Ecological Engineering 52 (2013) 224–227

Contents lists available at SciVerse ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Letter to the Editor

Comment on "Ecological engineers ahead of their time: The functioning of pre-Columbian raised-field agriculture and its potential contributions to sustainability today" by Dephine Renard et al.

Keywords:
Sustainable development
Indigenous knowledge
Ecologically intensive agriculture
Ecosystem engineers

In their recent review of the literature on the functioning of pre-Columbian raised-field agriculture, Renard et al. (2012) argue that "archaeology offers examples of prehistoric pathways to agricultural intensification that could be rich sources of inspiration for applying ecological engineering in agriculture today." As undeniably appealing as their message may be at first glance, in-depth reading of their article suggests however that they have sidestepped a significant body of literature, which would perhaps have led them in a different direction.

For one of the examples analyzed in detail by Renard et al. (2012), it would be difficult to contend with their enthusiastic endorsement. The Chinampas of the Basin of Mexico are indeed inspirational in sundry ways. This very particular form of wetland agriculture has been practiced in the region of Mexico City for perhaps as long as 2000 years. It was instrumental in giving rise to the Aztec civilization, was the "breadbasket" of Mexico until the mid-20th century, and it is still in use today, albeit in a much smaller area than was the case historically (Jacobson et al., 2009; Morehart, 2012). Recent observations confirm archeological records suggesting that the legendary productivity of chinampan agriculture resulted in several crops of corn, beans, squashes, and other vegetables per year on soils that remained fertile for centuries without having to lie fallow (Coe, 1964; Back, 1981). This is clearly an inspiring system, an engineering feat, on a par with the gardens of the Dogons in Mali (Africa), or with the hill-slope, terraced rice fields in China, which have been under continuous cultivation for thousands of years. There is no question that one would want to emulate these examples wherever possible.

However, evidence suggests that the Chinampas constitute a unique, atypical case among all those considered by Renard et al. (2012). Based on my own experience in Bolivia and Peru, as well as on a broad range of literature sources that Renard et al. (2012), regrettably, do not cite, I would argue that raised or "ridged" fields are a very different story than the Chinampas, and not just because the techniques developed for the construction of Chinampas are so unique. At this stage, in many situations, raised fields are more a puzzling occurrence than a model, and it is quite a stretch to portray them as a form of ecological engineering *avant la lettre*. For one thing, except in rare, isolated situations (Caillavet, 2008), raised fields were abandoned many centuries ago in the different parts of Latin-America where their remnants are found, and virtually no living tradition of any kind survives concerning them among the local populations in most regions in Latin America. In particular, Swartley (2002) demonstrates very convincingly (in a remarkably documented and well-written book) that whatever indigenous tradition may exist at the moment in Bolivia and Peru about raised fields, has been entirely "invented" by archeologists and Non-Governmental Organizations (NGOs) workers, starting in the 1980s.

This case of raised fields in Bolivia and Peru, around lake Titicaca, is interesting in many respects, and has been the object of considerable research. For many decades, as in other parts of Latin America (e.g., Parsons and Bowen, 1966; Smith et al., 1968; Siemens and Puleston, 1972; Parsons, 1969; Pozorski et al., 1983; Sattaur, 1988; Jacob, 1995; Wilson et al., 2002), archeologists working both in Bolivia and Peru noticed vast expanses of gently undulating ridges near lake Titicaca. They identified these ridges as eroded remnants of raised fields, which archeological artifacts indicated were contemporaneous with the pre-Inca Tiwanaku society. Until the early 1980s, nobody seems to have had a solid explanation for the fact that a city of the size and magnificence of Tiwanaku, with its enormous pyramid and impressive temples, could have arisen in the middle of what is now the inhospitable, semi-arid, cold, and sparsely populated altiplano, even accounting for significant climate change over the past millennium. Kolata (1993) and co-workers hypothesized that the tens of thousands of hectares of raised fields whose remnants were discernable in the area must have been cultivated all at once, and that crop production on these fields must have been plentiful enough to allow an important portion of the population to be urbanized, and therefore dispensed of farming duties.

There was no evidential support for that hypothesis at the time, and one could argue that there is still none at present. Whatever relevant evidence is available can be envisaged from a number of alternative perspectives. For example, it is abundantly documented that the water level in lake Titicaca has fluctuated appreciably in the past (e.g., Abbott et al., 1997; Binford et al., 1997; Delclaux et al., 2007; Flores et al., 2011), including during the period when the raised fields are claimed to have been constructed. Because the topography is very flat in the altiplano near lake Titicaca, it is more than likely that the shores of lake Titicaca moved historically over distances of many kilometers. Erickson (2000) has estimated that a lake level change of 1 m can either inundate or expose approximately 120,000 ha of land surface in the area. The simplest hypothesis therefore to account for the vast areas covered with remnants of raised fields is that a possibly small population of lakeshore dwellers followed the lake when it receded, and kept building raised fields as a form of drainage so that they could grow crops along the shores, to complement their fish-based diet with

http://dx.doi.org/10.1016/j.ecoleng.2012.11.011

potatoes and various types of cereals and vegetables. Or, as various authors (Smith et al., 1968; Zimmerer, 1991, 1995, 2011) suggest, the primary focus of farmers may have been irrigation, near the lake Titicaca or any of its tributaries. Whatever the purpose may have been to dig canals and pile the soil up (and we may never be able to tell for sure), it is likely that, as the lakeshore moved, near-shore raised fields were systematically abandoned and new ones were built, which would account for the abundance of vestiges of raised fields.

From this perspective, if there was such a thing at the time as an indigenous raised-field "technology", its use may have been extremely limited geographically, its purpose may have been solely to drain the soil/sediments sufficiently for plants to grow almost right at the lakeshore or, conversely, to irrigate them at some distance away, and it may not have been at all as productive as has been claimed. Lombardo (2010) and Lombardo et al. (2011a,b) recently reached a similar conclusion. Based on field and remote sensing data obtained in the Bolivian lowlands (Llanos de Moxos), they conclude that, far from a pre-Columbian green revolution, raised fields may have been only a survival strategy, meant to cope with periodic flooding. This perspective is consistent with some of the reasons that seem to have motivated other populations in the world to construct raised fields (e.g., Molle et al., 1999) and, incidentally, it pits raised fields against a whole range of other available techniques to drain (or irrigate) agricultural fields, which might be more water-conservative or versatile, and far less labor-intensive than raised fields.

Unfortunately, the simpler, "lakeshore dwelling" hypothesis does not seem to have been investigated seriously at the onset of the fieldwork on the rehabilitation of raised fields. The research that took place instead in Bolivia and Peru, in the eighties and early nineties, has been analyzed in great detail by Swartley (2002) and a number of other observers. It can best be described, from my perspective, as a missed opportunity for meaningful interdisciplinary work. Several archeologists did set out on their own, apparently without input from soil scientists or agronomists, to carry out small-scale demonstration experiments to provide support for the hypothesis that raised fields were a highly productive technology at the heyday of the Tiwanaku society. These efforts were also portrayed as a form of "applied" archeology, promoting the resurrection of ancestral techniques to help current indigenous populations alleviate poverty. Anyway, consistent with the need to validate the prevalent archeological hypothesis, local farmers were expected to re-construct raised fields only with tools available to their ancestors (see Fig. 12, "Tools for raised field cultivation", in Swartley (2002)), at various locations in the altiplano where vestiges of raised fields were found, even at distances of 20 or 30 km from the lake shores. In fact, in some cases, raised fields were constructed so far from any body of water that the canals among the raised fields never contained any water (Giandomenico, 1998).

Since many soils in the altiplano are saline (Morales et al., 1997; Morales-Belpaire and Amurrio-Ordonez, 2001, 2002; Tenpas, 2006), with, as is often the case, significant salt accumulation near the surface, and decreasing salt content in depth, one would expect that after digging soil and piling it up to construct raised platforms (which in most cases, to decrease labor, means simply inverting the soil profile), the resulting top soil on the raised fields would have lower salinity than the original soil and not significantly lower fertility otherwise (since the nutrient status of the soils in the altiplano tends to be low throughout the profile). This situation would likely lead to much higher crop yields. Lower salinity probably would also mean higher tolerance of crops to seasonal nighttime frosts (Swartley, 2002). The archeologists involved in the research did indeed obtain higher crop yields immediately after construction of the raised fields, in spite of occasional frost events, leading rapidly to claims that their theory regarding the raised fields was validated. The resistance to frost was attributed to the storage of heat during the day by water-filled canals, or by drainage of cold air in the dry canals (Bray, 1990; Kolata, 1993). The positive message concerning high crop productivity was emphasized further by reporting yields, not on the basis of total field area (i.e., raised fields plus canals), as one would expect, but relative to the surface area solely of the raised fields. Compared to traditional fields, this practice artificially inflated areal yields, sometimes by as much as 100% (depending on the width of the canals and of the raised fields). In spite of early warnings against it (Erickson, 1985), this way of reporting yields was the norm in Bolivia when my student Diego Sanchez de Lozada and I started working there in the early nineties.

If salinity dilution was the explanation of the high yields, then one would expect the effect to decrease after a year or two, during which the surface evaporation would progressively reestablish the original salinity profile of the soil. And indeed, after two or three growing seasons, the yields of the reconstructed raised fields often dropped back to their original levels if not even lower, leading many farmers who had been lured into re-building raised fields to abandon them. Indeed, by the early 1990s, many rehabilitation projects had failed (e.g., Giandomenico, 1998; Morris, 1999; Swartley, 2002). At that point, however, the high productivity of raised fields had already been promulgated by some almost as a dogma (e.g., Bray, 1990; Straughan, 1991; Kolata, 1993; Janusek and Kolata, 2004). On its basis, a very elaborate conceptual construct had been erected, representing the Tiwanaku empire as an efficient top-down organization, which eventually collapsed due to climatic reasons (Ortloff and Kolata, 1993). For all of this as well, it has been argued that there is very little supporting evidence (Graffam, 1992; Williams, 2002). In many ways, the lack of evidence did not seem to matter. The idea that a local, indigenous technology, associated with a supposedly prestigious past, was apparently more effective than mechanized agriculture in the altiplano, resonated very favorably with a number of different political agendas in Bolivia and Peru, as well as in Washington, where many officials were eager to keep migrant workers away from coca production and deforestation (Kojima et al., 2006) in the Chapare region of Bolivia.

When an effort was finally launched, around 1993, to investigate scientifically whether the supposedly "indigenous" raised-field technology presented any real interest under current conditions in the Altiplano, a first obstacle to overcome was to convince funding agencies that serious work required controlled field experiments, proper statistical design, and appropriate experimentation, all of which caused funding requests to be significantly higher than the low-technology, shoe-string operations advocated by leading archeologists. Soon after serious experiments started, they quickly yielded results indicating that simply reconstructing raised fields would not do much for the farmers in the Altiplano. The frost mitigation effect of raised fields appeared small (Sanchez De Lozada et al., 1998). Although crops could be protected under mild frosts (Stache, 2000), evidence suggests that the effect would not be significant under more intense ones (Lhomme and Vacher, 2002; Hijmans et al., 2003; Lhomme et al., 2007). Yields, even the first year after rebuilding the raised fields, were not drastically different than in traditional fields (Stache, 2000; Sanchez De Lozada et al., 2006), when evaluated on a comparable basis (total field area), so that in many cases farmers had the distinct impression they had wasted sizeable amounts of time in back-breaking labor, all for basically nothing. Finally, epidemiological investigations revealed that the canals associated with the raised fields, when filled with water, contributed to an increase in the spread of liver flukes within both the cattle and human populations of the area (Celiz Aquize, unpublished data, Cornell University, 1999). This problem is common on