LETTERS

Worthy investigations

Views are exchanged on whether "agricultural intensification" and "sustainability" are compatible. New developments in high-temperature superconductivity are examined, and two groups of researchers explore a nonproverbial "hill of beans" (right) and what it can tell us about "the natural development of hillslopes."

ROLF AALTO

Agricultural Strategies

The article "Agricultural intensification and ecosystem properties" by P. A. Matson *et al.* (25 July, p. 504) provides much useful information, but seems to imply that intensification and sustainability are incompatible.

Given population pressures, a more sustainable agricultural system must be more, not less, intensive, and intensification can, in fact, allow sustainability. For example, intensification usually provides increased ground cover through rapid plant growth, multiple cropping, or reduced tillage, which in turn reduces soil and water loss and increases soil biomass. However, the most important benefit is that intensification of agriculture on more suitable land can reduce the need to cultivate marginal land or allow marginal land to be cultivated in a more benign manner.

Everyone concerned with renewable natural resources, a livable environment, and adequate food supply should agree that we must intensify agriculture in order for it to be sustainable. The sophisticated strategies the authors suggest (labor, knowledge, management) are certainly more intensive than a monoculture system. Why not say so?

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Response: We hope (and believe) that our article in no way implied that agricultural intensification is incompatible with sustainability. We identified some of the ecological and environmental consequences of the particular intensification route that agriculture has taken over the past 50 years. At the same time, we described several strategies, such as integrated nutrient management and integrated pest management, that can help to reduce some of these negative consequences. As Massey points out and as we stated in our article, these latter strategies are knowledge and management intensive. Our article dealt with how understanding and manipulation of ecological processes can contribute to these strategies and provide an alternative route to sustainability and intensification.

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High-Temperature Superconductors

Developing new approaches for improving the critical current density (J_c) in bulk high-temperature superconductors is important to the commercialization of these materials in power transmission cables and other applications (*1*). I. Chong *et al.* (Reports, 2 May, p. 770) (*2*) describe significant improvements in J_c for lead (Pb)- doped $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals. Pb-doping of the bismuth (Bi)-based copper oxide superconductors has been studied extensively in polycrystalline and single crystal materials, because it was discovered that this process facilitates the formation of the higher critical temperature (T_c) phase (*3*) now known to be $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$. Chong *et al.* focus on the subset of this work that has investigated Bi-2212 single crystals. They state that earlier studies of $Bi_{2-y}Pb_ySr_2CaCu_2O_{8+\delta}$ did not address the effects of incorporating large fractions of Pb ($y > .0.4$), but some of these effects have been investigated (4–7). Wang *et al.* (4) showed that heavy Pb-doping of Bi-2212 single crystals ($y \approx 0.7$) produced large, order-of-magnitude increases in J_c. These results were confirmed and extended by Wu *et al.* (5) in their studies of heavily doped ($y = 0.7$) Bi-2212 crystals. Wu *et al.* used magnetization and muon spin relaxation measurements to show that Pb-doping increased J_c and shifted the irreversibility line upward, respectively, by large amounts relative to pure Bi-2212 crystals.

In addition, Chong *et al.* present structural data which indicate that Pb-doping creates a striped domain structure with modulation-free regions, and they reasonably suggest that the planar defects between domains might correspond to strong pinning sites responsible for the observed J_c enhancements. Similar structural features have been described previously as occurring in heavily Pb-doped single crystals (6, 7). In electron microscopy studies of series of Pb-doped Bi-2212 single crystals, Chen *et al.* (6) showed that Pb-doping causes complex structural changes that include a striped domain structure. The domain structure described by Chen *et al.* (6) has differences compared with that of Chong *et al.* (2), which may reflect different crystal growth conditions, but still results in the formation of planar defects central to the pinning argument made by Chong *et al.* Furthermore, we previously used scanning tunneling microscopy (STM) to elucidate the role of Pb-doping ($0 \le y \le 0.7$) on disorder and structural modulations in a series of Pb-doped Bi-2212 single crystals (7) and concluded that it was unlikely that atomic-scale point defects caused the large J_c enhancements (4). These previous studies (6, 7) bear directly on the structural data described by Chong *et al.*

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Response: We appreciate Lieber and Yang calling our attention to previous studies, some of which we were not aware. Particularly, the work by Wang *et al.* (1) should have been cited in our report (2). They found a large value for J_c in a Bi-2212 single crystal with a nominal Pb content of 0.7 per formula unit. Wang *et al.*, however, did not describe any enhancement of J_c above 30 K. It has long and widely been recognized that the increase of J_c at high temperatures is the key for the large-scale applications of Bi-2212, and many studies have been done to find how to generate pinning centers that work effectively at high temperatures. Wang *et al.* reported a large J_c at 5 K, but the high-temperature data available from their paper show $J_c \sim 5 \times 10^3$ ampere per centimeter squared at $T = 30$ K and a magnetic field (H) of 4 kilooersted. This value is much smaller than $J_c \sim 1 \times 10^5$ ampere per centimeter squared, which we obtained under the same conditions for our $x = 0.6$ crystal (2). Moreover, the upward shift of the irreversibility line exhibited in our study indicates that the enhancement of J_c continues at high temperatures also.

An upward shift of the irreversibility line was also described by Wu *et al.* (3): the irreversible field (H_{irr}) was 0.17 T at 50 K for their $Pb_{0.7}Bi_{1.3}Sr_2CaCu_2O_8$ crystal. The corresponding H_{irr} of our $x = 0.6$ crystal was 0.4 T, twice as large as their value. The lack of data at higher temperatures in their report (3) prevents us from making a comparison above 50 K. These differences in J_c and H_{irr} at high temperatures must reflect an essential difference in the inherent pinning mechanism between their and our crystals. Wang *et al.* attributed the increase of J_c to the disordering of the modulation, as deduced from the examination of one Pb composition. In contrast, we studied the Pb-doping effects in a systematic way using crystals with different Pb contents from both magnetic and structural points of view and deduced the relation between the enhancement of J_c and the appearance of the specific microstructures. Large enhancements of J_c and H_{irr} were revealed for crystals with Pb content of $x \geq 0.6$ in which a two-phase microstructure appeared. Relatively small but significant increases in J_c and H_{irr} were found for the $x = 0.4$ crystal, but not for the $x = 0.6$ crystal. The minor improvement in the $x = 0.4$ crystal must have another origin, such as reduction in anisotropy, generation of point defects, or a disorder in the modulation as pointed out by Wang *et al.* (3).

Our work clearly demonstrated that the flux pinning is dramatically enhanced even at 50 to 60 K, at which point the specific, Pb-content–alternating microstructure appears.

Lieber and Yang referred to the transmission electron microscopy (TEM) study by Chen *et al.* (4), where a striped domain structure was described. But these stripes were parallel to the [110] or [210] direction. This was not the case in our TEM observations, where the domain interface was always perpendicular to the [010] direction. Also, we noted the absence of any modulations in every second stripe. No comments were made by Chen *et al.* on the relation between the domain structure and the nature of modulation. It is difficult to find any definite relation between their TEM results and ours. Chen *et al.* (4) do not discuss J_c.

Finally, concerning the STM results by Lieber's group, we are not convinced that STM experiments can really detect inhomogeneity or disorder inside crystals. It is only a cleaved surface that is examined by this method. There are no guarantees that a BiO layer keeps its original properties after the counter BiO layer is removed.

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A Hill of Beans

Alexander L. Densmore *et al.* (Reports, 17 Jan., p. 369) address an important geomorphologic question: What is the relative importance of large, infrequent, slope-clearing events (SCEs) in determining hillslope longitudinal profiles? To model the frequency and magnitude distribution of SCEs, they filled a narrow [2.5-centimeter (cm)] flume with red beans, slowly lowered an outlet on one end to simulate an incising river, and recorded the resulting mass flux from their simulated hillslope with each 0.5-cm drop in base level. While occurring only 10% of the time, SCEs in their flume accounted for 70% of the total mass removed from the landscape. Between individual SCEs, smaller events developed steep "inner gorges" that were eventually cleared by the next SCE, which suggests that similar features in natural landscapes reflect SCE frequency, not changes in river incision rate as typically assumed.

We were intrigued by the results from this simulation of hillslope failure and recreated