priority; by analogy to the one and two TI-O layer prototypes[10], the T_c values of Hg-22XY should also be higher than the present 133 k record[2] for Hg-1223. The second requirement for applications is that the flux pinning be strong; this is indeed the case for Hg-1201 in the low temperature limit and $H^*(T)$ is also higher than for Bi-2212 and Bi-2223, consistent with the conjectures of Putilin *et al.* [1] The irreversibility line however, is somewhat lower than for Y-123. On balance, Hg-1201 does not appear to have any particular advantage over existing high-T_c superconductors. The prospect of large-scale applications of Hg-1212 and Hg-1223 awaits studies similar to this one. If these compounds too are granular, this will emphasize the desirability of synthesizing the double-mercury-layer compounds. Even if their normalized $H^*(T)$ behaviour (fig. 3) were to be no better than that of their double-bismuth-layer analogues, their expected higher T_c values should give them higher absolute values of $H^*(T)$. A 15–20 K increase in $H^*(T)$ could be of immense technological significance if the new materials were to retain the good intergrain connectivity of Bi-2212 and Bi-2223. □

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Nutrient and sediment retention in Andean raised-field agriculture

Heath J. Carney*†, Michael W. Binford‡, Alan L. Kolata§, Ruben R. Marin‖ & Charles R. Goldman*

*Institute of Ecology, Division of Environmental Studies, University of California, Davis, California 95616, USA
‡Landscape Ecology Group, Graduate School of Design, Harvard University, Cambridge, Massachusetts 02138, USA
§Department of Anthropology, University of Chicago, Chicago, Illinois 60637, USA
‖Instituto de Ecologia, Universidad Mayor de San Andres, La Paz, Bolivia

RAISED-FIELD agriculture was widespread throughout Central and South America in prehispanic times[1,2]. In this system of agriculture, crops are cultivated on a series of raised beds, which are separated from one another by deep, water-filled channels. In some regions, rehabilitation of the raised fields is now underway, largely because this practice leads to fertile soils, adequate water supply and protection from frost and therefore to substantially higher yields than more conventional methods[3,4]. Here we report analyses of water quality in the channels alongside rehabilitated raised fields in the vicinity of Tiwanaku, on the Bolivian side of the Lake Titicaca basin (Fig. 1). We find that high concentrations of nitrate, available phosphate and turbidity decline significantly as the water flows through the raised-field channels. Water flowing through control sites shows no significant change. Retention of nutrients and suspended sediments in the channels helps to maintain soil fertility and reduces pollution of downstream waters. Thus it seems there are environmental benefits in rehabilitating raised fields, which complement and help sustain the economic benefits demonstrated previously[3,4].

†To whom correspondence should be addressed.

The location of our study is the vicinity of Tiwanaku on the Bolivian side of the Lake Titicaca basin (Fig. 1). Our study of nutrient and sediment fluxes from land to the lake is part of the MAB/UNESCO (Man and the Biosphere/United Nations Educational, Scientific and Cultural Organization) land-inland water ecotone program[5,6]. We sampled along nine transects which allowed us to determine the effects of watershed ecotone type (short and simpler to long and complex) and type of land use (conventional versus raised field)[7]. The horizontal distance from the start of surface water flow to the lake shore was used to place transects in one of three categories: less than 1.5 km (short); 1.5 to 3.5 km (intermediate); greater than 3.5 km (long). With increasing length there is greater diversity and complexity in land cover, soil type, land use, terrain (hills, valleys, plains) and nearshore vegetation zones through which water passes and can thus be altered.

In this paper we compare two raised-field sites to two other sites with conventional land uses (Fig. 1). All these sites are located within long ecotones. This report focuses on how nutrients and suspended sediment concentrations are affected in raised-field sites compared to locations in other transects with conventional fields. Nutrients and vegetation were sampled at three or more locations along each transect. Concentrations of soluble available nitrogen (nitrate, ammonium), soluble reactive phosphorus (phosphate) and turbidity are compared at two locations within transects: the base of foothills and start of the broad plain adjacent to the lakeshore, and about 150 metres downstream in the plain. In raised-field transects these points are at the inflow and outflow of the canal system. In the other

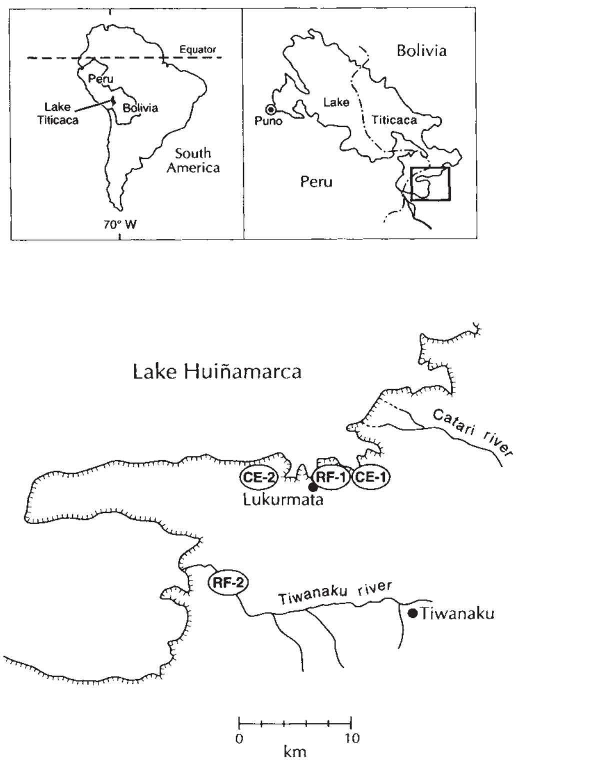

FIG. 1 Study region and transect sites in the Huiñamarca basin of Lake Titicaca. Codes for transects are: raised field 1-RF 1(Lukurmata); raised field 2-RF 2(Tiwanaku R.); conventional ecotone 1-CE 1(Chohasivi); conventional ecotone 2-CE 2(Huacullani).

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TABLE 1 Average nutrient inflow and outflow concentrations ($\mu g\ l^{-1}$ N or P ± standard error in parentheses) within ecotonal transects

Transect		Inflow	Outflow	O/I(%)
Raised field 1: (Lukurmata)				
	NO_3	4195(±533)	57(±20)	1.4
	PO_4	425(±41)	34(±6)	8
Raised field 2: (Tiwanaku R.)				
	NO_3	83(±27)	43(±19)	51.8
	PO_4	112(±7)	35(±5)	31.3
Conventional 1: (Chohasivi)				
	NO_3	3230(±530)	464(±108)	14.4
	PO_4	209(±25)	64(±8)	30.6
Conventional 2: (Huacullani)				
	NO_3	3338(±364)	413(±14)	12.4
	PO_4	234(±38)	69(±12)	29.5

Comparison of four transects from January 1990 to March 1991. Field sampling was monthly during the wet season and bimonthly during the dry season. Results of multiple-comparison tests[16] between transects and other analyses are discussed in the text. The declines in nitrate and phosphate were significantly greater ($P<0.05$) in the Lukurmata raised-field transect in comparison with the two conventional land use transects according to both the Fisher PLSD (protected least significant difference) and Scheffe F-tests. A one-factor repeated measures ANOVA (analysis of variance) showed significant differences in inflow minus outflow of both nutrients ($P=0.013$ for NO_3, $P=0.017$ for PO_4) between these three transects. The Tiwanaku raised-field transect was not included in this analysis because the inflow values and variance there were much lower. Nitrate was measured with the cadmium reduction method[17], and soluble reactive phosphorus was measured using the ascorbic acid/molybdenum blue method[18].

transects these locations are along streams that flow within grasslands.

Nitrate is a nutrient of special interest because it can indicate land use changes which have important consequences for water quality[8,9]. Nitrate moves readily through soil. Thus, the concentrations of this nutrient were quite high at the inflow to Lukurmata raised fields (average 4195 $\mu g\ l^{-1}$ N Table 1) because the source was a groundwater spring. After water passed through the canals between raised fields, nitrate concentrations declined dramatically to a mean of 57 $\mu g\ l^{-1}$ N at the outflow. The percent concentration in the outflow divided by inflow was substantially lower in this transect (1.4%) than in the other transects (Table 1). This may have been due to uptake of nitrate by the abundant macrophytes and algae in the raised-field canals. Experimental nutrient bioassays[10] demonstrated that growth of the aquatic vegetation in the canals was limited by both nitrogen and phosphorus[11]. This growth lowered concentrations of these nutrients in the canals. Other processes such as denitrification, nitrification and N mineralization in the canal sediments may also be important. This is the case in comparable systems of other regions[12].

Inflowing nitrate levels at the Tiwanaku raised-field site were relatively low (83 $\mu g\ l^{-1}$ N) because the source was the Tiwanaku River. Photosynthetic algae upstream in the river used and depleted this nutrient. Nitrate levels were reduced still further within this raised-field system to outflow levels (43 $\mu g\ l^{-1}$ N) that were below, but not significantly different from, the Lukurmata outflow values. In the two transects with conventional land use nitrate levels also declined substantially. Outflow levels (464 and 413 $\mu g\ l^{-1}$ N), however, remained an order of magnitude higher than at both raised-field sites (see below).

Soluble reactive phosphorus also declined substantially as the water passed through the raised fields. Inflow concentrations averaged 425 $\mu g\ l^{-1}$ P at Lukurmata, with outflow concentrations declining to 34 $\mu g\ l^{-1}$ P (Table 1). This was remarkably close to the outflow level of 35 $\mu g\ l^{-1}$ P at Tiwanaku. In the long ecotones without raised fields, phosphorus concentrations also decreased, but only to 64 and 69 $\mu g\ l^{-1}$ P. Multiple-comparison tests showed that declines in soluble reactive phosphorus concentrations were significantly greater in the Lukurmata raised-field transect ($P<0.05$) than in the adjacent conventional long ecotones (Table 1). These results are similar to those for nitrate.

The transect near the Tiwanaku River demonstrates that raised fields can also filter out suspended sediments and thus dramatically increase water clarity (Table 2). Most raised fields we have observed, as in Lukurmata, are fed by small streams and springs with clear inflowing water. Fields in the Tiwanaku transect, however, are fed by very turbid water diverted from the Tiwanaku River. This turbidity is due to the high suspended sediment load in the river. At the inflow to these fields we have noted very high concentrations (mean 29.5 turbidity units). Within this raised-field system, the concentrations declined substantially to 5 turbidity units; at the outflow they were even lower (1.7 turbidity units). At Lukurmata the water was still less turbid at the outflow (0.9 units). We have not observed such dramatic reductions in turbidity in any other transects. In fact, in the conventional long ecotones, turbidity increased significantly to a mean value of 6.5 (Table 2).

Concentrations of nutrients and sediments flowing into the raised-field systems varied substantially according to whether the source was surface water or groundwater. Thus, in order to evaluate the retention capacity of raised-field systems we compared differences in outflow concentrations between pooled raised-field transects and pooled conventional long ecotone transects (Fig. 2). We found strikingly lower outflow concentrations in raised-field transects for both major nutrients and

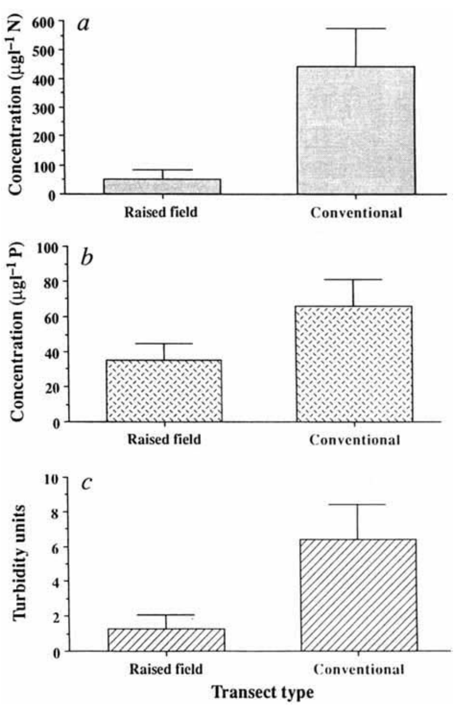

FIG. 2 Mean outflows of major nutrients and suspended sediments for raised fields and conventional land use in long ecotones (a nitrate, b phosphate, c turbidity). Error bars are 95% confidence limits.

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TABLE 2 Average turbidity changes within ecotonal transects

Transect	Inflow	Outflow	O/I(%)
Raised Field 2	29.5(±4.0)	1.7(±0.5)	5.8
Raised Field 1	2.0(±1.1)	0.9(±0.2)	45
Conventional 1	2.0(±1.0)	5.0(±0.7)	250
Conventional 2	1.7(±0.6)	7.9(±1.2)	465

Turbidity was measured as absorbance spectrophotometrically[19].

turbidity. This reflected enhanced and remarkably consistent retention of these materials by the two raised-field systems. The differences between raised fields and conventional methods were greatest for nitrate (Fig. 2*a*). The mean outflow at raised-field sites, 53μg l^{-1} N, was about one order of magnitude lower than at other long ecotones, 441 μg l^{-1} N. Mean outflow concentrations of phosphate and suspended sediments were also significantly lower ($P<0.05$) at raised-field sites.

In conclusion, this study indicates that there are environmental benefits of raised-field agriculture which help sustain improved yields. Nutrients are kept within the agricultural system since they are taken up in dissolved form by aquatic vegetation or are otherwise retained in canals. In addition, there is substantial growth in the canals of the water fern *Azolla* and its nitrogen-fixing endosymbionts. This vegetation is periodically recycled by farmers from canals to raised fields to serve as an organic fertilizer. We have observed extensive and regular use of two techniques for nutrient recovery during the rehabilitation: first, direct harvest of aquatic vegetation from the canals and second, shovelling of canal sediments into fields during the dry season, which both maintains the canal network and improves planting beds with organic nutrient-rich sediments. Archaeological evidence indicates that the farmers of Tiwanaku also used these techniques[13]. These practices add to the retention and recycling of essential nutrients and organic matter, and erosion is minimized. Thus, sediment and associated nutrients do not cause the downstream and nearshore pollution observed in other parts of the lake. Shifts in land use are recorded by clear changes in material fluxes to the nearshore sediments[14]. This nutrient flow and cycling in raised-field systems is in sharp contrast to regions where inorganic fertilizers are not retained in agricultural systems, and serious downstream nutrient contamination problems result[8,9]. Macrophytes, which function like the raised-field canal vegetation, can mitigate such problems throughout the world[15].

We should emphasize that the type and extent of these environmental benefits depends on the location of the raised fields in the landscape, hydrological conditions, and agricultural management practices. For example, the first raised-field site retains high levels of nutrients while turbidity is low throughout, whereas the second such site retains high suspended sediments while major nutrients are relatively low throughout. Ideally, raised fields should be located in the flat plains near the lake shore. This allows tnem to intercept and retain both nutrients and sediments from both nonpoint and major point sources before the water enters the lake. There is currently great variability in where and how raised fields are being rehabilitated. Thus, to help ensure more sustainable development, the environmental factors presented here should be considered and their applications optimized. A guiding principle should be the maintenance of the desirable features of wetlands: high productivity and biodiversity coupled with retention of soils and nutrients. As the raised-field agricultural expansion continues, long-term experimental research and monitoring of reconstructed raised fields are needed to further improve both economic and environmental benefits. □

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Extraction of bound porphyrins from sulphur-rich sediments and their use for reconstruction of palaeoenvironments

P. Schaeffer, R. Ocampo*, H. J. Callot & P. Albrecht*

URA 31 associée au CNRS, Institut de Chimie, Université Louis Pasteur, 1 rue Blaise Pascal, 67000 Strasbourg, France

PORPHYRINS, which are present in most sediments and crude oils, represent the 'molecular fossils' of compounds such as chlorophylls, bacteriochlorophylls and haems in the organisms from which the organic material is derived[1–4]. They have the potential to provide information about palaeoenvironmental conditions at the time of deposition[5–9]. Porphyrins derived from degradation of chlorophylls are of particular interest because of the possibility of relating palaeoproductivity estimates from sediments to chlorophyll-based measurements of present-day productivity determined by remote sensing. But standard analytical methods do not detect all of the porphyrins present in a geological sample — a substantial fraction of the porphyrins may be bound to kerogen[10,11] or to solvent-extractable macromolecules, or may be degraded by the oxidative extraction procedures. It has been shown recently[12–16] that sulphur may play a crucial part in binding 'biomarker' molecules at an early stage of sediment diagenesis, and that desulphurization using Raney nickel may liberate small molecules bound to sulphur-containing species. Here we show that this approach releases large amounts of porphyrins from the total organic extract of a sulphur-rich marl. Liberating bound porphyrins in this way may greatly enhance the amount of information on palaeoenvironments that can be extracted from geochemical analysis of sediments.

*To whom correspondence should be addressed.

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