Can the effects of El Niño be mitigated through a system of payments for environmental services? A study of the Piura River watershed, Peru

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To predict the viability of a system of payments for protection against floods and hydrological cycle disturbances, the estimated costs of modifying land use practices were compared with the amounts that users would be willing to pay.

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Andean cloud forests are vanishing with the ongoing advance of the agricultural frontier. The environmental degradation caused by inappropriate farming practices is destabilizing the hydrological cycle, increasing the seasonal fluctuations in river flows and disturbances such as landslides and floods. In the northern region of Piura, Peru, these problems are increasing vulnerability to the El Niño phenomenon – an oscillation of the ocean-atmosphere system in the tropical Pacific which has important consequences for weather around the globe (INRENA, 2005).

In recent decades El Niño disturbances have resulted in costly damage in the watershed of the Piura River by causing landslides in steep areas and severe floods downstream. In 1998, the losses were valued at more than US$100 million (CTAR, 1998). Rainfall in a 1983 event was even higher, but because of the high deforestation rate the damage was greater in 1998.

A study of the Piura watershed indicated that in view of such catastrophes inhabitants would be willing to pay for environmental services such as flood protection and control of the hydrological cycle (improvement in the quantity and quality of water and reduction in seasonal flow fluctuations). The study examined the feasibility of a system of payments for environmental services (PES) for the

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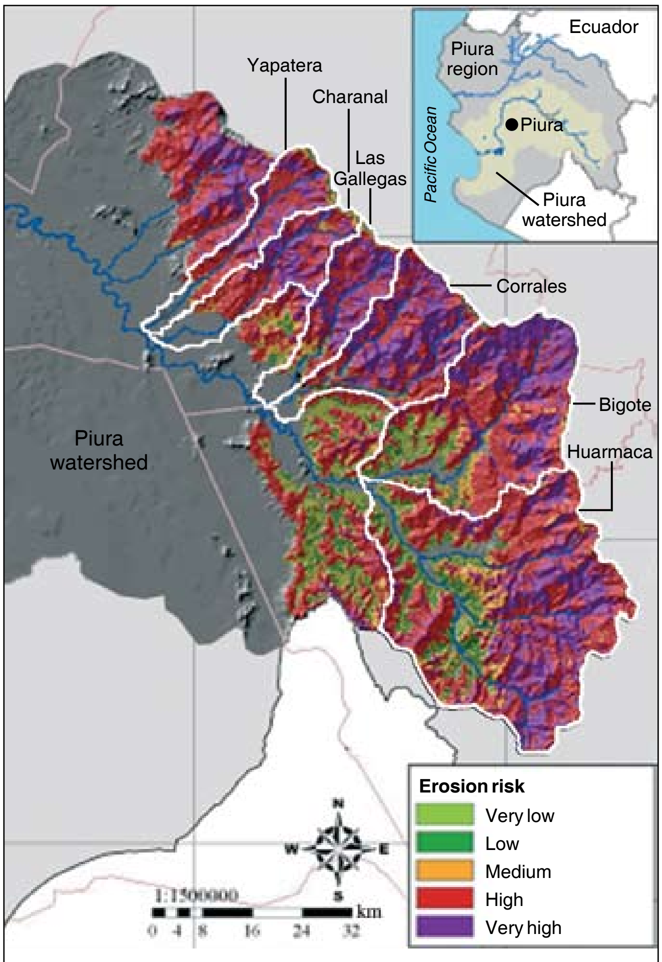
In the Piura River watershed, Peru, loss of forest cover has increased erosion; the hydrological system could be improved by compensating small upland farmers for reforestation, forest conservation and adoption of agroforestry, sustainable farming and silvipasture techniques that protect soil



Source: Based on the methodology of Jiménez *et al.*, 2006.

1 Erosion risk in the main subwatershed areas of the Piura watershed, Peru

watershed whose proceeds could be used to conserve forests and develop sustainable farming and livestock techniques (Martínez de Anguita *et al.*, 2006). Finance would come from downstream inhabitants who suffer from the effects of El Niño. The payments would be used to compensate small farmers for their labour on forest and river-channel conservation, to create incentives for the adoption of soil protection techniques in the farming systems used, and also to help improve the living conditions of peasant farmers in this mountain region.

The study included a socio-economic analysis of the watershed area to identify potential service providers; a survey of potential users of the environmental services and their willingness to pay for them; and mapping and hydrological study of the watershed area to identify the most important areas for maintenance of environmental services. By comparing the costs of the measures needed to conserve water resources and the amounts that service users and other investors could be expected to contribute, it was possible to analyse the viability of several alternative options for a PES system.

MODEL PES SCHEME

The high watershed of the Piura River has a population of about 70 000 potential providers of environmental services; they share similar farming systems and socio-economic conditions, with average annual income of about US$400. The downstream population includes some 300 000 potential buyers of the services, with average annual income of more than US$2 400.

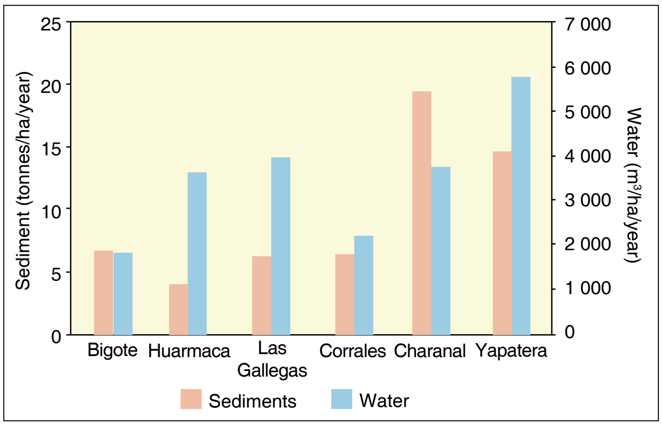
The watershed has six main subwatersheds where improvements could contribute to regulating the hydrological cycle. All of the banks of the Piura River from the outlets of its main tributaries to its arrival at the Pacific Ocean are vulnerable to sudden rises. Practically the whole zone, including most upland farmland, has a high to very high erosion risk (Figure 1). Geographic information system (GIS) analysis showed that erosion risk is influenced more by forest cover than by soil type. The solutions to the problem are clear: conservation of the remaining forests, recovery of lost areas, reforestation of stands, a shift to agroforestry and other systems that protect soil from erosion, and development of silvipasture (López Cadenas de Llano, 1990; Braud *et al.*, 2001).

The flow in the Piura River undergoes wide seasonal fluctuation, ranging from 5.72 m^3 per second for about ten months of the year to 200 m^3 per second in the rainy season. It also varies considerably from year to year; for example, in El Niño years it reaches peak flows of 1 600 m^3 per second, while in La Niña years flow is much lower.

The Yapatera and Charanal subwatersheds were identified as those that could benefit most from intervention, as they have particularly serious erosion (Figure 2). Although they are the smallest subwatershed basins, occupying only 15.4 percent of the total area, together they account for 38 percent of the sediment and 23 percent of the water supplied by the six subwatersheds of the Piura River.

A survey of almost 200 potential purchasers in the city of Piura, together with other studies, indicated that the inhabitants of the watershed are willing to pay for environmental services (Table 1). More than 80 percent of the city residents who responded to the survey acknowledged their readiness to pay. Some 66 percent of those surveyed would prefer to make payments to an independent institution set up for the purpose. Another 19 percent would prefer to make payments together with water bills for the sake of convenience. The choices of the remaining 15 percent were divided among city or regional government or unspecified others.

As some socio-economic groups would be willing to pay more than others, a scheme of differentiated payments by socio-economic group would maximize income from the PES system. By multiplying the amount that each group would be willing to pay by the number of households in that group (Table 2), it was calculated that annual income from the system would total more than 10 million nuevos soles (S./), equivalent to US$3.2 million.



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Average annual production of water and sediment in subwatersheds of the Piura basin

TABLE 1. Potential purchasers of environmental services identified in the Piura River watershed area

Identified purchaser	Environmental service demanded	Motive for purchasing the service
Piura regional government, inhabitants of the city of Piura and other smaller cities (Tambo Grande, Morropón, Chulucanas)	Mitigation of flood risks	Catastrophes caused by the 1983 and 1998 El Niño phenomena, with losses totalling more than US$100 million (CTAR, 1998)
Farmers in the lower areas of the mountains	Quality and quantity of water and reduction in seasonal fluctuations	Improvement in crops for domestic and international markets
Enosa Electric Company	Quantity of water and reduction in seasonal fluctuations	Reduced electricity production by mini-hydroelectric plants
Enterprises or industries	Some service or improvement in social image	Improvement or reduction of risks

TABLE 2. Population structure of Piura city according to socio-economic groups and their willingness to pay for the service

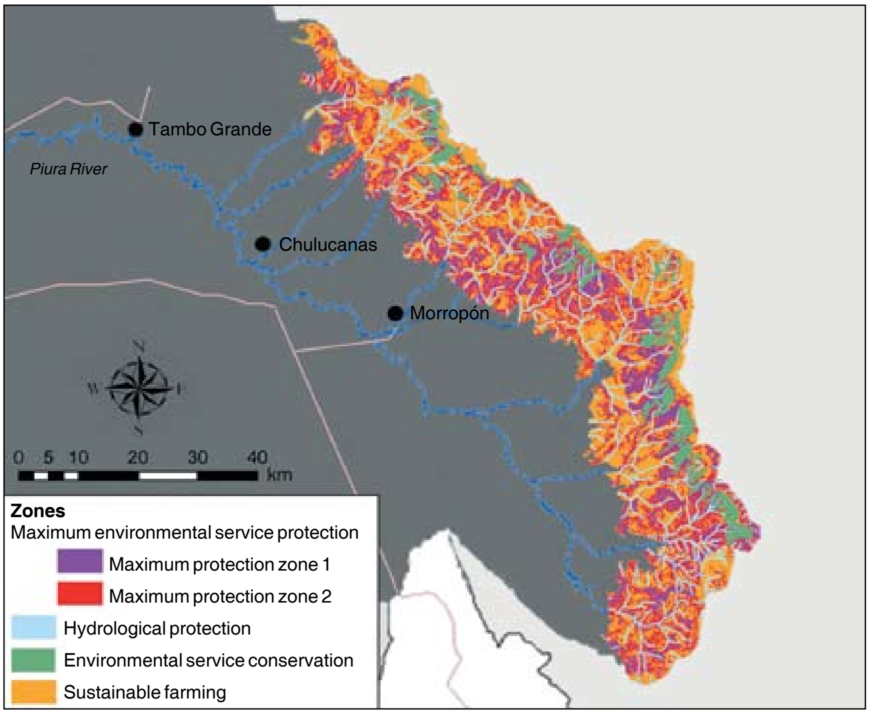
Monthly expenditure *(S/.)*	Average willing to pay per month *(S/.)*	Households		Inhabitants	
		No.	% of total	No.	% of total
>920	29.9	7 000	9.7	39 000	10.8
636–920	17.8	20 400	28.1	97 700	27
457–636	9.4	28 000	38.6	128 100	35.4
<457	n.a.	17 100	23.6	96 900	26.8

Note: S/.1 = US$0.3194 (3/8/2007).
Sources: Personal survey; APOYO Opinión y Mercado, 2003; INEI, 2005.

The providers identified were landowners in the upper part of the River Piura watershed who could maintain or improve the quality of water with good practices or a change in land use. Payments would compensate them in various cases for reforestation and management of reforested areas, for conserving forests or for adopting agroforestry practices. A physical planning model was created using the methodology proposed by Jiménez *et al.* (2006), dividing the providers' area into zones (Figure 3):

- ***maximum environmental service protection zone:*** areas on steep slopes and thus having a greater risk of erosion, divided into two subzones:
  - ***maximum protection zone 1:*** slope greater than 60 percent (40 728 ha);
  - ***maximum protection zone 2:*** slope between 40 and 60 percent (63 070 ha);
- ***hydrological protection zone:*** land located 150 m from water channels and springs and covered by vegetation that protects the channels, while also providing habitat and conservation corridors for diverse plant and animal species (35 333 ha).
- ***environmental service conservation zone:*** natural or primary forest areas, whose protection is vital for the quality of watershed environmental services as well as for conservation of biodiversity (16 091 ha);
- ***sustainable farming zone:*** land used for agriculture and animal husbandry (71 696 ha).

With a view to maximizing the area to be protected with limited funding, various types of contract are proposed for providers in the various zones to be included in the PES system (see Box). Incentives are designed to encourage adoption of best practices for each zone, with a view to conserving and improving the environmental service and improving



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Plan of the providers' area

TABLE 3. Alternative options

Option	Areas covered under the scheme	Total area *(ha)*	Average compensation *(soles/ha/year)*
1	The whole area, for the best possible environmental service and benefit to the greatest number of inhabitants	195 945	51.2
2	The whole area except the Huarmaca subwatershed, which was given a lower priority in the hydrological model because of its lower degree of degradation	130 846	76.7
3	All subwatershed areas except Huarmaca	115 419	86.9
4	Priority hydrological response units of upland crops with the greatest sediment production per hectare, and zones requiring no initial outlay (forests and hydrological protection zones)	82 579	121.5

the quality of life of families in mountain areas by increasing their income.

On the basis of the income of the purchasers living in the city of Piura, and supposing that all the properties in the watershed subscribed to the PES system, the average amount that could be paid per hectare as opportunity cost was calculated. Four alternative options were drawn up, encompassing decreasing portions of the watershed area (Table 3). The average sum to be paid per hectare would be adjusted according to the various contracts to which the owners might subscribe, depending on the type of land owned and their specific interests.

Under Option 1, it was estimated that an initial investment of US$28.7 million would be needed (Table 4), and Options 2 and 3 would require a similar outlay. This sum would be used to supply the materials needed to meet the providers'

Proposed contract types

TYPE I: FOREST OWNERS

- ***Primary forest.*** **The sum received per unit area should be greater than or equal to what a farmer would receive under the PES system. Some activities are restricted.**
- ***Secondary or reforested forest.*** **The sum received should be lower than that received by owners of primary forest, but higher than that of the other categories.**

In each of these cases, an extra incentive is included if the area owned lies within any of the protection zones defined in the physical plan.

TYPE II: OWNERS OF RIVERBANKS WITHOUT NATURAL VEGETATION

Owners of land located 150 m from rivers and water sources (hydrological protection zone) will receive payment similar to that under a Type I contract, to compensate them for the opportunity cost of maintaining these areas with natural plant cover.

TYPE III: OWNERS OF AGRICULTURAL LAND

The sum received must be adjusted so that, when it is combined with profits from production, the owner will draw greater profit from subscribing to the contract than from eliminating the forest.

TYPE IV: OWNERS OF PASTURELAND

The sum offered must be attractive enough to encourage the owner to subscribe to the system. Payment would be received after the proposed silvipastoral model is achieved.

TYPE V: COMMUNAL FORESTS AND LANDS

Previous contracts should be adjusted depending on whether the land is forested or can be reforested. Payment will go to the city council, which must use it for the conservation and management of these forests.

TABLE 4. Estimated initial cost of Option 1 with local government contribution for labour

Zone	Area (ha)	Initial cost		Labour cost	
		(S/. per ha)	(S/.)	(S/. per ha)	(S/.)
Maximum protection 1	28 931	792	22 913 252	173.5	5 019 507
Maximum protection 2	49 954	792	39 563 873	173.5	8 667 086
Conservation of the service	16 091	0	0	0	0
Hydrographical protection	35 333	0	0	0	0
Sustainable farming	71 696	382.5	27 421 710	283.5	20 325 757.3
Total			89 898 835 US$28 714 387		34 012 350 US$10 863 787

Source: Elaborated on the basis of farming models and costs proposed by Piura University for the Programa de Desarrollo Sostenible de Ecosistemas de Montaña del Perú.

TABLE 5. Cost of implementing the PES system, divided into stages, focusing on priority areas in order to achieve the ideal proposed in the physical plan

Zone	Area (ha)	Initial cost		Labour cost	
		(S/. per ha)	(S/.)	(S/. per ha)	(S/.)
Year 0: Option 4 (49% of environmental services)					
Maximum protection 1	3 446	792.0	2 729 559	173.5	597 953
Maximum protection 2	9 651	792.0	7 643 727	173.5	1 674 478.0
Hydrological protection	35 333	0	0	0	0
Conservation	16 091	0	0	0	0
Sustainable farming	18 058	382.5	6 906 792	283.5	5 119 512
Total			17 280 078 US$5 514 855		7 391 943 US$2 361 042
Year 2: Option 3 (68% of environmental services)					
Maximum protection 1	14 004	792.0	11 091 133	173.5	2 429 686
Maximum protection 2	18 235	792.0	14 441 802	173.5	3 163 703
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	26 265	382.5	10 045 716	283.5	7 446 173
Total			35 578 651 US$11 354 757		13 039 562 US$4 164 934
Year 4: Option 2 (75% of environmental services)					
Maximum protection 1	2 045.9	792.0	1 620 376	173.5	354 968.6
Maximum protection 2	4 818.6	792.0	3 816 363	173.5	836 034.1
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	5 337.7	382.5	2 041 509.0	283.5	1 513 225.0
Total			7 478 248 US$2 386 647		2 704 228 US$863 751
Year 5: Option 1 (100% of environmental services)					
Maximum protection 1	10 227	792.0	8 099 665	173.5	1 774 358
Maximum protection 2	17 696	792.0	14 015 443	173.5	3 070 302
Hydrological protection	0	0	0	0	0
Conservation	0	0	0	0	0
Sustainable farming	21 350	382.5	8 165 962	283.5	6 052 845
Total			30 281 070 US$9 664 060		10 897 506 US$3 480 745
TOTAL			US$28 920 319		US$10 870 471

requirements without their having to invest any initial capital; the providers would furnish the labour required to make the changes in land use. With local government able to contribute US$10.9 million (calculating the cost of labour at the market rate) and Piura city purchasers US$3.2 million per year, funding would be insufficient to make this proposal viable. This cost would also be very high for attracting international aid or a loan.

More feasible options, however, would be Option 4, focusing on priority hydrological response units (identified by their soil type, plant cover and meteorological conditions) or a staged approach starting with the zones of highest priority (Table 5) or focusing on Options 2 and 3. Option 2 would be the most efficient, providing 75 percent of the environmental services at a cost of US$19.2 million.

CONCLUSIONS

A PES system focusing on mitigating damage caused by the El Niño phenomenon could be viable. Although high initial costs would preclude implementation of an optimal conservation scheme, less complete options could be practicable with contributions from the government or international donors in addition to payments by the users of environmental services. Although they would contribute less than inhabitants of the city of Piura, other potential purchasers, especially farmers in the lower area who could pay for the regular supply of a sufficient quantity of good-quality water, would add to the total. The differentiation of payments on the basis of the purchasers' ability to pay would increase income under the PES system and contribute to social equity. Particularly in the Andean countries, where social inequalities are a common problem, the relation of buyers and providers could help to level social differences.

The method described here, although specific to the Piura River watershed, could also be extrapolated to other situations.

Although assistance from the government or, failing this, international assistance would be necessary for such a scheme, such assistance would be justifiable. It is enough to remember that the 1998 El Niño event caused infrastructure damage of over US$100 million in the Piura region, which is much more than the cost of implementing the proposed plan. ◆

Bibliography

APOYO Opinión y Mercado. 2003. *Informe Jefes de Hogar*. Miraflores, Peru.

Braud, I., Vich, A.I.J., Zuluaga, J., Fornero, L. & Pedrani, A. 2001. Vegetation influence on runoff and sediment yield in the Andes region: observation and modelling. *Journal of Hydrology*, 254: 124–144.

Consejo Transitorio de Administración Regional (CTAR). 1998. *Evaluación de los daños ocasionados por el fenómeno El Niño (periodo de emergencia 1998)*. Piura, Peru, Dependiente del Ministerio de Economía y Finanzas. Available at: www.mef.gob.pe

Instituto Nacional de Estadística e Informática (INEI) del Perú. 2005. *Censo del 2005*. Lima, Peru. Available at: www.inei.gob.pe

Instituto Nacional de Recursos Naturales (INRENA). 2005. *Evaluación de la vulnerabilidad física natural futura y medidas de adaptación en áreas de interés en la cuenca del río Piura*. Lima, Peru. Available at: www.conam.gob.pe

Jiménez, L., Martínez de Anguita, P., Gómez, I., Romero, R., Ruiz, M.A., Dunin-Borkwski, M.S. & Guerrero, D. 2006. Metodología para la zonificación del riesgo de erosión en cuencas andinas. Estudio de caso en el río Chalaco, Piura. In *Ordenación territorial y medio ambiente*. Madrid, Spain, Dykinson.

López Cadenas de Llano, F. 1990. El papel del bosque en la conservación del agua y del suelo. *Ecología,* 1: 141–156.

Martínez de Anguita, P., Rivera, S., Beneitez, J.M. & Cruz, F. 2006. Establecimiento de un mecanismo de pago por servicios ambientales sobre un soporte GIS en la cuenca del río Calan, Honduras. *Geofocus*, 6: 152–181. ◆