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Thinking Outside the Continent and Outside the Box: Cross-Continental Comparative Studies Can Enrich Studies of Pre-Columbian Raised-Field Agriculture

Doyle McKey^{1*}, Leonor Rodrigues², Javier Ruiz-Pérez³, Rumsais Blatrix¹, and Stéphen Rostain⁴

¹CEFE, Univ Montpellier, CNRS, EPHE, IRD, Univ Paul Valéry Montpellier 3, Montpellier, France.

²Agroscope Reckenholz, Research group Climate and Agriculture, Reckenholzstrasse 191, 8046 Zürich, Switzerland.

³CaSEs - Culture and Socio-Ecological Dynamics research group, Department of Humanities, Universitat Pompeu Fabra, C/ Ramon Trias Fargas 25-27, 08005 Barcelona, Spain.

⁴UMR 8096 “Archéologie Des Amériques”, CNRS, Panthéon-Sorbonne University, Centre Malher, 9 rue Malher, 75004 Paris, France.

*Corresponding author: doyle.mckey@cefe.cnrs.fr

Abstract. Despite an attempt at intercontinental synthesis by Denevan and Turner almost 50 years ago, studies of agricultural raised fields (RFs) in the Neotropics, on the one hand, and in Africa and New Guinea, on the other, are separate research traditions, with almost no communication between them. Neotropical studies refer to “raised-field agriculture”, and almost exclusively concern archaeological systems in wetlands. Studies in Africa and New Guinea refer to “mound” or “ridge” cultivation, and concern mostly present-day systems (in Africa) or both present-day and archaeological systems (in New Guinea), in both uplands and wetlands. Ethnographic studies of present-day systems provide insights into questions about past systems that are inaccessible using archaeological methods alone. Our review suggests that the Neotropical focus on RF agriculture as an exclusively wetland adaptation is misleading. We argue that the most widespread purpose of building RFs, in both wetland and upland environments, is to concentrate topsoil and organic matter, enabling creation of fertile patches in infertile and low-biomass grassland environments. Avoiding flooding is an important function of RFs built in wetlands and wetland margins. We further show that Old-World RFs are often not perennial, but are short-lived structures that rotate over the landscape, being torn down and rebuilt nearby in successive cycles. Short fallow periods are allowed (or even favored) by methods of managing fertility. Finally, we argue that the restriction—in all continents—of archaeological raised fields to wetland and wetland-margin environments is in part a result of their better preservation from erosion in wetland than in upland environments.

Keywords: raised-field agriculture, cross-continental analysis, pre-Columbian Amazonia, mound cultivation, ridge cultivation

1. Introduction

The earliest studies of earthworks in the Americas that function as elevated planting surfaces were placed solidly within a comparative framework. Denevan (1966) drew explicit parallels between pre-Columbian earthworks he studied in Bolivia and extant or historically documented elevated planting surfaces in Africa, in Oceania, and in medieval England. He considered their comparative study to be a source of insight into how pre-Columbian earthworks were managed. Through the work of Denevan and of others, such as Plafker (1963) or Turner and Harrison (1981), the pre-Columbian earthworks came to be known as “raised fields” (which we will abbreviate as “RFs”) and the systems based around them came to be termed “raised-field agriculture” (“RF agriculture”, for brevity).

Further developing the comparative framework, Denevan and Turner (1974) reviewed extant systems of RF agriculture in the Old World, defining RFs as “any prepared land involving the transfer and elevation of soil above the surface of the earth to improve cultivating conditions” (Denevan and Turner 1974:24). It is interesting to note that prior to Denevan and Turner’s review, the terms “raised field” and “raised-field agriculture” seem not to have been applied to Old-World structures and systems. The studies they reviewed referred most often to “mound cultivation” or “ridge cultivation”. For example, of the 65 references cited by Denevan and Turner (1974), none included “raised fields” in the title, whereas in five the words “ridge”, “ridged”, “camber bed”, or “mound” appeared in the title. Furthermore, in some of the principal references cited by Denevan and Turner (1974) (e.g., Miracle [1967]), the term “raised field” never appears in the entire text, while “mound” and “ridge” are frequently used. Thus, before Denevan

and Turner's seminal review (1974), students of farming in the Old World were using different terms to describe a diversity of structures that students of the New World increasingly frequently grouped as "raised fields".

Despite the attempt at synthesis by these two pioneers—who clearly saw mound and ridge cultivation as types of practices encompassed by "raised-field agriculture"—the terminological disconnect has persisted in the almost 50 years since. A cursory literature search indicates the extent of the disconnect. A search in Google Scholar (May 14, 2021) for the term "raised-field agriculture" gave 1,490 results. Of the first 100, 92 concerned exclusively Neotropical systems. The list also included the article by Denevan and Turner (1974) and five recent comparative studies from our group (Comptour et al., 2018; McKey et al. 2014, 2017; Renard et al. 2012; Rodrigues et al. 2020) that began to present the message developed in this paper. Only three studies concerned Old-World systems, in Europe (Groenman-van Waateringe et al. 2017) and in China (Lan et al. 2012; Yanying et al. 2014), all referencing articles on Neotropical systems. In contrast, of 1,570 studies found in Google Scholar referencing "ridge cultivation", the first 100 all concerned systems in the Old World and Oceania. Similarly, of 280 studies referencing "mound cultivation", of the first 100, 94 concerned exclusively systems in the Old World and Oceania and one was a North American study grounded in European traditions (Page-Dumroese et al. 1997). The list also included Denevan and Turner (1974), McKey et al. (2017), and two general reviews by Kiviat (1991, 2014). The only article focused solely on a New-World system was that by Killion (2008).

Two research traditions have thus developed along independent paths over the past 50 years. One is almost exclusively Neotropical, focused on archaeological (pre-

Columbian) systems (and on the *chinampas*, a system with pre-Columbian roots that persists today [Sluyter 1994]), and strongly associated with perennial or seasonal wetlands to which the known examples are restricted. The other tradition almost exclusively concerns the Old World and New Guinea, is largely actualistic (but also archaeological in the case of New Guinea [e.g., Denham 2018; Golson et al. 2017]), and associated with a diversity of environments, including but not restricted to wetlands.

Such differences between continents in how researchers name similar objects of study hinder communication and can lead to misinterpretation. We argue that archaeological RF agriculture in the Americas does not differ qualitatively from the mound or ridge cultivation systems known today in many settings in Africa and Oceania. The separation between these two research traditions is artificial, and examining them within a single conceptual framework, as Denevan and Turner (1974) proposed, would advance ecological and archaeological synthesis.

2. Pre-Columbian RFs in Tropical America: Present Knowledge and the Potential Contribution of Actualistic Studies

Vestiges of pre-Columbian RFs in Mesoamerica and South America are mounds, ridges, and platforms of diverse shapes and sizes, with many names in English, Spanish, and French, related to local idiosyncrasies and to subtly different techniques of construction. Known examples are restricted to wetlands, usually seasonally inundated wetlands, although some in Mesoamerica are in permanent wetlands (see examples in Table 1 and Figure 1). Their various designs and dimensions suggest they may be adapted to local edaphic conditions (Rodrigues et al. 2018; Rostain 2010), or that they

may reflect cultural differences (Erickson 1995; Walker 2011), two hypotheses that are not mutually exclusive. They are often considered together with ditched fields (which differ by the absence of raised planting structures) and like these, their association with wetlands suggests that avoiding flood risk is an important function (Denevan 2001). In contrast, the importance of other functions is sometimes minimized. For students of Mesoamerican RFs in permanent wetlands, the abundant evidence of nutrient management in present-day *chinampas* contributes to the easy acceptance of the importance of this function (e.g., Dahlin et al. 2005). However, for RFs in South American seasonal wetlands, speculations about addition of nutrient amendments to RFs (e.g., Erickson 2008; Erickson and Balée 2006) have been challenged. Critics point out that the *chinampas* model that dominates these speculations (i.e., the importance of muck and aquatic vegetation as nutrient amendments) cannot apply in highly seasonal wetlands (e.g., Baveye 2013; Lombardo et al. 2011). Furthermore, the absence of convincing evidence of nutrient management during the periods when these RFs were in cultivation has been used to suggest that nutrient management was unimportant (Lombardo et al. 2011) or that no organic amendment was practiced (Boixadera et al. 2019; Rodrigues et al. 2018).

Hypotheses about past functioning and management can be tested with several kinds of methods: geoarchaeological, archaeobotanical (plant microfossils), and dating (e.g., ^{14}C and OSL). The current soil preserves features owing to past land use, including modification of topography, stratigraphy, and micromorphology, presence of charcoal, burned earth, or other evidence of fire, presence of crop microfossils, and enrichment in certain elements (e.g., phosphorus, carbon) often concentrated by human

activities (Goldberg and MacPhail 2008; Pearsall 2015). However, many such traces of past practices can be quickly lost in the highly dynamic environments of the lowland tropics. High temperature and rainfall lead to constant physical and chemical weathering and erosion. While soil engineer organisms can sometimes work against erosion and preserve certain structures (McKey et al. 2010, 2021), at the same time they can also erase stratigraphy and enhance microbial weathering (Holliday 2004). For example, a study of present-day African RFs by our group showed that within less than 40 years, bioturbation almost completely removes the initial stratigraphic evidence of how fields are constructed and maintained with the periodic addition of organic matter (Rodrigues et al. 2020). In addition, archaeobotanical proxies can often under-represent certain crops (e.g., manioc produces few diagnostic phytoliths [Chandler-Ezell et al. 2006]), may be affected by post-depositional modifications and taphonomic processes (e.g., macro-charcoal in wetlands [Graves et al. 2019]), or are not even well preserved in tropical soils, as occurs with starch and pollen grains (Pearsall 2015).

Given the (at least temporary) limitations of geoarchaeological and archaeobotanical methods, researchers have turned to actualistic studies in attempts to answer unresolved questions about the functioning of pre-Columbian RFs. These studies follow two approaches. The first is to construct (or rehabilitate) and cultivate experimental RFs in areas and environments where RFs were formerly cultivated, using practices thought to be similar to those used by pre-Columbian farmers (e.g., Erickson 1995; Stab and Arce 2000). This approach can help to test different agricultural models derived from archaeological data, but it is logistically difficult to explore long-term dynamics. Such experiments are also fraught with uncertainties that sometimes make it

difficult to interpret their results (Lombardo et al. 2011; McKey et al. 2014). The other approach is that of ethnoarchaeology, the use of ethnographic information to address archaeological questions. Ethnoarchaeology draws analogies from the present to infer the techniques that past societies may have used when faced with similar environmental circumstances (David and Kramer 2001; Denham et al. 2007). This approach is based on the expectation that different societies may independently devise similar technical solutions to similar adaptive problems. Analogies are never perfect, and there may be subtle, or not-so-subtle, differences between environments that appear similar. Also, we do not expect convergence across continents in all aspects of RF agriculture. Environment influences, but does not determine, cultural adaptations; environment and human agency act together to shape technical solutions (Smith 2013). If applied judiciously, however, the ethnoarchaeological approach can provide key information on practices (e.g., construction, amendments, fallow periods, etc.) developed over the long term and applied in functioning agricultural systems. It also allows identifying what proxies can potentially serve as “smoking guns” for archaeological reconstructions. Adopting a cross-continental comparative approach, in this paper we ask what actualistic studies in the Old World can tell us about pre-Columbian systems in the Neotropics. Actualistic studies of ethnographic analogues can never supplant archaeological investigations. They can, however, complement them and suggest new questions for archaeologists.

Specifically, we use information on present-day RF agriculture in the Old World to explore the following open questions about pre-Columbian RF agriculture: (1) Were archaeological RFs exclusively wetland adaptations? (2) How important were non-

hydraulic functions of RFs? (3) Were RFs periodically left in fallow? If so, for how long? (4) Were archaeological RFs perennial structures like the *chinampas*, as appears to be often assumed? (5) Whereas present-day RFs in the Old World occur in both upland and wetland environments, how do we explain that not only in the Neotropics, but also in Africa and New Guinea, archaeological RFs found so far appear restricted to wetlands?

3. RFs Are Not Restricted to Flood-Prone Environments

In the Neotropics, recognized archaeological RFs appear to be restricted to wetlands (Denevan 2001; see examples in Table 1 and in Figure 1). In contrast, one of the most important conclusions of actualistic studies in the Old World—as already emphasized by Denevan and Turner (1974)—is that RF agriculture is not restricted to wetlands, being practiced in upland environments in many regions of Africa and Oceania. Interestingly, the same may be true in the Americas. Present-day agricultural systems in the Neotropics offer examples of mound cultivation that by Denevan and Turner's definition would qualify as raised fields. Two such examples are RFs in Haiti (Bier 2019) and maize mounds in Mesoamerica and northern Central America. There is a remarkable resemblance between the latter (see Figure 7-13 in Wilken [1987]) and the vestiges of pre-Columbian RFs in coastal savannas of French Guiana (see Figure 1 and Figure 4A in McKey et al. [2010])—on which maize was also grown (Iriarte et al. 2010; McKey et al. 2010). Similarly, except for their smaller size, present-day *camellones* (ridges) in upland environments in Mesoamerica (Figure 2-7 in Wilken [1987]) resemble pre-Columbian *camellones* in seasonally flooded savannas of the

Llanos de Mojos in Bolivia (see for example Figure 8.4 in Erickson and Balée [2006]). Has the disconnect between “raised fields” and “mound and ridge cultivation” affected our ability to detect commonalities, not only between the Old and the New World, but also between different systems in the New World? “Raised-field agriculture” in the Americas may be alive and well and hiding in plain sight.

4. The Importance of Non-Hydraulic Functions, in Both Flooding and Non-Flooding Environments

Because RF agriculture in the Neotropics is associated with flood-prone environments, drainage and the avoidance of flood risk are often considered to be the principal advantages conferred by raised fields (e.g., Denevan 1966; Lombardo et al. 2011; Nordenskiöld and Denevan 2009). However, these advantages are not relevant in upland environments, such as those in Africa and New Guinea where RFs are currently in use (e.g., Denham 2018; Golson et al. 2017; Krings 1991; Miracle 1967; Sillitoe 1998; Stromgaard 1988, 1990; see examples in Table 1 and in Figure 2). In both kinds of environments, advantages unrelated to hydraulic functions include the provision of deep loose soils that offer favorable physical conditions for root growth (particularly important for root crops) (Walker 2008:930), reduction of soil-borne pathogens (Thurston 1990), modification of microclimate around mounds (Denham 2018; Kolata and Ortloff 1989) and within mounds (heat generated by decomposition warms mound soils at high altitudes [Denham 2018]), control of weeds (Denevan and Turner 1974:26; Miracle 1967:162), control of erosion (Carney et al. 1993; Erickson 1992), facilitation of live storage of root crops and easier harvesting (Denevan and Turner 1974).

Of all these non-hydraulic functions, perhaps the most widespread is increasing soil fertility by the concentration of topsoil and organic matter, as proposed for pre-Columbian RFs by authors including Erickson (1992), Carney et al. (1993), and Biesboer et al. (1999). Throughout Africa and New Guinea, construction of RFs from uncultivated land includes the heaping up of turf and vegetation hoed from the surrounding area into piles, where it is buried in mounds or ridges (see for example Rounce and Thornton 1939; Sillitoe 1998; Stromgaard 1990; among many others). Methods of construction of RFs are also adapted to other needs, often showing striking convergence in widely separated sites. For example, in both Mossaka, Congo Republic (Rodrigues et al. 2020), and Tanzania (Mbegu 1996), farmers dig up grass with root clumps, placing the turf on the outside of the mound or ridge with the attached grass facing inwards. The root clumps impart mechanical stability to the wall of the mound or ridge (Rodrigues et al. 2020).

The nutrient-concentration function of RFs may be particularly important in low-fertility soils, and this could help explain patterns in the distribution of RFs across environments. In farming systems on poor soils without external inputs of fertilizers, and where the parent material does not enable rapid renewal of nutrients lost to harvest and erosion, organic matter from vegetation and litter is the key resource for soil fertility (Ruthenberg 1971). Trees have much greater ability than tropical grasses to remobilize nutrients (e.g., via upward transport from deeper soil layers) and to accumulate organic matter (Ruthenberg 1971), so that in forests, the amount of nutrients present in plant biomass and litter on a plot is usually sufficient to support a crop on the plot, once nutrients are released in plant-available form. In grasslands, however, plant biomass is

much lower and the amount of nutrients present in the vegetation on a plot is often insufficient to support crop growth on that plot. Crop production may thus depend on the concentration of nutrients from larger areas onto smaller areas that are cultivated (Mazoyer and Roudart 2006), either by taking advantage of pre-existing resource islands created by other organisms (Félix et al. 2018) or by transferring topsoil and biomass from the surrounding area and piling it into a smaller area, creating RFs.

In both Africa and New Guinea, the practice of making mounds and ridges is strongly associated with grasslands (usually anthropogenic in New Guinea), and is much less common in forests (Fresco 1986; Miracle 1967). Where people of the same society farm in both savanna and forest, as in forest/savanna mosaics in the Congo Basin, they practice large-scale mound or ridge cultivation only in savanna environments (Fresco 1986; Miracle 1967). However, there are areas in Congo-Basin savannas where neither mounding nor ridging is practiced, and the reasons for this uneven distribution are unknown (Miracle 1967). Furthermore, in fields cut in forest, root crops, particularly yams, but also manioc, are grown in mounds (Miracle 1967). In these cases another non-hydraulic function of mounding, the improvement of soil physical properties favoring growth of roots and tubers, may be more important than improvement of fertility (Kang and Wilson 1981). In several villages along the Alima River from Tchikapika to Boyoko, in the Cuvette province of Republic of Congo, Mbochi farmers build small RFs in patches of seasonal or permanent swamp forest after cutting and (incomplete) burning of the trees (Solibiéda 2013; see Table 1). On these RFs, termed *atshoro* (plur.; sing. *tshoro*), are planted maize, manioc, sweet potato, *Hibiscus sabdariffa*, and other crops (Figure 2E). Flood avoidance is an obvious function of these

RFs, but not the only one. Both muck from the flooded basin and herbaceous vegetation cut during weeding are periodically added to *atshoro* to increase their fertility. In these swamp forests, incomplete burning probably leads to lower ash deposits than in well-drained forests, so that these organic matter amendments may be as crucial as in grassland systems.

In New Guinea, mound cultivation is conducted in anthropogenic grasslands resulting from deforestation. It is regarded not as a wetland adaptation but as a kind of intensification made necessary by rapid loss of forest (and with it, of long-fallow swidden cultivation) (Denham 2018; Denham et al. 2017). Similarly, mound cultivation systems widespread in southeastern Africa seem to have developed when deforestation and population pressure (induced by government policies and through migration) reduced the area of miombo woodlands and made the *chitemene* system of slash-and-burn cultivation typical of the region unsustainable (Grogan et al. 2013; Stromgaard 1989).

The nutrient-concentrating function of RFs may be particularly important where livestock are not raised and animal manure is thus unavailable. In fact, the best-documented raised-field systems in Africa (Comptour et al. 2018; Rodrigues et al. 2020) concern human groups with little or no access to livestock and animal manure. For example, the Bemba people of northern Zambia, well known for mound cultivation (Stromgaard 1989, 1990), lack a tradition of animal husbandry (Grogan et al. 2013). However, in New Guinea, manure of pigs and other farmyard animals is often incorporated into compost mounds (Denham 2018; Sillitoe 1998, 2013).

Forest and grassland farming also differ in the major pathway by which nutrients are released in mineral form to become available to plants. Most shifting-cultivation

systems in forests depend on nutrients from biomass being released in the form of ash by combustion (Miracle 1967). In contrast, in grassland systems, particularly where animal manure is unavailable, decomposition of organic matter is an important source of plant-available nutrients, and the organic matter is usually composted in mounds or ridges. RFs in the Old World appear universally to function as compost mounds, and this is often viewed as their most important function (e.g., Shetto 1999:69). Decomposition-based systems offer two important advantages in grassland farming. First, herbaceous vegetation decomposes much more rapidly than woody vegetation, making composting much more practicable in grassland than in forest farming (Miracle 1967:134). Secondly, whereas biomass combustion and soil heating result in rapid release of mineral nutrients (e.g., Giardina et al. 2000), they also lead to nutrient loss to the atmosphere via both particulate (ash convection) and non-particulate pathways (volatilization of nutrients such as carbon, sulfur and nitrogen) (e.g., Neary et al. 1999; Qian et al. 2009). Thus, compared to ash-dependent systems, decomposition-based systems allow more efficient use and storage of the limited amount of organic matter that is available in low-biomass environments (Lunan 1950:88). Fire is not absent in RF cultivation in savannas, because burning confers many benefits besides nutrient release (Denevan 2001; Gliessman 2015). Controlled burns may be used to avoid uncontrolled fires during the peak “burn season” that would destroy the vegetation to be used for composting (Miracle 1967). Although ash and charcoal are included in compost mounds when available, in both Africa (e.g., Miracle 1967) and New Guinea (e.g., Sillitoe 1998), they are less important for nutrient supply in grassland than in forest systems.

Almost all of the modern examples from the Old World in the preceding paragraphs concern raised fields in non-flooding environments. However, fertility management through composting of organic matter is an important function of raised fields in flooding environments as well (Rodrigues et al. 2020). In both Africa and New Guinea, there is no sharp distinction, in terms of morphology and mode of construction, between wetland raised fields and raised fields in non-flooding environments. In at least three areas we are aware of in Africa, farmers construct very similar raised fields in non-flooding and adjacent flooding environments. The Senoufo people in Mali (Krings 1991), the Bemba and Unga people in the Bangweulu Basin in Zambia (McKey et al. 2017; Stromgaard 1990), and the Mboochi people in the Congo Basin (Solbiéda 2013) construct RFs over gradients from non-flooding uplands to wetlands, those in the latter environment differing mainly in their larger size, to protect crops from flooding. In New Guinea, mounds are cultivated in drylands and in wetland margins, with no striking differences in form or mode of construction between the two settings, except for the larger size of mounds constructed in swampy and flooded areas (Ballard 2017:80; Taraken and Ratsch 2009). In wetlands themselves, mound cultivation represented a first phase of intensification (during the mid-Holocene), being later replaced by even more intensively managed ditched fields (Denham et al. 2017).

In both Africa and New Guinea, we find support for the conclusion that concentration and composting of organic matter is a general function of RFs. RF agriculture is not simply a wetland adaptation (Denham 2018); rather, wetland RF agriculture is a specialized variant of a system that is widespread in grassland agriculture (McKey 2021). Protection from flooding is an important function of RFs in

these environments, where they are often built higher than in non-flooding environments.

5. It's About Time: Temporal Patterns in the Use of RFs

5.1. Fallow Periods in Old-World RFs

Fallow periods after cultivation allow restoration of nutrient stocks, as nutrients are increasingly immobilized in the regrowing vegetation. Whereas the *chinampas* can be continuously cultivated, studies postulating continuous cultivation of other pre-Columbian RFs, for example in Amazonian seasonal wetlands (Erickson 2008; Erickson and Balée 2006), have been strongly challenged (Baveye 2013; Lombardo et al. 2011; Rodrigues et al. 2015; Ruiz-Pérez 2020). The suggestion that fallow periods must have been required for RF agriculture in the infertile soils of seasonally flooded peri-Amazonian savannas appears to be generally accepted (Lombardo et al. 2013; Renard et al. 2012; Rodrigues et al. 2017; Ruiz-Pérez 2020; Walker 2004). What can studies of Old-World RFs suggest about questions around fallows in archaeological systems in the Neotropics?

Fallow periods certainly are a widespread feature of RF agriculture in Africa (Comptour et al. 2018; Rodrigues et al. 2020) and New Guinea (Sillitoe 1998; Taraken and Ratsch 2009), although mounds are in some cases reported to be continuously cultivated in the latter region (Denham 2018; Sillitoe 1998). When land is plentiful, fallows can be long, in grassland as in other environments, and long fallows delay soil exhaustion. However, grass fallows in RF agriculture are often short, for example 3-5 years after cultivation for 3-5 years in Zambia (Grogan et al. 2013), and 2-4 years after

cultivation for 5-6 years at Mossaka, Republic of Congo (Comptour et al. 2018). Although lower vegetation biomass makes many grassland soils less fertile under cultivation than soils under forest, several factors permit, necessitate, or even inevitably lead to, shorter fallow periods in grassland farming than in forest farming. (1) Grassland farming *permits* shorter fallow periods. Although total nutrient stocks per area in grassland vegetation can never reach those in forest vegetation, the rate of recovery during fallows is comparable to that of forest vegetation, or even faster, and also more rapidly reaches a plateau (Bartholomew et al. 1953). (2) Short fallows may be positively *favoured*, or even *made necessary*, in grassland farming. Short fallows lower the risk that an uncontrolled fire will destroy the vegetation required for compost before it can be buried in the mounds or ridges. The Pende people of Kwango (in present-day Democratic Republic of Congo) make (or made) mounds before the period of “bush fires”, “and because of fear of these annual fires the Pende reportedly never let a plot lie fallow more than nine months” (Miracle 1967:137). (3) Shorter fallows and grassland vegetation may be *ineluctably linked* consequences of a single underlying process. In areas where anthropogenic grasslands occupy formerly forested landscapes, grassland farming is a consequence of environmental degradation driven by fallow periods that were too short to allow complete restoration of forest nutrient stocks following depletion during the period of cultivation, with reciprocal positive feedbacks between grass and fire leading to a grass-dominated landscape (Ruthenberg 1971:47).

Under these circumstances, grassland farming is a kind of intensification that develops where forest farming is no longer possible, or when forested uplands are used for other purposes. For example, in the Llanos de Mojos, forest patches were probably

used for agroforestry, for habitation, or both (Denevan 1966:16; Walker 2018). The short fallows made necessary by population pressure in anthropogenic grasslands can be sustainable, apparently for long periods (Sillitoe 1998; Stromgaard 1990), but this requires diligent application of practices aimed at maintaining soil fertility, chief among them the concentration of nutrients, and their protection from fire, by composting in mounds and ridges. This scenario of intensification appears to apply to RF cultivation in parts of Africa—most notably the miombo woodlands of northern Zambia (Grogan et al. 2013; Stromgaard 1989)—and generally in the highland valleys of New Guinea (Denham 2018; Sillitoe 1998, 2013).

5.2. Rotational Cultivation: “Mound-Shifting”

It has often been assumed, explicitly or tacitly, that, like the *chinampas*, pre-Columbian RFs elsewhere were also built to be long-lived structures, and that, although not continuously used, they were rehabilitated (e.g., by addition of new topsoil and organic matter) and re-used after fallow periods. In many cases, this is likely to be true. RFs in flood-prone wetlands, particularly in zones where floods may be deep, must of necessity be quite tall (and broad) structures. Because building them requires substantial labor (see, for example, Walker 2004:43-47), once built, they should be used, and re-used, as long as possible. Not surprisingly, the largest present-day wetland raised fields so far documented in the Old World, those studied by Rodrigues et al. (2020) in the Republic of Congo, are long-lived structures that are maintained by the addition of topsoil and plant biomass for planting of a new crop after each fallow period.

However, a very frequent pattern seen in both Africa and New Guinea is a kind of “rotational cultivation” or “mound-shifting”. In this case, all the mounds of a plot are in fallow at the same time. At the end of the fallow, the old mounds are broken down. Crop residues and vegetation hoed from the old mounds are piled in the spaces between the mounds. Soil from the old mounds is then moved onto these piles to form new mounds. Mounds thus move “diagonally across the checkerboard” from one cycle to the next. This practice is followed, for example, by the Senoufo in Mali (Figure 20 in Krings [1991]), by the Bemba and Unga in Zambia (Figures 2A, B, this article), and by farmers in the Mount Hagen area of New Guinea (*kongderemen* type, Figure 4.7 in Denham [2018]). A similar rotational cultivation is practiced with ridges, for example, in the Mwanza District of what is now Tanzania (Rounce and Thornton 1939:352). Such shifting of RFs may slow down soil exhaustion under intensive cultivation.

In many sites, these short-lived mounds or ridges are structures of modest size (mounds of diameter c. 1-1.5 m) in non-flooding environments. However, in at least one site in Africa, even quite large wetland RFs are torn down after a single cycle of cultivation. On the Lunga Bank in Zambia’s Bangweulu Basin, Unga farmers construct mounds up to 1.7 m tall and 4 m diameter in an area in which flood waters rise to 70 cm or more (Figure 2A). Like smaller mounds in non-flooding environments, these large mounds are also torn down between cycles of cultivation (McKey et al. 2017). In New Guinea, mounds in upland settings that are torn down and rebuilt in rotational cultivation include mounds comparable in size to those on the Lunga Bank, as shown by photographs (e.g., Fig 4 in Taraken and Ratsch [2009]). Frequent destruction of RFs might also contribute to control of pests and pathogens. In a variant of rotational

cultivation, the Lunga Bank RFs are flattened after one manioc crop: RFs are not rebuilt, but wetland rice is grown the following year in the flat, flooded landscape. According to Unga farmers, beetle larvae feeding on manioc roots would destroy the crop if manioc were planted every year (McKey et al. 2017).

Many pre-Columbian RFs of the mound type, both in French Guiana (McKey et al. 2010) and in the Llanos de Mojos (Rodrigues et al. 2018; Ruiz-Pérez 2020), are smaller than these largest Old-World mounds subjected to rotational cultivation (Table 1). Were these, or other pre-Columbian RFs, similarly short-lived structures? For most cases, we lack the information to answer this question. However, for at least one site in wetlands in the Llanos de Mojos, Bermeo, there is evidence that ridge RFs were used, abandoned, and re-used episodically in several phases (sometimes separated by 100 years or more) over a period spanning almost 900 years until their final abandonment (Rodrigues et al. 2015).

If land is abundant, farmers may prefer to abandon an entire plot of RFs and construct new ones some distance away, instead of continuously rotating RFs in checkerboard fashion within a limited area where soils become increasingly exhausted. In a part of the Bateke Plateau in Gabon where savanna land is not limiting, farmers do not practice rotational cultivation, but abandon their savanna ridge fields after one or two cycles of cultivation, opening up new fields in areas that they often consider never to have been previously cultivated (Delêtre 2004).

Did any of these patterns characterize the use of space over time by RF farmers in pre-Columbian South America? The sites we know best are in the savannas of the Llanos de Mojos. With the fragmentary data available for this region, a hotspot of

linguistic, cultural, and biophysical diversity, any generalization rests on shaky ground. We tentatively note some apparent patterns. First, in many areas, satellite imagery and aerial photographs show numerous small complexes of RFs. Second, in areas where platform fields were built, these images show spatial superposition (overlapping) of fields, indicating that they were not all used at the same time (Lombardo 2010; Rodrigues et al. 2017). Third, there is no clear relationship between the density of RFs and human population density. Even in the part of the Llanos with the greatest concentration of RFs, just one large settlement has been found so far (Walker 2018; Whitney et al. 2014). Could these patterns indicate the presence of small, mobile groups moving over a sparsely populated landscape, rather than large, more sedentary settlements (Rodrigues et al. 2017; Walker 2004)? Did people abandon RF plots after a few years and build new ones on well-rested soil elsewhere? Again, evidence is too scanty to allow firm conclusions. Research in the areas where RFs have been found has concentrated on these earthworks and not on habitation sites, so that archaeological excavations of settlements are unfortunately scarce. The sole habitation site investigated in the entire RF area, El Cerro in the platform-field area (Walker 2018; Whitney et al. 2014), is over 100 ha in size and has deposits containing abundant charcoal and pottery, indicating intensive, long-term occupation, similar to the scenario of intensification seen in some regions of the Old World. Excavations of other settlements throughout the RF area, with complete chronological reconstructions, are sorely needed to estimate the demography and the patterns of use of space by pre-Columbian RF farmers.

6. Explaining Differences Between the Distribution of Archaeological RFs (Only in Wetlands and Wetland Margins) and Present-Day RFs (in Wetland and Upland Environments)

The cases we document show that in both Africa and New Guinea, forms of RF agriculture are practiced today in both wetland and upland environments (Table 1). However, in both regions—as in the Neotropics—known archaeological examples of RF agriculture are found only in wetlands, either seasonally flooded savannas as in the lower Ogooué Basin in Gabon (Oslisly 2017) and the *cuvette congolaise* in Republic of Congo (McKey et al. 2014), or in permanent wetlands such as Kuk swamp in New Guinea (Denham et al. 2017). How can we explain this difference between the past and present known distributions of RFs?

We see several possible explanations for the apparent restriction of archaeological RFs to wetlands. First, the difference may be real. Wetlands may have been occupied earliest because their moist soils were easier to dig (particularly in the absence of metal tools) and because trees were absent, or because they were favored locations for RF agriculture, offering proximity to aquatic resources such as fish and snails, soils that retained humidity and were cultivable over a longer period each year, and more abundant herbaceous vegetation that could serve as compost in making RFs (see, for example, Bandy 2005:286-287). Less productive upland savanna environments may have been used for RF agriculture only later, or for agroforestry and habitation sites (Denevan 1966:16; Walker 2018).

Secondly, hydrological conditions today may not reflect those of the same site in the past. This is clearly the case for the RFs from the Casma Valley in Peru, for

example, but this particular case does not help to solve the puzzle, as these RFs are in current drylands (the only such example we know) but are thought to have been built when the area was a wetland (Moore 1988). Also, RFs in the Llanos de Mojos, currently in wetlands and wetland margins, are thought to have been built during a period when flooding risk was even higher than now (Moy et al. 2002). Thus, while hydrological conditions have certainly varied over time, the known cases include none that suggest that vestiges in wetlands today were built in a drier environment than today's.

Third, most research has understandably been focused on “visible” RFs, i.e., those in open environments. As in Africa today, most pre-Columbian RFs in Amazonia and elsewhere in the Neotropics are found in savannas, but some are in currently forested environments (see Table 1). Also, recently deforested areas have sometimes offered up surprises, a spectacular example being the discovery of large numbers of geoglyphs after deforestation in southwestern Amazonia (Saunaluoma et al. 2018). Similarly, forest removal has divulged complexes of RFs in unsuspected upland locations in French Guiana (Figure 3), while use of LiDAR has shown vast areas of wetland drained fields in currently forested areas in Mesoamerica (Beach et al. 2019). In the Llanos de Mojos, Bolivia, one of the regions where distribution of archaeological vestiges of RFs has been best documented, archaeological research on RFs was first driven by observations from airplanes (Denevan 1966, 2001). Although recent studies investigated earthworks in forested environments (Prümers & Jaimes Betancourt, 2020), research on RFs is still biased toward savannas, as these open habitats are where RFs are easiest to detect. The only studies of RFs conducted in forested areas in

the Mojos are those in Bermeo (Lombardo et al. 2011; Rodrigues et al. 2015), Estancia San Pedro and Moxitania (Boixadera et al. 2019).

Fourth, RFs built in wetland environments may be better preserved than those that were built in upland environments. After being abandoned, elevated earthworks are subject to erosion. RFs built in upland environments are often smaller to begin with than those built in wetlands, which must be high enough to protect crops from flooding. Under similar rates of erosion, smaller structures would be more rapidly effaced. But rates of erosion may be lower in wetlands. Furthermore, in seasonally flooded environments, earthworms, social insects, and plants all preferentially colonize vestiges of RFs and their activities compensate for loss via erosion (McKey et al. 2010; Renard et al. 2013). In non-flooding environments, no mechanism acts to concentrate activity of these soil engineers on mounds. There is thus no compensation for erosion.

Little information exists to evaluate these alternative hypotheses. We know of no such information for Africa. For New Guinea, however, Denham (2018) notes that while some researchers have speculated that mound cultivation originated in the wetlands and then spread to dryland slopes, he believes the data support the conclusion that mound cultivation was adopted as a response to environmental degradation and establishment of grassland on valley floors, and that “mound technology was not a wetland adaptation, even though early archaeological evidence for it is only preserved in wetlands” (Denham 2018:199). If he is correct, then differential preservation, whatever the mechanism behind it, would appear to explain the differences between past and present distribution of mound cultivation in New Guinea. In the New World, aerial images show differential preservation of RFs (e.g Figure 1 in McKey et al. [2021]),

but whether preservation differs between environments, and if so, what mechanisms account for this, are unknown.

It is not our expectation that RFs were built in all savanna environments in regions such as the Llanos de Mojos. Purely cultural reasons may have introduced some patchiness in their distribution, as appears to be the case for Congo-basin savannas (Miracle 1967). In other cases, environmental differences may account for their absence. For example, with the exception of a small area in the northeastern Mojos (Rodrigues et al. 2018), RFs are not known from savannas east of the Mamore River. Excavations of the Monumental Mounds of this region provide abundant evidence of high population density and a well-developed social and political hierarchy (Prümers and Jaimes Betancourt 2014), supported by maize-based agriculture (Dickau et al. 2012) on fertile alluvial soils (Lombardo et al. 2013) not subject to annual flooding (Lombardo et al. 2011) that did not require such labor-intensive farming methods. In contrast, on the weathered infertile soils west of the Mamore, subject to annual flooding, RF construction was necessary to support subsistence agriculture conducted by less stratified societies at lower population densities.

7. Conclusions

Fifty years after Denevan and Turner (1974), studies of RFs in the Neotropics and the Old World remain disconnected. Our cross-continental comparative review provides new insights for the interpretation and study of archaeological RFs in the Neotropics. Although the main purpose of constructing RFs in pre-Columbian times has been traditionally interpreted as being drainage or water storage—consistent with their

apparent restriction to wetland and wetland-margin environments—evidence from present-day systems in Africa and New Guinea, where RFs occur in both wetlands and uplands, highlights the importance in both kinds of environments of non-hydraulic functions, the most widespread being the increase of soil fertility by concentration of topsoil and organic matter. In addition, contrary to the conceptual model based on the *chinampas*, which has been broadly applied in the interpretation of RFs in the Neotropics and which assumes that the RFs were long-lived and continuously cultivated structures, the data gathered in present-day Africa and New Guinea point towards short-term use of RFs, with cultivation punctuated by fallow periods and rehabilitation of RFs, and even to short lifespans of individual RFs.

While studies of present-day systems in Africa and New Guinea show that RFs are not restricted to wetlands (and, we suggest, the same is true of the Neotropics), most of the archaeological RF systems investigated up to now in all these three regions are found in environments that are today seasonally or permanently flooded. This apparent difference between past and present distributions of RFs might be explained by changes over time in preferences about where to build RFs (or in the environmental opportunities open for building them). Alternatively, RFs may have been also built in uplands, but their vestiges in these environments were more rapidly effaced by erosion.

Further archaeological, palaeoecological and palaeohydrological studies in the Neotropics are needed to test the hypotheses we suggest. Multi-proxy studies, integrating the use of LiDAR, dating methods, archaeobotanical (particularly phytoliths) and geoarchaeological data, offer promising opportunities. Most importantly, these

studies must be combined with more detailed investigations of present-day systems to identify “smoking guns” that can support archaeological reconstructions.

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Tables and Figures

Table 1. Raised fields in the New- and Old World according to their location and environment.

Highlands (HL), Lowlands (LL), Pre-Columbian (PC), Present-day (PD), Mound fields (MF), Platform fields (PF), Ridge fields (RF), Ditched fields (DF), Seasonally flooded (SF), Non flooded (NF). For Africa, the list is not exhaustive and mostly includes sites reviewed in this paper.

Country/Region	Relative altitude	Type of fields	Time period	Dimensions	Modern flooding behavior	Modern vegetation	References
New World							
South America							
Chile / Puren and Lumaco valleys	HL	PF	PC	50-100 cm high, up to 15 m long, 20-100 wide	SF	Grass savanna	Dillehay et al. 2007
Chile / Lake Bundi	LL	PF	PC	70-120 cm high, up to 200 m long, 17-20 m wide	SF	Grass savanna with dispersed shrubs	Dillehay et al. 2007
Bolivia / Llanos de Moxos - Bermeo	LL	RF	PC	1-2.5 m high, 20-100 m long, 2-5 m wide	SF	Forest	Rodrigues et al. 2015
Bolivia / Llanos de Moxos - San Borja	LL	RF	PC	25-60 cm high, 9-582 m long, 5 m wide	SF	Grass savanna	Rodrigues et al. 2016
Bolivia / Llanos de Moxos - Santa Ana	LL	MF	PC	50-100 cm high, 5-10 m in diameter	SF	Grass savanna	Rodrigues et al. 2018; Ruiz-Pérez 2020
Bolivia / Llanos de Moxos - Exaltación	LL	PF	PC	40-100 cm high, up to 1 km long, 15-100 m wide	SF	Grass savanna, <i>Cerrado</i> trees and shrubs	Rodrigues et al. 2017
Bolivia / Llanos de Moxos - Nueva Esperanza	LL	DF	PC	Ditches 20-40 cm deep, 50-100 m long and wide	SF	Grass savanna	Rodrigues et al. 2018
Bolivia-Peru / Lake Titicaca	HL	RF, PF	PC	On average 100 cm high, 10-100 m long, 4-10 m wide	Permanently flooded around lake shore; SF	Grassland plains	Erickson 1988

Peru / Casma valley	LL	RF in blocks separated by ditches	PC	40-130 cm high, up to 80 m long, 2-3 m wide	NF	Halophytic succulents	Moore 1988; Pozorski et al. 1983
Ecuador / Guayas valley	LL	RF and rectangular platforms	PC	RF: 0.6-1.2 m high, 10-12 m long, width not reported Rectangular platforms: not reported	SF	Grass savanna; secondary forest	Parsons 1969
Ecuador / Northern highlands - Chillogallo	LL	RF	PC	0.8 m high, 25-75 m long, width not reported	Occasionally flooded	Pasture	Knapp and Ryder 1983
Colombia / Bogotá - Suba	HL	RF and PF in blocks separated by ditches	PC	Height not reported, 2-50 m long, 1-2 m wide	Occasionally flooded	Dense brush; forest	Broadbent 1968
Colombia / Mompós Depression	LL	RF, PF	PC	1 m high, length not reported, 6-7 m wide	SF	Grass savanna; forest	Denevan 2001:222; Parsons and Bowen 1966
Venezuela / Barinas - Caño Ventosidad	LL	RF	PC	0.25-0.75 m high (1.59 m high reconstructed), 1-1.5 km long (up to 2 km), 6.7-25.3 m wide	SF	Grass savanna	Denevan and Zucchi 1978; Zucchi and Denevan 1979
Venezuela / Barinas - La Tigra	LL	DF	PC	Ditches 0.3-2 m deep, length not reported, 4-6 m wide (up to 8 m)	SF	Secondary forest	Spencer et al. 1994
Venezuela / Llanos del Orinoco - Karinya	LL	DF	PD	Ditches 0.3-0.7 m deep (up to 1-1.3 m), 10-100 m long (up to 500 m), 0.7-1 m wide (up to 1.3-1.7 m)	SF	Groves with palms	Denevan and Bergman 1975
Guyana	LL	RF	PC	Height not reported, 5-8.2 meters long, 1.7-6.9 m wide	SF	Grass savanna	Plew 2005; Rostain 2012
Suriname	LL	MF, RF	PC	MF: height not reported, 1-6 m diameter	SF	Grass savanna and forest	Boomert 1976; Rostain 2012

				RF: height not reported, 5-30 m long, 1-7 m wide			
French Guiana	LL	MF, RF	PC	MF: height not reported, 1-6 m diameter RF: height not reported, 5-30 m long, 1-7 m wide	SF; permanently flooded	Grass savanna and forest	Rostain 2010, 2012
Mesoamerica							
Panama / Chinina	LL	RF in blocks separated by ditches	PC	0.6 m high, 50 m long, 2.5 m wide	SF	Grass savanna with forest patches	Martín et al. 2015
Belize / Pulltrouser Swamp	LL	DF, PF	PC	DF: deep of ditches not provided, 10-20 m long, 2-3 m wide PF: up to 2 m high, 80-750 m ²	Permanently to SF	Grass savanna; forest	Turner and Harrison 1981
Mexico / Veracruz	LL	DF	PC	Ditches 1 m deep (reconstructed), length not reported, 5-10 m wide	Permanently to SF	Pasture	Stoner et al. 2021
Mexico / Valley of Mexico - Xochimilco	LL	PF separated by ditches or embankments (<i>chinampas</i>)	PC, PD	PC fields: 50-70 cm high, 8-100 m long, 2-25 m wide PD fields: not reported	Permanently flooded	Agricultural landscapes	Ebel 2020
Mesoamerica (mostly Mexico, Guatemala)	Mostly LL	Diverse earthworks	PD	Diverse mounds, ridges, raised planting beds	From NF to SF or permanently flooded	Agricultural landscapes (in secondary forest and grasslands)	Chapters 4, 7 and 10 in Wilken 1987
Caribbean							
Haiti / Léogâne	LL	RF	PD	20 cm high, 10 m long, 1.10 m wide	NF	Forest	Bier 2019
Old World							
Africa							
Republic of the Congo / Mossaka and neighboring regions	LL	MF, RF (<i>maanga</i>)	PD	MF: >1.5 m high, 7-10 m in diameter RF: >1.5 m high, 10-20 m long, 2-3 m wide	SF	Grass savanna	Comptour et al. 2018; Rodrigues et al. 2020; Sautter 1962

Republic of the Congo / Tchikapika	LL	MF, RF (<i>atshoro</i>)	PD	MF: 50-75 cm high, 1-1.5 m in diameter RF: 85-110 cm high, 6-7 m long, 3-4 m wide	SF or permanently flooded	Swamp forest	Solibiéda 2013
Republic of the Congo / Tchikapika	LL	MF	PD	Gradient from large mounds and ridges in flooded forest (<i>atshoro</i>) to smaller mounds (<i>ika</i>) in adjacent non-flooded forest	SF, NF	Forest	Solibiéda 2013
Republic of the Congo / Tongo and other sites along the Alima River	LL	RF	PD	Up to c. 60 cm high, 3-4 m long, 1.5-2 m wide	NF	Grass savanna	D. McKey, unpubl. field notes
Republic of the Congo / Cuvette province	LL	MF	Archaeological	Diversity of mounds of varying size (up to 20 m diameter), curvilinear ridges (up to c. 50 cm high, 100 m long, 2 m wide)	SF	Grass savanna and pasture	McKey et al. 2014
Congo Basin	LL	MF, RF	PD	Diversity of mounds and ridges, sizes not given	NF	Upland savanna; upland forest	Miracle 1967
Democratic Republic of the Congo / Kwango-Kwilu region	LL	MF, RF	PD and historical (pre-1960)	MF: < 25 cm high, diameter not provided RF: 20 cm high, length not given, 60 cm wide,	NF	Grass savanna	Fresco 1986
Gabon / Bateke Plateau	LL	RF	PD	50-60 cm high, length not provided, 80 cm wide	NF	Grass savanna	Delêtre 2004
Gabon / Lower Ogooué valley	LL	MF, RF	Archaeological	Diversity of structures, including ridges up to 500 m long, circular and rectangular platforms of varying size; height not given	SF	Grass savanna	Oslisly 2017
Mali / Kadiolo	LL	MF, RF	PD	50-80 cm high, up to 1 m	Gradient	Grass savanna	Krings 1991

				high for yam mounds and ridges; length of ridges not given but up to some tens of m	from NF to SF		
Zambia / Bangweulu Basin	HL	MF	PD	In upland, mounds 50-70 cm high, 1.5-2 m in diameter; in SF wetlands, up to 1.7 m high and 3-4 m in diameter	Gradient from NF to SF	Grass savanna	McKey et al. 2017; Stromgaard 1990
Oceania							
New Guinea / Southern highlands - Wolalad	HL	MF	PD	Not reported	NF	Cleared forest	Sillitoe 1998
New Guinea / Highlands - Enga province	HL	MF	PD	0.5-1.5 m high, 2-4 m in diameter l (built taller in flooded areas); long mounds following contours on sloping sites to reduce erosion (0.4 m tall, 4-6 m long, 1-2 m wide)	Gradient from NF to SF	Bush and grass savanna	Taraken and Ratsch 2009
Many sites in New Guinea (detailed study of Haeapugua Swamp in central highlands)	HL and LL	MF, DF, lobate or rectilinear platforms	PD	Not provided	Gradient from SF to NF	Swamp, wetland margins, drylands, grassy vegetation	Ballard 2017
New Guinea / Central highlands - Kuk Swamp	HL	MF	Archaeological	Height not provided, up to c. 1.5 m in diameter	Permanently flooded	Grass swamp	Golson et al. 2017

Figure 1. Examples of archaeological raised fields (RFs) in the Neotropics.

A, B, C: Pre-Columbian raised fields in the Llanos de Mojos, Bolivia. A: Ridge fields close to the city of San Borja. B: Platform fields close to the village of Exaltación. C: Mound fields in the vicinity of the village Santa Rosa. D: Mound fields seen from the air in French Guiana. E: Inundated ridge fields in Guyana. F: Mound fields in Suriname. Photos L. Rodrigues (A-C), S. Rostain (D and F), G. Simon (E).

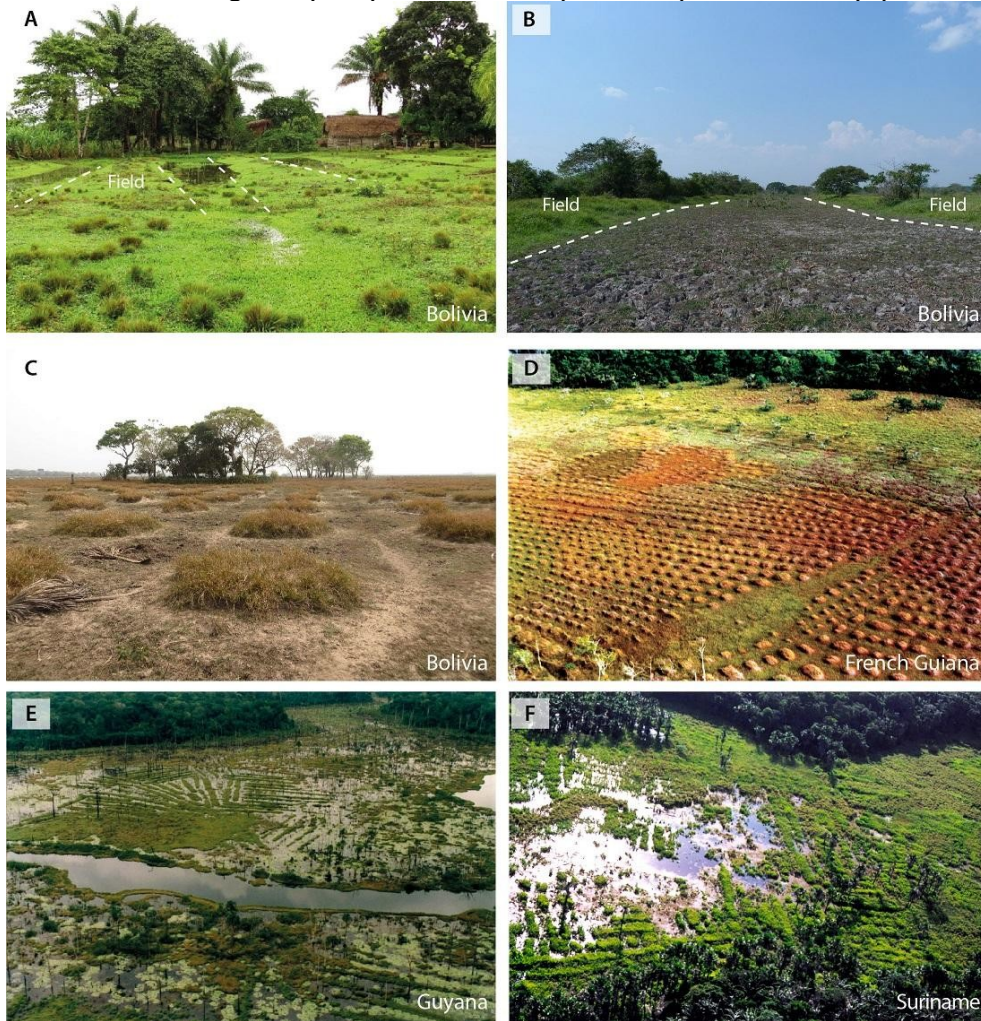


Figure 2. Examples of raised fields (RFs) cultivated today in Africa.

A, B: Raised fields in the Bangweulu Basin, Zambia. A: in seasonally flooded savanna, Lunga Bank; B : In upland savanna, near Kapata. Mounds in both upland and seasonally flooded savannas are broken down and rebuilt between successive cultivation cycles (“mound-shifting”). Photos D. McKey.

C, D: Two kinds of raised fields (maanga) in seasonally flooded savanna, Mossaka, Republic of Congo. Photos L. Rodrigues.

E: Atshoro, raised fields in a plot made by cutting swamp forest, Tchikapika, Republic of Congo. Two types of atshoro are built, ridge (pictured here) and mound. Photo D. McKey.

F: Raised field built in upland savanna near Tongo, Republic of Congo, planted with Bambara groundnut (*Vigna subterranea*). Photo D. McKey.

Images of present-day RFs in New Guinea can be seen in Denham (2018), Sillitoe (1998, 2013), and Taraken and Ratsch (2009).



Figure 3. Raised fields in an upland forested area near Matiti, French Guiana, revealed by forest removal.

Photo S. Rostain.

