Improving Land Use by Slope Farmers in the Andes: An Economic Assessment of Small-Scale Sprinkler Irrigation for Milk Production

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Improving Land Use by Slope Farmers in the Andes:

An Economic Assessment of Small-Scale Sprinkler Irrigation for Milk Production

Milk production is an important source of secure and regular income, especially in mountain areas. However, slope farmers in the Andes commonly face difficulties in shifting to milk production, given the limited access to land and water for fodder production. The implementation of sprinkler irrigation to expand the cultivation of permanent fodder crops, reduce soil erosion, and enhance soil productivity would represent a promising step forward. This study stresses the feasibility for small-scale farmers of shifting to sprinkler irrigation. It draws on farm household data and analysis of 10 family-based sprinkler irrigation projects in northern Peru. A farm-optimization model and a farm investment model were applied to assess expected changes in production and profitability and the development of farmers' savings and liquidity over a 10-year period. Independent of the water efficiency gain, results show that smallholders face a strong cash flow (liquidity) problem when shifting to sprinkler irrigation. To make this investment feasible for farmers, longer repayment periods (of several years) should be implemented and interest rates kept low. Close collaboration between nongovernmental organizations (NGOs) and regional milk buyers would best guarantee credit because farmers' repayments could simply be deducted from regular milk bills. Given their own interest in increasing local milk supply, these milk buyers are also good NGO partners in implementation of effective extension to improve fodder and herd management, in order to maximize the payoff of the sprinkler investment.

Keywords: *Irrigation; credit; milk production; small-scale farming; Peru; Andes.*

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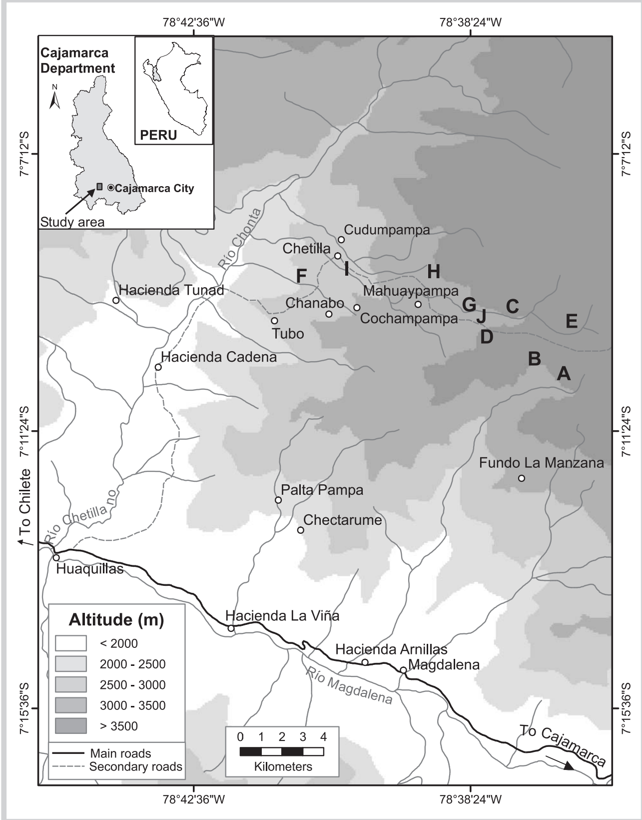


FIGURE 1 Location of the study area and the sprinkler projects analyzed, Chetilla District, Cajamarca Department, northern Peru.

Introduction

Since the arrival of the Spaniards in South America in the 16th century, livestock has played an important role in Andean agriculture. Cattle and sheep have adapted to the heterogeneous climatic conditions across the Andes, providing work (animal traction), meat, wool, dung, fuel, and security. Since the early 20th century, milk production has been an important activity for small-scale farmers in the Andean highlands, fostered by dairy cattle imports, mainly from Europe.

The current increase in domestic demand for dairy products in Andean countries promises an interesting future for small-scale milk producers in the highlands. Milk processors tend to augment their milk collection in rural areas by expanding their collection routes or paying higher milk prices to farmers. Milk production offers clear advantages over crop production for small-scale farmers in highland areas because it leads to more regular income (Bernet and Tapia 1999) and security (Ørskov 1993), causes less erosion on slopes when permanent fodder crops are grown (Stocking 1988; Winpenny and Willis 1995), and enhances the status of women in farm households as the primary caretakers of livestock (Franqueville and Vargas 1990).

However, market access and the regular availability of cheap fodder are preconditions for highland farmers to successfully shift from crop to milk production (Mosley 1982; Seifert 1990; Malpartida et al 1994). The strong seasonality of precipitation in the Andean highlands implies that milk production depends either on access to vast natural pastures or on irrigation for growing permanent fodder crops. Thus, most farmers on slope areas who have limited access to land and irrigation face constraints in shifting to milk production.

Because of the considerable benefits of milk production for farmers and society, this study assesses how slope farmers facing constraints on water could shift to milk production by taking advantage of the more efficient water use offered by sprinkler irrigation systems to expand permanent fodder crops. Using data from 10 family-based sprinkler irrigation projects implemented in Cajamarca, a milkshed in northern Peru, cost-effective practices for implementing small-scale irrigation systems in slope areas were analyzed. Although the use of a static household model and a dynamic investment model relates to site-specific data in the study region, the results are of wide interest, given the generally deficient and inadequate promotion and implementation of credit programs for sprinkler irrigation in developing countries (Linden 1995).

Irrigation and milk production in the study region

Most milk in the Andean highlands is produced at the bottoms of valleys, where access to irrigation is best, and at higher altitudes, where dairy cattle graze on vast natural pastures. In slope areas, permanent fodder is scarce because of the pronounced dry season between May and September and limited access to irrigation. Hence, agricultural production dominates on slopes, despite the higher rates of erosion, whereas crop residues and fallow land are the main sources of feed, primarily for sheep (Bernet and Tapia 1999).

Where there is access to water, gravity irrigation is most common. Sprinkler irrigation is still rare and is only used, with very few exceptions, when public extension offices or local nongovernmental organizations (NGOs) provide the necessary technical and financial support to farmers. In general, though, these interventions are very selective and involve high costs and subsidies.

Data used in this study came from 10 family-based sprinkler projects implemented by the technical staff of CEDEPAS, a local NGO in the Chetilla District, Cajamarca Department, northern Peru (Figure 1; Table 1). The objective of the sprinkler projects was to improve long-term production and income for slope farmers.

TABLE 1 Data collected from 10 family-based sprinkler systems in Chetilla District, Cajamarca Department, northern Peru.

Type of data	Variables	Executed sprinkler projects									
		A	B	C	D	E	F	G	H	I	J
General	No of beneficiaries (families)	1	4	1	1	3	1	1	1	3	4
	Altitude (m)	3600	3600	3500	3500	3500	2000	3400	3200	2700	2800
	Slope inclination (%)	5–10	15–20	10–20	10–25	20–25	10–30	20–25	20–30	0–15	10–30
	Approximate farm size (ha)	4	3.5	5	2	2	3	3	3	3	6
	Off-farm income	No	No	No	No	No	Yes[a]	No	No	Yes[a]	Yes[a]
	Induced investments	Yes[b]	Yes[b]	Yes[b]	No	Yes[c]	No	Yes[c]	Yes[a]	Yes[b]	Yes[b,c]
Technical	Water flow in dry season (L/s)	0.018	0.08	0.5	0.2	0.08	2.5	0.2	0.2	0.3	1.5
	Area previously irrigated by gravity (ha)	0.01	0	0.25	0.25	0.1	0.5	0.2	1	0.25	1
	Area now irrigated by sprinklers (ha)	0.2	0.25	0.5	0.5	0.7	1.5	1.5	2	2	3
	No of sprinklers used	1	2	2	2	2	2	2	2	2	2
	Radius of wet area (m)	6	5	8	15	13	16	12	8	10	14
	Surface of wet area (m^2)	113	79	201	707	531	804	452	201	314	616
Costs	Project planning costs (US$)	143	143	286	143	143	143	143	286	286	286
	Installation costs (US$)	715	763	551	766	474	513	587	571	1195	1078
	Annual maintenance costs (US$)	14	6	10	14	14	14	14	10	10	29
Credit	Credit payback period (mo)	6	6	6	6	6	8	6	6	12	6
	Credit payback problems	(New)	(New)	No	No	No	Yes	No	No	Yes	No
	Subsidies (%)	59	58	66	77	64	62	57	64	58	59

[a]Contract for road maintenance.
[b]Expansion of sprinkler system.
[c]Purchase of dairy cattle.

The production context of slope farming

Farmers in the study region are relatively poor. Families are rather large, but farms are small (80% are less than 5 hectares in extent). Agriculture is by far the most important source of income. Some farm households earn additional income from weaving tissue out of sheep wool and from a contract with the municipality for road maintenance (Burga et al 1995).

Farmers' use of irrigation is limited because only about 20% of the district's cropland has access to irrigation. Irrigated land is mostly used for cultivation of permanent pastures, primarily ryegrass–clover mixtures that serve as feed for dairy cows. Milk provides an important regular income even for farmers with only 1 or 2 cows. Milk is primarily sold to Nestlé SA, the most important milk buyer in the region, which collects more than 150,000 L/d throughout Cajamarca (Malpartida et al 1994).

However, because limited access to irrigation limits cultivation of permanent fodder crops for milk production, agricultural crops are equally or even more important for farmers (eg, cereals, potatoes, beans, and peas). These are grown mainly during the rainy season, from November to May. Because farmers face relatively high price and production risks with agricultural crops (eg, drought and frosts), production is rather extensive in terms of seed, labor, and pesticide use, and a high share of the produce is consumed by the farm family.

Liquidity is a particular constraint for these small-scale farmers, especially when growing market-oriented produce such as potatoes, which require a considerable initial investment. Moreover, farmers have difficulties accessing credit because they cannot offer adequate security to moneylenders. Thus, NGOs frequently offer the only access to investment capital. But NGO credits are relatively expensive because of high transaction costs: interest rates are between 2 and 3% per month, in US dollars. Farmers who are official milk providers for Nestlé (ie, larger milk producers) can also access credit-like services (for example, to buy feed concentrate and medicine). Loan and interest payments are then directly deducted from farmers' milk payments.

Execution of family-based sprinkler irrigation projects

The establishment of sprinkler irrigation in the study region is driven by the extension activities of CEDEPAS, a local NGO, guaranteeing both technical and financial support that enables farmers to expand the area they irrigate. The sprinkler projects discussed here target untapped or underused small wells. Given the low water flow of these wells in the dry season and the inclination of the terrain (Table 1), gravity irrigation is not very effective. Taking advantage of the difference in altitude between the well and the irrigated area to achieve the necessary water pressure, sprinkler irrigation makes much better use of the available water, irrigating an area at least twice the size of that irrigated by a gravity system. The selection of sprinklers used in each case depends on the available water pressure at the field level (difference in altitude between the field and the water reservoir and water volume). Overall, sprinkler irrigation is expensive to set up, especially for wells with low water flow, where project-planning costs account for a high proportion of total costs (Table 1).

Altogether, the profitability of the sprinkler projects analyzed varies greatly, depending on individual project execution costs (the sum of planning and installation costs) and the increase in irrigated area after the establishment of the sprinklers. Moreover, all projects are highly subsidized by the NGO. Farmers' payments amount to 50% of all material costs (paid without interest), not considering labor invested by farmers and the NGO (farmers pay only around 40% of the total sprinkler installation costs). Loans are repaid within 6–12 months after project completion. Sometimes, additional loans are provided for the purchase of dairy cattle and the installation of permanent pastures. When farmers must find their own means to make these additional investments, they often have problems repaying their loans on time (Table 1).

The advantages farmers enjoy from shifting to sprinkler irrigation include not only the increased irrigated area and the corresponding increase in productivity but also flexibility and time saved in irrigating their crops, compared with their previous partial access to community water channels. Taking advantage of wells on their land, farmers can tap their own water supply, which is available at any moment. Moreover, farmers tend to save additional hours of labor because children and women often take over irrigation tasks, as no heavy work is involved in connecting and moving the sprinklers. Maintenance costs are minimal, given the rather simple sprinkler technology. Reservoir cleaning requires the biggest effort at the beginning of the dry season, but labor is not a limiting factor during this period (Salirrosas and Villanueva 1997).

Methodology

To analyze the feasibility and cost-effectiveness of installing small-scale sprinkler irrigation systems on small slope farms, a "typical" water-constrained 2.5-hectare farm with crop and livestock options was modeled and analyzed. This "typical" farm reflects average farm survey data (Bernet and Tapia 1999) as well as sprinkler establishment and maintenance costs (Table 1). First, a (static) farm household optimization model was used to anticipate the potential production changes when farmers shift to sprinkler irrigation (Bernet et al

2001). Second, a (dynamic) investment model was applied for detailed study of the development of farmers' liquidity when such an investment is made. The farm investment model compensates for the inability of the farm household optimization model to reflect the dynamics of a farm. In contrast to the household optimization model, which is based on 1 average year, the investment model can show the development of savings and liquidity over a 10-year period, taking into account variation in the timing of repayment practices. Savings are defined as agricultural profits less family expenditures; liquidity refers to the amount of disposable cash, which is calculated by adding amortization and credit capital to savings and subtracting credit payments and investments (Figure 2). The usefulness of this model is strictly related to its ability to reflect the development of liquidity, a widely overlooked key constraint for small-scale farmers when undertaking investments.

Overall, this methodological approach is based on the assumption that land use decisions and their long-term implications (eg, for soil fertility and erosion) are driven by farmers' production choices aimed at obtaining maximum profits in the short term, as stressed by Cary and Wilkinson (1997) and Winters et al (1998).

Economic assessment of small-scale sprinkler irrigation establishment

Expected changes in farmers' production, profitability, and land use

The application of the household optimization model to a common water-constrained small farm (2.5 ha)

TABLE 2 Application of the household optimization model and the investment model to assess the impact of irrigation and fodder conservation on agricultural production on a 2.5-hectare farm.

	Type of irrigation						
	None	Gravity	Sprinkler				
Irrigated land (ha)		0.25	0.25	0.50	0.75	1.00	0.75
Animal traction	Yes	No	No	No	No	No	No
Fodder conservation	No	No	No	No	No	No	Yes
Net income							
Net income farm ($)	353	491	402	566	706	829	831
Net income per hectare ($/ha)	141	196	161	226	282	332	332
Capital costs ($)	18	25	86	98	107	115	108
Net income balance trimester 1 ($)	–909	–818	–843	–462	–531	–762	91
Net income balance trimester 2 ($)	1066	1044	1020	869	884	946	269
Net income balance trimester 3 ($)	323	360	342	299	344	436	239
Net income balance trimester 4 ($)	–127	–94	–117	–141	9	209	232
Land use							
Potatoes and oca (ha)	1.32	1.36	1.36	1.45	1.18	0.80	
Beans, peas, and barley (ha)	1.09	0.89	0.89	0.44	0.39	0.50	0.87
Oats and field beans (ha)	0.09			0.11	0.18	0.20	0.88
Alfalfa (ha)		0.17	0.17	0.20	0.22	0.28	0.11
Ryegrass–clover (ha)		0.08	0.08	0.30	0.53	0.72	0.64
Livestock production							
No of dairy cows		0.7	0.7	1.2	1.8	2.3	2.6
No of sheep	2.5	2.3	2.3				
Sprinkler installation							
Total costs ($)			649	790	887	962	887
Costs per hectare ($/ha)			2596	1580	1182	962	1182

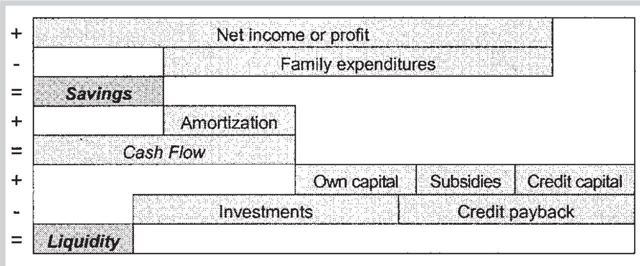


FIGURE 2 Calculation of savings and liquidity using the farm investment model.

reveals clear discrepancies in expected farm profits for farms with and without access to water, as well as differences in the expansion of the irrigated area in the case of sprinkler irrigation (Table 2).

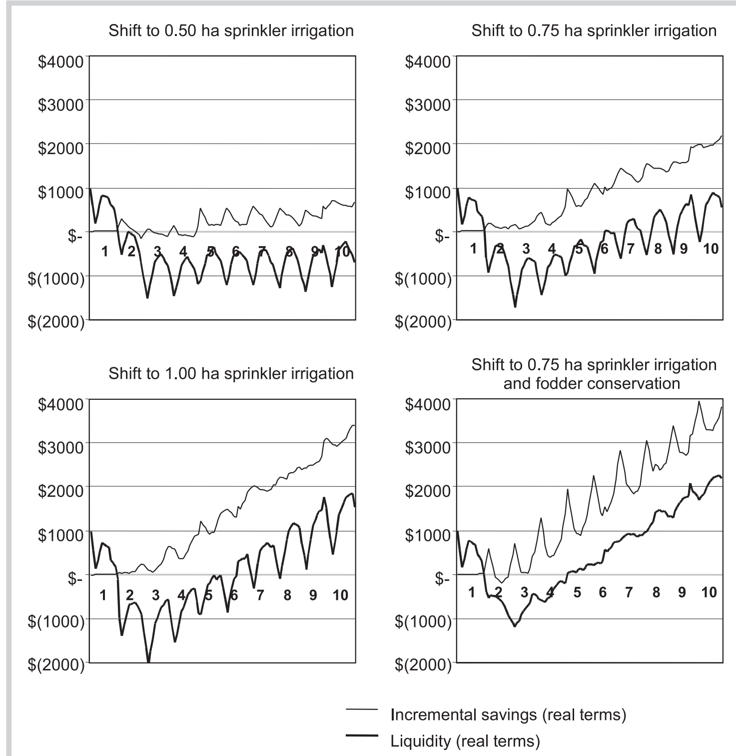
In contrast to dryland agriculture, farm profits are approximately 40% higher when 0.25 hectare is irrigated by gravity, and they reach an even higher level when sprinklers irrigate at least 0.50 hectare; when 0.75 hectare is irrigated by sprinklers, profits double. The obvious impact of the irrigated area on profits results from the fact that expanding the sprinkler system to increase the irrigated area is fairly inexpensive in relation to initial planning and infrastructure costs (Table 1).

The increased importance of milk production that follows the expansion of irrigated area is remarkable (Table 2). However, unless fodder conservation is implemented—which is not generally the case in the study area—fodder production remains limited and agricultural crops continue to play a predominant role, whereas tubers (potatoes and oca) are responsible for large seasonal fluctuations in income. In this sense, implementing fodder conservation would not only lead to higher and more secure farm profits but would also reduce seasonal fluctuations in liquidity and hence increase farmers' livelihood security. Moreover, because a smallholder can keep at least 2 dairy cows when fodder conservation is implemented, he will be in a better position among his neighbors during milk price negotiations, if not actually becoming an official milk provider for Nestlé SA (Mosley 1982). The implementation of fodder conservation would also induce positive land use changes, with production of oats (for fodder), peas, and beans expanding at the expense of tubers (Table 2). This would enhance soil fertility in the long term because of a reduction in soil erosion resulting from the greater plant densities of these crops. Equally, the now common overgrazing problem during the dry season would be effectively diminished by fodder conservation practices.

Tracking farmers' liquidity problems

The application of the investment model to the different scenarios in Table 2 shows that both savings and liquidity are crucial indicators of the feasibility of shifting to sprinkler irrigation (Figure 3). Under the given con-

FIGURE 3 Development of incremental savings and liquidity on a small farm (2.5 hectare) when sprinkler irrigation is established (previous access to 0.25 hectare of gravity irrigation).



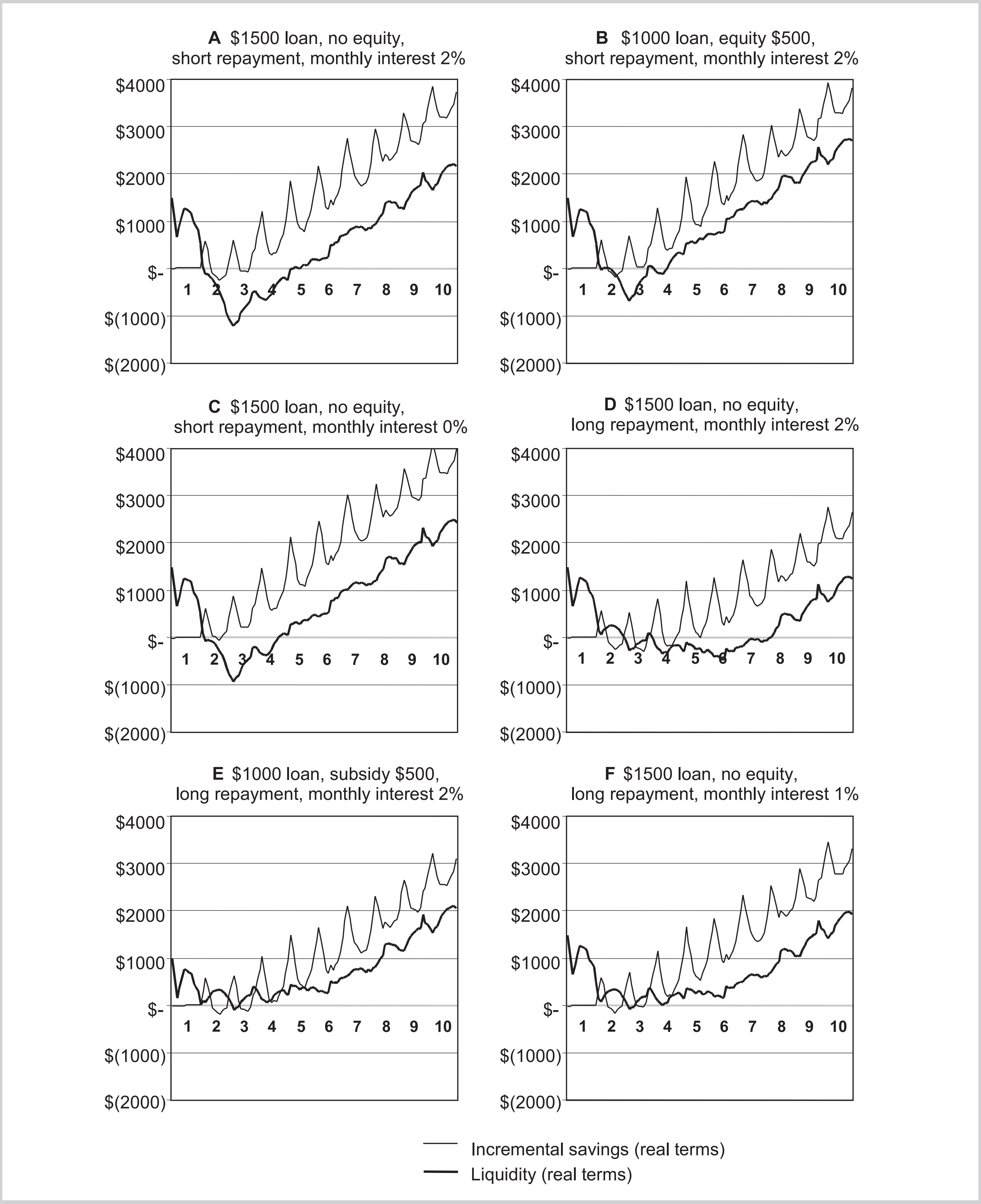
ditions—a loan of US$ 1000 at a monthly interest rate of 2%, repayable in the first year after the investment—farmers would face severe liquidity problems during the first months of investment. This problem persists even when the irrigated area is considerably expanded by sprinklers, by a factor of 3 or 4 in comparison with gravity irrigation, where savings are considerable.

The liquidity gap is heavily influenced by the requirement to repay a loan in the first months after the investment—at the time when additional investments are needed for pasture cultivation and dairy cattle to guarantee effective use of the expanded area under irrigation. Because these latter investments are similar in magnitude to the initial investment in sprinkler irrigation, the loan of US$ 1000 is insufficient. Although the simultaneous implementation of fodder conservation would be beneficial in terms of smoothing seasonal fluctuations in liquidity and generating greater savings, it cannot eliminate the liquidity problem, partly because more dairy cattle are purchased in this scenario, where more fodder is available during the whole year.

Analyzing the feasibility of different financing options

Defining financing options that are efficient for farmers—to help avoid a liquidity gap in the first years and, for NGOs and other credit institutions, to guarantee a

FIGURE 4 Impact of different financing options on the development of incremental savings and liquidity of small farms when sprinkler irrigation and fodder conservation are established.



good rate of loan repayment—is a key issue. However, there is a clear trade-off between these 2 aspects: farmers' repayments unquestionably help lenders recover their funds, but at the same time they tend to cause liquidity problems for farmers.

Modeling results show clearly that the only way to meet these 2 requirements is to implement credit options that allow farmers to repay their loans over a longer period (5 years or more) (Figure 4). At the same time, there is no appropriate way to prevent liquidity problems, given the lending practices of NGOs, which are designed to recover loans quickly—even if farmers have their own equity and no interest rates are applied (Figure 4B,C). The availability of equity reduces the severity of the liquidity gap to some extent. But the farmers' financial bottleneck in the first months of the investment would still inevitably jeopardize adoption of efficient production structures because they might sell production factors (eg, cattle) to meet minimum family expenses.

The main problem of lengthy payback conditions is the high capital costs created, given the commonly high interest rates (2% monthly in nominal terms, or 19% annually in real terms). Applying interest payments on unrepaid loans over a long payback period (5 years) results in high total interest payments. This has a heavy impact on savings capacity and liquidity flow (Figure 4D). In this context, a loan or interest subsidy is essential to provide an adequate basis for farmers to sustain their liquidity over time (Figure 4E,F).

The relatively high interest costs are also reflected in the calculated internal rate of return (IRR), which is an important indicator for assessing whether an investment under consideration seems to be more profitable than alternative investments. Case studies from developing countries conclude that an IRR of around 30–50% must be achieved to provide the necessary incentive for small farmers to make the investment (Perrin et al 1976; Pender and Walker 1990). The IRR of 20% calculated here, when no subsidies are applied, thus indicates a rather weak economic incentive for establishing sprinkler irrigation. Subsidies of at least 25% of the initial loan are required to reach the minimum 30% IRR; with a 50% subsidy the investment becomes highly worthwhile because the IRR would be higher than 50%.

Conclusions

This study clearly shows that profitability, as an important financial indicator, is not sufficient for assessing investments on small-scale farms. Analysis of farmers' liquidity flows, which are greatly affected by payment conditions for loans and interest, is equally important. The results presented in this study also show that analysis must be very thorough and take into account the additional investments that must be made for optimal payoff of the initial investment. In this case, investments in fodder establishment and dairy cattle are indispensable for taking advantage of the expanded surface that can be irrigated.

Because the development of farmers' liquidity—and hence the feasibility of an investment—depends greatly on individual investment costs, the expansion factor of the irrigated surface, family expenditures, etc, the results of this study cannot be a substitute for case-specific project assessment. However, the findings indicate what economic issues must be closely considered in a specific sprinkler project to improve both its feasibility for farmers and efficiency for moneylenders:

- Low sprinkler establishment costs relative to the expanded area under irrigation.
- Farmers' own equity and savings capacity.
- Provision of technical assistance, especially for fodder and herd management.
- Moneylenders' flexibility in providing additional loans (pasture establishment and cattle).
- Lengthy repayment periods (5 years or more).
- Subsidies that "pay" for positive side-effects (externalities).

Overall, this study does not provide a final answer to the question of what level of subsidies is justified. What costs and benefits are induced by this investment for others, especially farmers downstream? Most important, the greater irrigation efficiency generated in slope areas could reduce well water flow downstream, leading to potentially considerable loss of income for farmers who have better climatic conditions for producing high-value crops downstream. In this sense, a broader and more detailed analysis would be required at the watershed level, taking into account larger-scale development priorities (Keller et al 1996; Molden 1997). But political priorities should also be reflected. It must be assumed that an additional dollar earned by a poor farmer upstream is worth more than an additional dollar earned by a richer farmer in the fairly well developed coastal area.

For the directly targeted farmer, the analysis fails to some extent in not valuing all the benefits of sprinkler investment. Unconsidered factors include (1) the additional benefits of more pronounced livestock orientation for the farmer's livelihood security, (2) the positive long-term effects of cultivated pastures and animal manure on soil productivity (Koeijer et al 1995), and (3) the positive implications of sprinkler irrigation in combating the liver fluke (*Fasciola hepatica*), the most important parasite in the study region, by eliminating gravity irrigation channels.

In any case, close collaboration between NGOs and regional milk buyers is suggested. As illustrated in other milksheds (Morel et al 1991), contracts between credit institutions and milk processors have proven to be very cost-effective because farmers' repayments are simply discounted from the regular milk payments, providing good conditions for full recovery of loans. Such collaboration is in the best interests of the milk processors, whose actual interest is to increase total milk production in the region to reduce average milk collection costs. In fact, such collaboration could also be the departure point for promoting fodder conservation practices. Linking these technical and financial forms of support is especially crucial in sprinkler investment because fodder and herd management significantly impact the overall payoff of the investment.

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REFERENCES

Bernet T, Ortiz O, Estrada RD, Quiroz R, Swinton SM. 2001. Tailoring agricultural extension to different production contexts: a user-friendly farm-household model to improve decision-making for participatory research. *Agricultural Systems* 69:183–198.
Bernet T, Tapia M. 1999. *Análisis de los sistemas de producción en la microcuenca de la Encañada: Documento base para investigaciones y acciones futuras en la Sierra Norte del Perú.* Departamento de Ciencias Sociales, Documento de Trabajo No. 1999-1. Lima, Peru: Centro Internacional de la Papa.
Burga M, Miranda T, Rivasplata M, Silva C, Tapia M. 1995. *Cuenca del Jequetepeque—diagnóstico preliminar*. Cajamarca, Peru: CEDEPAS [Centro Ecuménico de Promoción y Acción Social], DEJEZA [Dirección Ejecutiva Jequetepeque-Zaña], CESDER [Centro de Estudios para el Desarrollo Rural].
Cary JW, Wilkinson RL. 1997. Perceived profitability and farmers' conservation behaviour. *Journal of Agricultural Economics* 48(1):13–21.
Franqueville A, Vargas E. 1990. *La cuenca lechera de la Paz, Bolivia.* La Paz, Bolivia: INAN [Instituto de Alimentación y Nutrición], ORSTOM [Office de la Recherche Scientifique et Technique Outre-Mer].
Keller A, Keller J, Seckler D. 1996. *Integrated Water Resource Systems: Theory and Policy Implications.* Research Report 3. Colombo, Sri Lanka: IIMI [International Irrigation Management Institute].
Koeijer TJ, Renkema JA, Van Mensvoort JJM. 1995. Environmental–economic analysis of mixed crop–livestock farming. *Agricultural Systems* 48:515–530.
Linden V. 1995. *Hill Irrigation—Water and Development in Mountain Agriculture*. London, UK: Intermediate Technology Publications, Overseas Development Institute.
Malpartida E, Pinares C, Bello J. 1994. Sistemas de producción en la cuenca lechera de Cajamarca. *In:* Hervé D, Rojas A, editors. *Vías de Intensificación de la Ganadería Bovina en el Altiplano.* La Paz, Bolivia: ORSTOM [Office de la Recherche Scientifique et Technique Outre-Mer], pp 83-92.
Molden D. 1997. *Accounting for Water Use and Productivity.* SWIM Paper 1. Colombo, Sri Lanka: IIMI [International Irrigation Management Institute].
Morel D, Hervé D, Rios H. 1991. *Role du crédit sur l'intensification laitière —Altiplano central bolivien*. Informe No. 25. La Paz, Bolivia: ORSTOM [Office de la Recherche Scientifique et Technique Outre-Mer].
Mosley P. 1982. Marketing systems and income distribution: the case of milk producers in highland Peru. *Food Research Institute Studies* 18(3):275–291.
Ørskov ER. 1993. *Reality in Rural Development Aid.* Aberdeen, UK: Rowett Research Services Ltd.
Pender JL, Walker TS. 1990. *Experimental Measures of Time Preference in Rural India*. Resource Management Program Economics Group Progress Report-97. India: ICRISAT [International Crops Research Institute for the Semi-Arid Tropics].
Perrin RK, Winkelmann DL, Moscardi ER, Anderson JR. 1976. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual.* Information Bulletin 27. Mexico City, Mexico: CIMMYT [Centro Internacional de Mejoramiento de Maíz y Trigo].
Salirrosas G, Villanueva V. 1997. *Intensificación productiva con riego presurado en la cuenca alta del Jequetepeque—validación de experiencias.* Cajamarca, Peru: CEDEPAS [Centro Ecuménico de Promoción y Acción Social].
Seifert R. 1990. *Cajamarca: vía campesina y cuenca lechera*. Lima, Peru: CONCYTEC [Consejo Nacional de Ciencia y Tecnología], CAPLECAY.
Stocking MA. 1988. Assessing vegetative cover and management effects. *In:* Lal R, editor. *Soil Erosion Research Methods.* Wageningen, The Netherlands: Soil and Water Conservation Society, pp 162–185.
Winpenny J, Willis R. 1995. *Economic Assessment of Production-related Environmental Impacts*. Rome, Italy: FAO, Commodity Policy and Projections Service, Commodities and Trade Division.
Winters P, Espinosa P, Crissman C. 1998. *Manejo de los recursos en los Andes ecuatorianos: Revisión de literatura y evaluación del proyecto 'Manejo del Uso Sostenible de Tierras Andinas (PROMUSTA) de Care'.* Quito, Ecuador: CIP [Centro Internacional de la Papa].