45
2009	18,409	5,523	359	139,243	216,646	541,614	1.48
2010	20,370	6,111	397	154,075	216,646	541,614	1.64

Source: Villacís, 2011

A- 5. Research Cost Estimates Based on 2010 Prices (US$)

Year	Generation and Evaluation				Land Rental				Office	Total
	S-2	RCV	S-3	SS-44	S-2	RCV	S-3	SS-44	Rental	Cost
1993	110,700	27,675	-	-	11,852	2,963	-	-	7,200	160,391
1994	1,500	27,675	-	-	375	2,963	-	-	7,200	39,713
1995	1,500	27,675	-	-	375	2,963	-	-	7,200	39,713
1996	-	27,675	-	-	-	2,963	-	-	7,200	37,838
1997	-	-	-	-	-	-	-	-	7,200	7,200
1998	-	-	-	-	-	-	-	-	7,200	7,200
1999	1,500	-	-	-	375	-	-	-	7,200	9,075
2000	1,500	-	-	-	375	-	-	-	7,200	9,075
2001	-	1,500	6,667	12,120	-	375	357	1,000	7,200	29,218
2002	-	1,500	6,667	12,120	-	375	357	1,000	7,200	29,218
2003	1,500	-	6,667	12,120	375	-	357	1,000	7,200	29,218
2004	1,500	-	-	12,120	375	-	-	1,000	7,200	22,194
2005	-	-	-	12,120	-	-	-	1,000	7,200	20,320
2006	-	1,500	-	-	-	375	-	-	7,200	9,075
2007	1,500	1,500	1,500	-	375	375	375	-	7,200	12,825
2008	1,500	-	1,500		375		375	-	7,200	10,950
2009	-	-	-	1,000	-	-	-	268	7,200	8,468
2010	-	-	-	1,000	-	-	-	268	7,200	8,468

Source: Author's computation based on information provided by Clara, 2011

A- 6. Extension and Transfer Cost Estimates Based on 2010 Prices (US$)

Year	Cost of Transfer				Israeli	Proleche	Total
	S-2	RCV	S-3	SS-44	Extension	Extension	Cost
1993	17,190	-	-	-	150,000	24,000	191,190
1994	-	-	-	-	150,000	24,000	174,000
1995	-	-	-	-	150,000	24,000	174,000
1996	-	17,190	-	-	150,000	24,000	191,190
1997	-	-	-	-	150,000	24,000	174,000
1998	-	-	-	-	150,000	24,000	174,000
1999	-	-	-	-	150,000	24,000	174,000
2000	-	-	-	-	150,000	24,000	174,000
2001	-	-	-	-	150,000	24,000	174,000
2002	-	-	-	-	150,000	24,000	174,000
2003	-	-	17,190	-	150,000	24,000	191,190
2004	-	-	-	-	150,000	24,000	174,000
2005	-	-	-	17,190	-	24,000	41,190
2006	-	-	-	-	-	24,000	24,000
2007	-	-	-	-	-	24,000	24,000
2008	-	-	-	-	-	24,000	24,000
2009	-	-	-	-	-	24,000	24,000
2010	-	-	-	-	-	24,000	24,000

Source: Author’s computation based on information provided by CENTA, 2011

A-7. Total Research and Extension Cost Estimates Based on 2010 Prices (US$)

Year	Total Research Cost	Total Extension and Transfer Cost	Total Investment
1993	160,391	191,190	351,581
1994	39,713	174,000	213,713
1995	39,713	174,000	213,713
1996	37,838	191,190	229,028
1997	7,200	174,000	181,200
1998	7,200	174,000	181,200
1999	9,075	174,000	183,075
2000	9,075	174,000	183,075
2001	29,218	174,000	203,218
2002	29,218	174,000	203,218
2003	29,218	191,190	220,408
2004	22,194	174,000	196,194
2005	20,320	41,190	61,510
2006	9,075	24,000	33,075
2007	12,825	24,000	36,825
2008	10,950	24,000	34,950
2009	8,468	24,000	32,468
2010	8,468	24,000	32,468
Total	490,157	2,300,760	2,790,917

Source: Author’s computation, 2011

A-8. Net Benefits Per Year to the Society			
Year	Privet Net Benefits	Total Research Costs	Net Benefits to the Society
1993	-	351,581	(351,581)
1994	194,276	213,713	(19,436)
1995	235,484	213,713	21,772
1996	276,694	229,028	47,665
1997	332,639	181,200	151,439
1998	390,423	181,200	209,223
1999	448,208	183,075	265,133
2000	505,994	183,075	322,919
2001	563,777	203,218	360,559
2002	621,561	203,218	418,343
2003	679,340	220,408	458,932
2004	749,680	196,194	553,485
2005	897,461	61,510	835,952
2006	1,194,518	33,075	1,161,443
2007	1,429,438	36,825	1,392,613
2008	1,622,910	34,950	1,587,961
2009	1,816,401	32,468	1,783,933
2010	2,009,836	32,468	1,977,368
Total	13,968,640	2,790,917	11,177,722

Source: Villacis, 2011