Working Paper 405

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ENVIRONMENT AND INDIGENOUS AGRICULTURE IN THE AMERICAN TROPICS

INTRODUCTION

At the time of European contact, agriculture was widely practiced throughout the Americas from the lands of the northern Algonkians to the temperate regions of Argentina and Chile (Snow, 1976) (Fig.1). It is, however, to the tropical and sub-tropical areas of Central and South America that attention will be focussed for it is from these physically diverse parts of the New World that much of the evidence for indigenous, pre-Hispanic agriculture has been derived. Not only was the range of crops and agricultural methods greater in this region but we can be fairly certain that it was from this area, or from sub-centres within it, that agricultural impulses spread to areas north and south (Pickersgill and Heiser, 1978).

The tropical regions now provide some of the earliest evidence of plant domestication and crop husbandry (Golson, 1977) and in parts of the American tropics prior to the arrival of the *conquistadores* indigenous agriculture had reached its climax. In other areas it had disappeared or degenerated centuries before, as in the Maya lowlands (Harrison and Turner, 1978), while the development of state and confederate structures in the century or so prior to Spanish contact had led to a mixture of abandonment and reclamation of former agricultural lands (Collier *et al.*, 1982; Murra, 1960; Rowe, 1946). Yet, to use European terminology, American civilizations, culminating in the Maya, Aztec (Mexica) and Inca empires were technologically in the Bronze Age. Because of acknowledged parallels between prehistoric cultures, (see e.g. Bronson, 1978) the study of pre-Hispanic agriculture and society may give us unique insight into the nature of early societies in general. In Europe, several thousand years of landscape change and cultural evolution separates us from the action while in Latin America we are, thanks to sixteenth century chroniclers, at the threshold of the culture itself (Cieza de Leon, 1553/4; Collier *et al.*, 1982; Hemming, 1970; Murra, 1975; Prescott, 1908).

Pre-Hispanic and contemporary indigenous agriculture reveal not only a range of technical achievement (e.g. Denevan, 1982) but also an evident understanding of ecological principles, contrasting with much of what has happened in the last four hundred years. During and after the conquest vast areas of former agricultural land, much of it in geographically remote and less rewarding situations, was abandoned while better quality irrigable

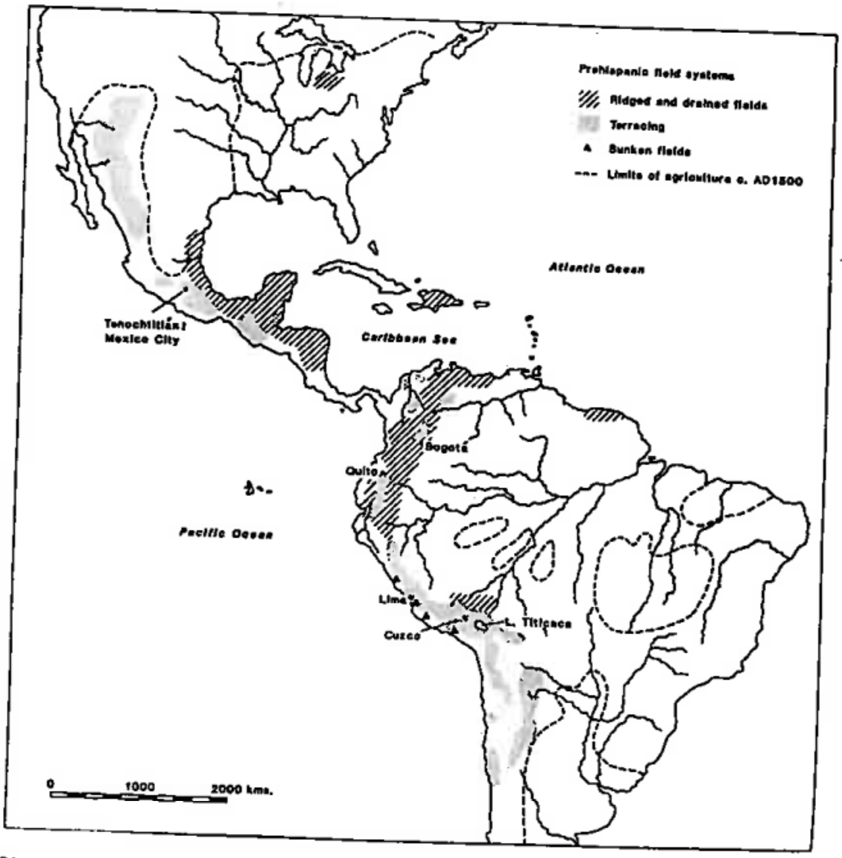


Figure 1 : Indigenous American agriculture : some locations and limits
(based partly on Donkin, 1979)

lowlands were taken up into large *haciendas*. The remainder, representing varying degrees of difficulty for mechanised agriculture, continues in peasant holdings in a manner which indicates that some of the past is alive in the present but struggles to survive.

To provide a backcloth for discussing pre-Hispanic agriculture a review will firstly be given of environmental history. This will be followed by an introduction to pre-Hispanic crop plants and a discussion of the origins and expansion of agriculture. A major part of this article is then devoted to a variety of pre-Hispanic agricultural forms appropriate to different terrain, their role in growing particular crops and their significance for local subsistence and wider exchanges. The final sections are concerned with changes in agricultural outlook since the Spanish conquest, with problems which are believed to lie ahead and whether indigenous practices have a future role to play.

ENVIRONMENTAL HISTORY AND AGRICULTURAL ORIGINS

Environment and man

Major environmental changes have occurred over the last 20,000 years throughout the Americas. During the latter part of the last glacial period until about 12,000 years ago lowland equatorial forests were restricted to moist refugia while savanna was widespread (Brown *et al.*, 1974; Haffer, 1969; Prance, 1978; Simpson, 1971; Simpson and Haffer, 1978; Turner, 1976; Van der Hammen, 1974). Vegetation belts in the cordillera were lower by 1000m such that the *páramo* (high altitude) flora, instead of forming isolated mountain communities, displayed a more continuous range (Flenley, 1979a, 1979b; Van der Hammen, 1974). Northern forest elements such as pine entered the flora of Central America (Graham, 1973; Tsukada and Deevey, 1967) and the deserts of the southwest United States were under pine savanna or juniper scrub (Martin and Mehringer, 1965). Enhanced snow melt in the Peruvian sierra led to more active steam flow and valley cutting in the coastal desert (Hastenrath, 1981; Pickersgill and Smith, 1981) while the *salares* of the central altiplano were large lakes (Servant and Fontes, 1978).

The conventional view of the peopling of the Americas is by way of the Bering land bridge which existed during the last glaciation (Ceram, 1971; Fladmark, 1979; Lynch, 1974; Zubrow *et al.*, 1974). It is not the purpose of this essay to review the evidence or indeed the necessity for this view but were an overland, immigrational hike from Alaska to Tierra del Fuego to have actually taken place it would have been accomplished relatively easily at this time. Aside from northern ice, plant resources were more equably distributed while north to south access was assisted by the existence of corridors through areas which are now dense forest or desert and coastlands were more extensive prior to the major rise of sea level which undoubtedly facilitated movement particularly within the Caribbean region. The opening of the Holocene period some 10,000 years ago witnessed a marked rise of temperatures and for tropical regions the next thousand or so years was a period of relatively high rainfall (Goudie, 1977; Pickersgill and Smith, 1981; Street, 1981). Temperatures continued to rise until about 6000 years ago at which time forests had extended to their highest levels. Parts of Amazonia and the geologically-sensitive limestone provinces of Florida and Yucatán may not have possessed true forest until about 6000 years ago, by which time rising sea level had significantly raised water-tables inland. As there is evidence of periodic drying of the climate since 8000 years ago such eustatic change probably did provide valuable hydrological compensation in low-lying areas. In any event, American low latitudes were not as conspicuously affected by desiccation as were other tropical areas (Street, 1981) though reciprocal fluctuations of savanna and rain forest have been detected (Eden, 1974; Van der Hammen, 1974). In time, man would have occupied an increasingly warm and forested landscape yet, owing to the ecological importance of the forest-grassland fringe (Harris, 1969; Simmons, 1979) some supposed evidence for climatic drying may eventually be equated with human disturbance (Flenley, 1979a). Moist tropical lowlands, even more than arid environments, pose particular problems for palaeoecological work and the paucity of studies means that statements about man's impact in prehistoric times are still largely inferential on the basis of archaeological records. Sudden later advances of savanna in South America do strongly implicate man (Van der Hammen and Correal, 1978) while a series of studies in the Yucatán improves our picture in the Maya area. Here the earliest Holocene landscapes consisted of pine forest and savanna with man present somewhat before 10,000 years ago, complete with a tool kit resembling those found in Panama and Ecuador (MacNeish, 1982). Broadleaved forest expanded later, while around 4000 years ago savanna once more increased at the expense of forest, this being particularly marked and containing evidence of agriculture prior to the Classic Maya period (Vaughan, 1979). Thick clay layers are widespread and associated mainly with the Classic period while Maya collapse in the ninth century A.D. prompted a rapid and widespread advance of forest within about 150 years (Covitch, 1978; Tsukada and Deevey, 1967; Vaughan, 1979; Wiseman, 1978).

Plant domesticates

The diversity of plants utilized on Spanish contact is impressive and a brief cross-section is offered here (see Camacho-Zamora, 1983; Lévi-Strauss, 1950; Marcus, 1982; Pickersgill and Heiser, 1978; Pickersgill and Smith, 1981; Towle, 1961; Yarnell, 1976). There were plants such as totora reeds (Scirpus sp.) and cattails (Typha sp.) whose fibre provided raw material for the manufacture of boats and houses. The rhizomes of these species were also a potential source of food. Cotton (Gossypium hirsutum and G. barbadense) was the basis of textiles and such items as fishing nets. There were roots and tubers of forest origin such as manioc (Manihot esculenta) and sweet potato (Ipomaea batatas) together with yautia, the American version of taro (Xanthosoma sp.) and yam (Dioscorea trifida). The Andes were the home of the potato (Solanum tuberosum and other species) (Brush, 1980; Brush *et al.*, 1981) while achira (Canna edulis) was one of many roots grown locally but of less widespread importance than the sweet potato. The ubiquitous cucurbits were represented by the common gourd (Cucurbita sp.), squash (C. moschata) and the bottle gourd (Lagenaria siceraria). The latter was used for utensils while gourds and squash were used as moulds for pottery and probably as floats in fishing. The legumes were represented by common beans (Phaseolus vulgaris), lima beans (P. lunatus), jack beans (Canavalia sp.) and the peanut (Arachis hypogaea). Grain crops included maize (Zea mays), probably the most famous of all American cultigens but also amaranths (Amaranthus spp.) and the chenopods, quinoa (Chenopodium quinoa) and cañihua (C. pallidicaule). Certain species were prized as spices and flavourings, for example chile peppers (Capsicum annuum)and vanilla (Vanilla planifolia) the climber of Mesoamerican forests. Some were of medicinal use, including the alkaloid-bearing tobacco (Nicotiana sp.) while others were a source of dyes as was the prickly pear (Opuntia sp.) which, being associated with the cochinilla insect, was a source of the red pigment cochineal. Among beverage and masticatory plants were cacao (Theobroma cacao) which was much planted and highly prized in the lowlands of ancient Mexico and the coca bush (Erythroxylon coca) grown in the Andean highlands, the leaves of which are chewed to gain the effects of the alkaloid cocaine. Fruits included pineapple (Ananas comosus), a ground-level fruit native to South America, avocado (Persea americana), tomato (Lycopersicon esculentum) papaya (Carica papaya) and the breadnut (Brosimum alicastrum) which may have been an important staple of the Mayas (Puleston, 1968, 1978). Other fruits included pepino (Solanum muricatum), guava (Psidium guajava), lucuma (Lucuma bifera), sapote (Achras zapota), the bark of which contains the milky fluid which is the raw material for chewing gum. It also remains a possibility that bananas and plantains (Musa spp.) were pre-Hispanic in parts of South America though the basis for this assumption is slim (Heyerdahl, 1978; Simmonds, 1966).

The majority of these plants have undergone major genetic changes in order to enhance their usefulness and although wild varieties are often identifiable, as with potatoes, the progenitor(s) can sometimes elude attempts at discovery as witnessed by the story of maize (Mangelsdorf, 1974). Some plants are little more than wild species, perhaps used as a last resort. Cañihua, for example, grown above 3500m in the Andes, retains its natural ability for seed dispersal and therefore must be harvested before maturity (Gade, 1970). The enormous variety of cultivated plants is undoubtedly due to the intrinsic richness of the indigenous floras, notably the equatorial rain forest, and the sharply contrasted ecological zones, which, in the cordilleran areas, are separated by very short horizontal distances. Such a juxtaposition could not fail to promote speciation and, in the human context, the exploitation of new cultigens (Rindos, 1983; Vavilov, 1950). Variety also bespeaks a lengthy period of plant domestication.

Agricultural development and origins

The origins of plant domestication in the Americas, as elsewhere, recede into an ever more remote past with each new decade of research. Domestication and exploitation of a small number of genera has certainly been carried on from the very start of the Holocene. In the Peruvian highlands at Guitarrero Cave, Smith (1977) and Flannery (1973) have reported common beans, lima beans and chile peppers as early as 8500 BC while maize appears around 4000 BC. All occurences of these and other crops appear later in the Peruvian coastal sequences demonstrating later spread to this area where it appears that non-food plants such as cotton and cucurbits were among the first crops grown on any scale. In the Mexican highlands maize appears about 5000 BC at Tehuacán while bottle gourds have been found at Oaxaca dating from about 7400 BC (MacNeish, 1967). These early examples provide a very incomplete picture and do not hint that one of the striking features of ethnobotany is the difference in the suite of crops grown in ancient Mexico and the Andean region (Heiser, 1965). This accounted for Sauer's superficial distinction (Sauer, 1952, 1959) between the seed croppers of Mexico, producing mainly maize, beans, squash and amaranths and the root croppers of Peru producing manioc, potatoes, sweet potatoes and pineapple. Nevertheless, Pickersgill and Heiser (1978) point out that "the differences in the species cultivated are the more remarkable because the dry highlands of Mexico and Peru are ecologically very similar and crops have been readily exchanged between the two areas in historic times". But the two areas are separated by forests and mountain systems and were perhaps, in addition, formerly separated by hostile tribes. The overland distances involved therefore favour a filtering and diffusion process rather than direct transfer while the journey would have promised survival no more for courier than for cultigen. This situation also suggests a strong territorial integrity among earlier societies.

In view of the dates already mentioned there are grounds for arguing a common early origin for a few cultigens while admitting that forest expansion may have led to increasingly isolated development in time. Crops of tropical forest origin do not in fact appear in the records until comparatively late.

Around 1500-1000 BC when the stylistically analogous Olmec and Chavín cultures were expanding their influence from, it is thought, the tropical lowlands,(Taylor and Meighan, 1978; Weaver, 1981) manioc first appears on the Peruvian coast. Lathrap (1966) and Coe (1960, 1962) also report evidence of coastal contacts between Mexico and Ecuador at this time. Major cultural impulses are thus likely to have initiated trade networks between peoples previously living an isolated and inbred existence. This example should also remind us of the tropical lowlands as a third major locus of plant domestication. Indeed, it was Sauer's (1959) view that agriculture had originally spread from these lowlands to the central Andes and highland Mexico. Much recent evidence can be used to argue against this view but we should realise that these regions lack the intensive archaeological investigation and preserved records of the drier highlands (Lathrap, 1970). Furthermore, it is only within the last 10,000 years that these regions have become so extensively forested (Bryan, 1973; Meggers, 1977) while it would only become possible to expand cultivation at higher elevations as temperatures rose during the Holocene.

Cultural expansionism can obviously arise for different reasons (Adams, 1960) but one very important factor seems to have been the control of water. In Peruvian prehistory the Ceramic period, associated with the spread of Chavín influence around 1500 BC, saw a movement of population from the arid coastal region to the highlands. Irrigation is thought to have played a crucial part in this move (Pickersgill and Smith, 1981) while the development of pottery is obviously connected with the need to prepare, contain and cook a widening range of agricultural products. A decisive point appears to be reached if society gains mastery not simply over plants and animals but over the landscape itself and begins to intensify food production around a variety of water-control systems. Hence it took a considerable time from initial domestication of corn in Mexico to real dependency upon it for subsistence (MacNeish, 1967). Increasingly centralised power is capable of harnessing labour and resources on a larger scale and impells the twin processes of intensification and diversification (Boserup, 1965; Farrington, 1964; Wittfogel, 1972). Moreover, as a better-fed population increases in size its dependence on agriculture escalates and the society presumably finds ways of meeting these needs or collapses. Society's capacity to meet its obligations may well be frustrated by exigencies of nature, such as climate, (Paulsen, 1976) but as we know from modern parallels, so in the past, forces within society often prove to be more influential (Conrad, 1981; Hamblin and Pitcher, 1980; Hammond, 1977). Society is thus seen to be impelled by both exogenous and endogenous forces.

If this is the position with regard to the changing fortunes of cultures which become 'advanced', views on the ultimate origins of plant domestication in the Americas, as elsewhere, are, to say the least, confused, since they so clearly fail to illustrate the same duality of approach. It is in this field that cultural materialist philosophy is rampant, arguing as it does that cultural processes are merely a response to a combination of climatic, resource, population and technological constraints (Cohen, 1977; Conrad, 1981; Harris, 1979; Rindos, 1983). Many extremely plausible arguments thus make some of man's most important discoveries and advances seem almost accidental. Chance or random events, such as devastations of early Maya people by volcanic activity do fashion the course of history (Sheets, 1979) but one has to realise that it is environmental events and the results of cultural development which are preserved in archaeological sequences rather than deeper causes within society. It is now clear that cultigens were possessed by hunter-gatherer peoples at the end of the Ice Age. What exactly does this imply for views about the primacy of sedentism in agriculture and were hunting peoples ever more than exceptionally nomadic anyway? Furthermore, in tribally-based societies the world over, leaders and shamans have guided the people though time and it is reasonable to suppose that the emergence of priestly elites in later periods represents an evolution of this basic reality. The role of the shaman is well documented (Dobkin de Rios, 1982; Eliade, 1964; Halifax, 1980) and suffice it to say that a visionary who was able to cure sickness, largely through an alchemical understanding of plants, would be the most likely originator of plant genetic manipulation. It is not as if we are without later allusions to just such a role for, while both Inca and Aztec legends speak of culture bearers (Viracocha and Quetzalcoatl), Mayan bas reliefs and frescoes depict priestly figures in association with corn plants and codices appear to record acts of planting by 'elite' figures (Stocker *et al.*, 1980; Turner, 1978b). American anthropology and archaeology therefore provides us with an excellent opportunity to develop a more balanced appraisal of the whole question of agricultural origins.

PRE-HISPANIC AGRICULTURAL STRATEGIES

Agricultural forms and the problems they pose

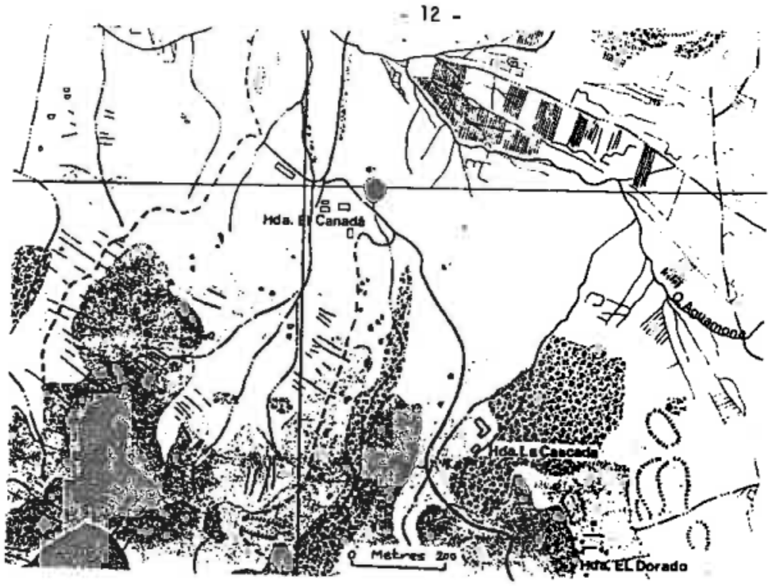
A principle aim of research into early agriculture is to find out what individual areas and particular techniques produced. In many cases this is frustrated becaused the form of agriculture is no longer being practiced or is carried on only is restricted localities making the discussion of crops and whether these were raised on a seasonal or perennial basis more speculative. We need also to address the role of former productive systems in the overall politico-economic life (Collier *et al.*, 1982). Without taking account of such wider considerations we may be short of essential explanation for the initiation of systems and for the relative care lavished in their construction and implementation (Donkin, 1979; Smith, 1979; Weaver, 1981). With few exceptions the examples to be discussed required a substantial labour input and, by their overall design, betoken centralised direction. At the time of Spanish contact the major powers held sway over varied ecological zones and we must therefore see the various forms of agriculture as elements within 'agricultural complexes', each making a distinctive contribution to the 'state' while providing for more local subsistence and exchanges (Conrad, 1974; Flannery, 1982; Harrison and Turner, 1978).

It is axiomatic that plots or larger-scale field systems will result from crop husbandry. The size, shape and configuration of these features relate to a combination of functional, ecological and organizational factors while their subsequent discovery depends upon agricultural subsistence having so expanded as to leave widespread remains. Ancient fields will also only be found where they have not been obliterated by later events such as are endemic to shifting cultivation and which are typified by modern commercial agriculture and urban development. It is therefore only a partial picture of pre-Hispanic agriculture which can be studied and one which relates disproportionately to marginal lands as well as to areas of more intensive research. But not all features forming integrated patterns need immediately be equated with cultivation. In highland Ecuador there are extensive areas of steep hillslopes with parallel systems of curvilinear banks (David Preston pers. comm.). Perusal of the relevant air photographs (and see Bray, 1983) shows a marked resemblance with pre-Iron Age patterns in Britain (Fowler, 1983; Riley, 1979) which often appear to be territorial land allotments in the first instance. Such divisions will in most cases form the primary context within which cultivation occurs (see Figs. 2 and 3).

The types of agriculture shortly to be discussed represent a variety of adaptations to terrain and climate and most required periods of rehabilitation so that only a proportion of their extent would have been under crops at any one time. Furthermore, field systems represent aggregates of enterprise and for this reason also, to view them as having all been in use together would be completely erroneous. This is important to realise in the case of the many terrace systems and the emergence and decline of successive Maya cities well illustrates this process (Hamblin and Pitcher, 1980). As far as dating is concerned, fields are therefore likely to reflect their most intensive phase of use or latest remodelling rather than their initial construction.

Agriculture and domesticated animals

Discussion of agriculture inevitably raises the question of animal domestication, but unlike the Old World there was no equivalent dependence upon domesticated animals for dairy products, draft animals were unknown, and cultivation was exclusively based on hand tools (Donkin, 1970; Rojas Rabiela, 1982) (Fig.4). Bronson (1978) notes somewhat sarcastically of the Maya that "their only farm animals were the stingless bee, the dog and possibly the ocellated turkey". To fatten dogs on maize, as did the Maya, suggests to us a degree of destitution or depravity but, although people did eat them, dogs were also used as sacrificial animals, for instance in certain rites in cacao plantations conducted to propitiate the rain god, among others (Wilkerson, 1983). Animal use in the coastal Yucatecan context has recently been discussed by Hamblin (1984) and perhaps coastal loci were generally more favourable for maintenance of domestic or domesticated animals in the humid and sub-humid tropics owing to the proximity of salt supplies (Andrews, 1983). A similar ecological argument may be applied on the semi-arid Andean altiplanos. While it is tempting to view the relative sophistication of agriculture as an artefact of the paucity of suitable animals for domestication, we must not overlook the fact that fish and shellfish were available (Friedel and Scarborough, 1982; Parsons, 1970; Pickersgill and Smith, 1981; Stark and Voorhies, 1978) and that in the forested lowlands there were peccary and deer whose numbers no doubt increased in appreciation of the improved diet within agricultural plots and abandoned clearings (Pohl and Feldman, 1982). The central Andes, moreover, appear to have been a centre of limited animal domestication with the llama and alpaca camelids



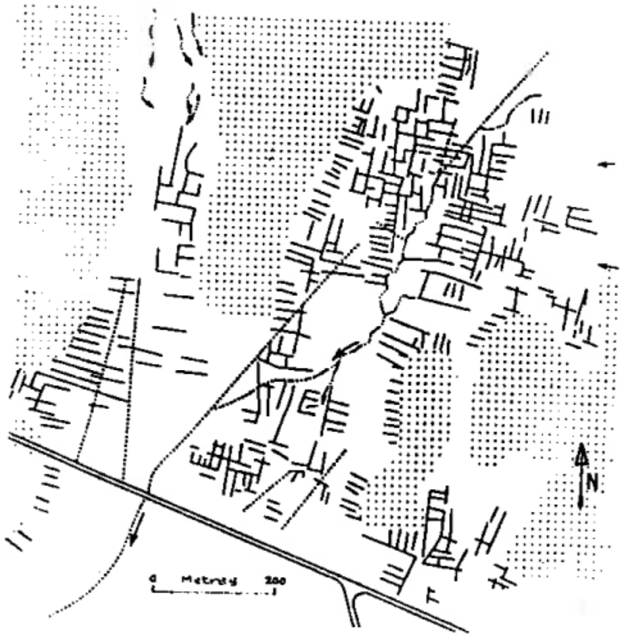
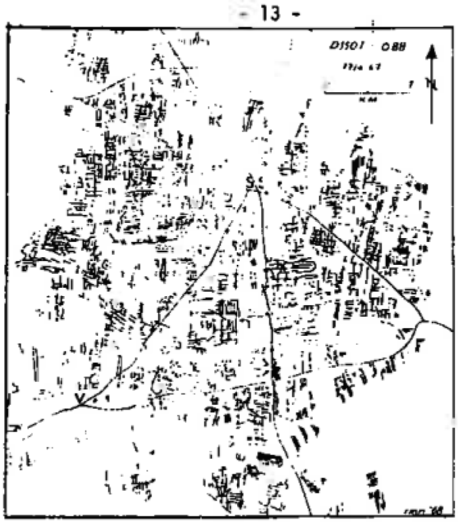


Figure 2 : Patterns of early field systems
A. Fields in the Calima district of western Colombia (from Bray, 1983)

B. Fields in the Vera Cruz lowlands of Mexico (from Siemens, 1984)



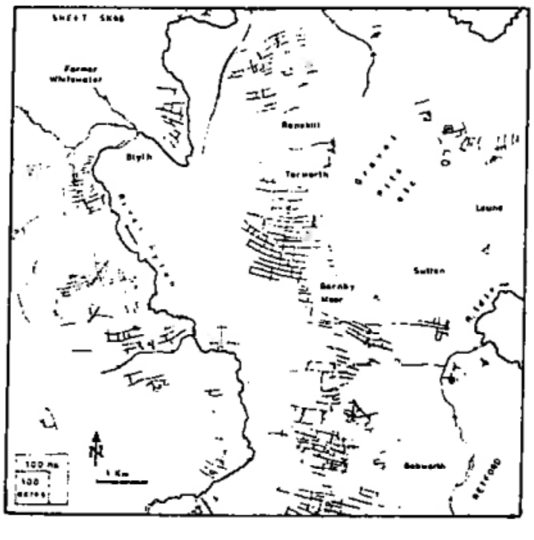


Figure 3 : Field system analogues from prehistoric Europe
A. Patterns in Denmark (from Newcomb, 1971)
B. Patterns in northern England (from Riley, 1979)

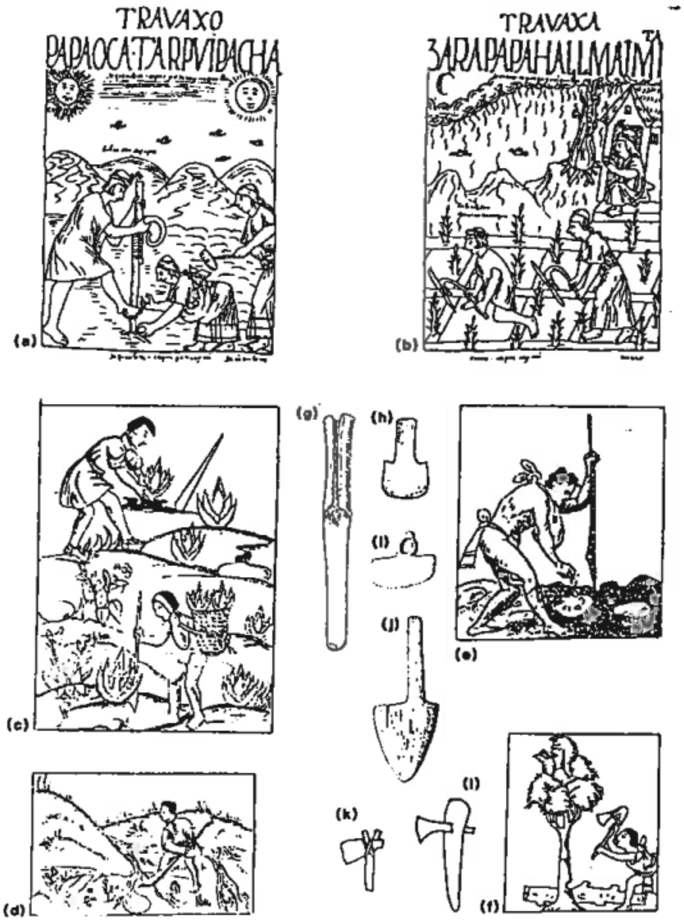


Figure 4 : Some early American agricultural and related implements

a) Planting potatoes with the chaquitaclla footplough (Poma de Ayala,1615)
b) Cultivating irrigated maize with the liukana (Poma de Ayala, 1615)
c) Uictli or coa used for planting and harvesting metl (maguey) (Codex Florentino, c. 1570)
d) Uictli or coa used for directing irrigation water (Codex Florentino, c. 1570)
e) Uictli or coa used as a planting stick (Codex Florentino, c. 1570)
f) Hacha (axe) used for tree cutting (Codex Florentino, c. 1570)
g) Socketed copper point - possibly blade of taccla-like instrument (University Museum, Cambridge)
h) Copper adze (University Museum, Cambridge)
i) Bronze blade of an azada (adze)
j) Blade of wooden spade (after von Rosen, 1924)
k) Small stone hacha (axe) used for working rock (Matrícula de Huexotzinco)
l) Axe (Codex Mendocino)

having been derived from a guanaco-like ancestor, while guinea pigs were also domesticated, eaten and used for sacrifice. Dogs, though not native to South America, would appear to have accompanied man from the most remote times (Wing, 1978).

There is little to suggest that animals were confined in, or indeed excluded from, any of the manifestations of agriculture to be described but stone-walled, enclosed fields do exist on flat terrain in southern Campeche, Quintana Roo (Mexico) and the Petén (Guatemala) and while these might, as Turner (1978b) suggests, mark boundaries of ownership, they could equally well have acted to keep wild fauna from areas where vulnerable horticultural crops were being raised. In addition, field boundaries are reported from Sabandia, Arequipa, in Southern Peru (Donkin, 1979) yet the stature of these would only have been sufficient to exclude guinea pigs! It therefore seems most likely that, then as now, animals were closely associated with settlement and kept in compounds rather than in fields.

Swidden and tlacolol

Swidden or shifting cultivation occurs in the humid lowlands while tlacolol, an upland analogue, is, or at least, became, integrated with other more intensive methods such as terrace farming and irrigation and is associated with fixed settlement (Flannery, 1976). These systems are widespread and important for their unrelenting disturbance of forest vegetation, tending to encourage rapidly-colonizing species (UNESCO-FAO, 1978). Though ubiquitous throughout the tropical world they were once more general elsewhere. Many have considered swidden capable of providing the surplus necessary at the time of Classic Maya ascendency (see bibliography in Turner, 1978a) even if this belief was heavily influenced by cognates elsewhere (Dumond, 1961). A more modest position regards it as capable of supporting "chiefdoms and non-urban states" (Sanders and Price, 1968). These systems are here regarded as the formative base onto which intensive methods were later grafted by expanding city spheres. When the latter collapsed - loss of at least 80 percent of the population occurred at the time of the Classic Maya collapse - the remaining population became dependent on these rustic and less labour-intensive methods for, in terms of man-hours of work per kg of food produced, swidden is one of the most productive systems in the world. Swidden is adapted to low population densities and dispersed settlement and, in forested lowlands, provides the perfect complement to other forms of subsistence. Johnson (1983) notes that the contemporary Machiguenga of the Peruvian montaña depend on a "mixture of hunting, gathering and fishing combined with cultivation of a variety of crops that provide food, medicines and materials for clothing, tools, storage containers and other manufactures". The perceived advantage of agriculture is that it alone, in the shape mainly of starchy tubers such as manioc, can provide the storable surplus against disasters and contingencies to which isolated peoples are vulnerable. In this contemporary indian view we therefore have a convincing motive for plant domestication.

But swidden and tlacolol have been heavily blamed for land degradation of various kinds (McNeil, 1964; Watters, 1971) while deforestation, not necessarily for agriculture alone, would appear responsible for thick clay layers deposited in parts of the Maya lowlands during the Classic period (Olsen, 1981; Turner, 1978a). In the Petén of Guatemala, Rice and coworkers (Rice *et al.*, 1983) have studied two small lakes which show increasing silica and adsorbed phosphate concentrations in their sediments in the late pre-Classic and early Classic periods. The results are reproduced in figure 5, in which particular note must be taken of the logarithmic scales for lake chemistry and estimated population densities. Soil loss appears to have taken place following removal of forest in a longish period of formative agriculture. It is equally evident that some stabilisation occurred during the Classic period when we are to presume that soil and water management was under the most rigorous control. Swidden has been consistently condemned as wasteful and inefficient (Webster and Wilson, 1980) and has even excited the anger of the FAO (1957). The trouble undoubtedly is that modern population increases, in forcing people to a greater dependence on agriculture, have disrupted the traditional balance between cultivation and fallow leading to soil exhaustion (Arnason *et al.*, 1982; Clarke, 1976; Lambert, 1981; Nye and Greenland, 1960). Most swiddeners approach the problem of declining soil fertility by planting first the most demanding crop, usually maize, and it is for this reason that swidden gained its Mesoamerican name of milpa or corn plot. Swiddens are variable in the detail of their management; in drier areas burning is no problem but two crops a year may not be possible (Carniero, 1983) while in wetter areas initial preparation of sites may be more fraught yet continuous cropping can be achieved. Tubers are normally grown in raised beds and various forms of under-planting and inter-planting may be carried out, such as growing mixtures of corn and beans which help to

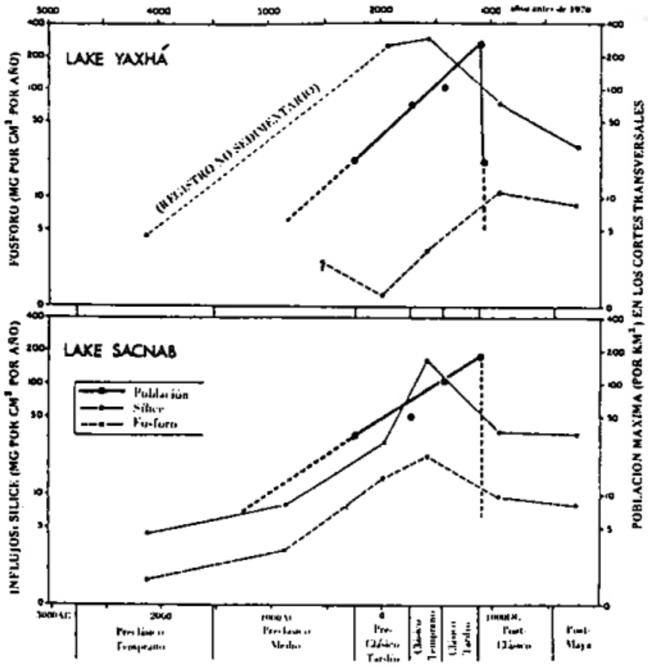


Figure 5 : Phosphate and silica influx in two lakes of the
Petén related to local population densities
(from Rice *et al.*, 1983)

conserve soil fertility and appear to maximise yields (Gleissman, 1979). There is no reason to suppose that this situation was any different in pre-Hispanic times.

Tlacolol is widespread on slopes in the humid parts of Mesoamerica and Andean South America. It involves a shorter fallow cycle than swidden and traditionally makes use of a hoe (coa or uictli - see Fig.4) to prepare land for sowing and for subsequent weeding. The land is divided into sectors some of which are planted for 2-3 years then left fallow for periods of up to 7 years. The length of the cycle depends on inherent soil fertility - many are based on fertile volcanic rocks - as well as humidity and the depradations of plant parasites and pathogens. The ratio of land lying fallow to that cultivated may therefore be as low as 1:1 but more commonly is around 1:3 comparing with true swidden where an optimum ratio might be around 1:12 (Sanders and Price, 1968). Tlacolol, although it may once have been a completely free-standing system became in time part of an infield-outfield system, with permanent, intensively-cultivated lands around the settlement, nearer to irrigation water and sources of domestic refuse (Flannery, 1976; Sanders and Price, 1968). It is in this broader ecological and community context that tlacolol has helped to sustain populations beyond those of swidden.

Hoe cultivation of suitable freely-draining slope soils expanded in parts of the Andes from about 4000 BC while stone hoes, suitable for cultivating root crops appear to be restricted to high elevations from 1500 BC onwards. From this time it is thought that maize, beans and squash were more widely produced at lower elevations (Pickersgill and Heiser, 1978). In parts of central America at Spanish contact, the drier, forested slopes were the main sites of agriculture while the lower, wetter parts of valleys were open (Johannessen, 1963) and periodically burned, possibly to encourage grazing (Dozier, 1958). Similar patterns are discernible in the Peruvian montaña today (Scott, 1977). The parallel lineations observed in Highland Ecuador while bespeaking an equable division of hill lands into allotments may also fit the sectoral model of tlacolol and the tendency for early agriculture to avoid bottom lands. It may be that these features represent a prototype of the Andean sectoral fallow system known as laymi (Brush, 1980) where land is held communally, utilized for 2-3 years then left for at least a further 7. Donkin (1979) reports the frequent practice of burning upslope in which fire can be more easily controlled, so the logic of narrow uphill strips becomes clearer.

Swidden and tlacolol are not equal to generating a large surplus but more can clearly be squeezed from them for short periods. Their role at times of centralised power in ancient America can only have been extremely peripheral though the Peruvian montaña and the Gulf Coast lowlands clearly did provide exotic produce for Cuzco and Tenochtitlán. Nevertheless it is a matter of some speculation as to what the effect of agricultural intensification was on these native systems. The latter may have led to such a withdrawal of labour as to induce abandonment of marginal lands while, locally, increased demands on these fragile systems might have had disastrous ecological and political consequences.

Terrace farming

Agricultural terraces represent a truly astonishing investment of effort by aboriginal peoples in the New World. They signified the growth of agriculturally-dependent communities and are therefore to be seen as a form of agricultural intensification (Spencer and Hale, 1961). The benefits were not simply increased production but larger and less fluctuating yields with the possibility this allowed for wider exchanges. They were also a context in which to build and maintain soil fertility and reduce the length of fallow periods although many terraces in the driest areas would only have been used for annual crops in the wetter years. In the more humid areas terracing might have developed in response to long-term problems of managing tlacolol. Characteristic of arid and seasonally-dry areas, terraces were adapted to irrigation, the history of which closely parallels terrace construction from the first millennium B.C. Significantly, there was also an expanded development of pottery and metalworking from this time. Nevertheless, many areas of terracing are too high and remote from water sources or are constructed in a manner which otherwise militates against effective irrigation.

By far the most widespread are the many kinds of contour bench terrace, usually stone-faced and sometimes with elaborate foundations (Figs. 6-8). On gentle slopes, terrace surfaces often maintain a slight downhill gradient while on steeper slopes the planting surface can often be nearer the horizontal (Keeley, 1984). On coca terraces, which are very narrow, planting takes place in a trench which runs along the backwall (Fig. 9). The terrace form not only stabilizes the soil but improves water absorption and retention, thereby maximizing the benefits of meagre rains. Terraces also contribute to a more uniform drainage condition along contours than normally obtains in nature.

Figure 6 : Soil cross-sections through terraces in the Cusichaca Valley, tributary of the Rio Urubamba, Peru (from Keeley, 1984)

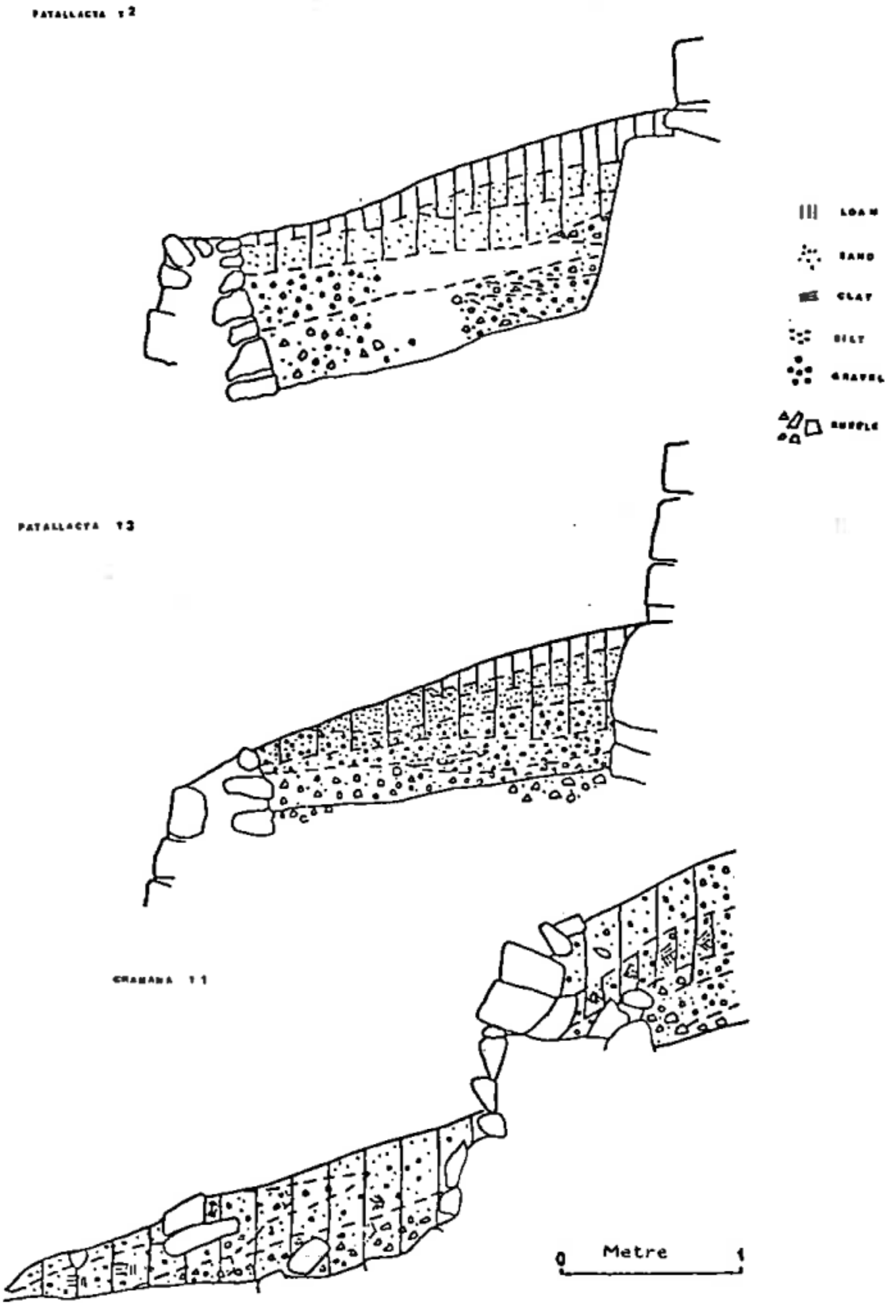
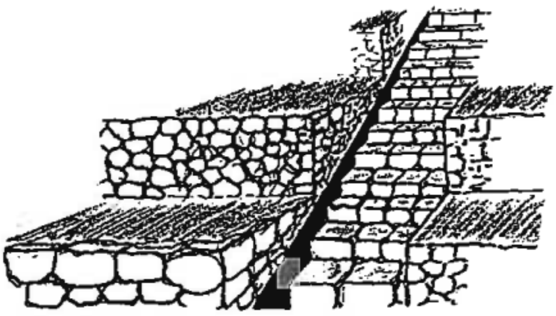


Figure 7 : Inca agricultural terrace at Pisac, near Cuzco, Peru. Note chute for irrigation water at side of steps (drawing by the author)



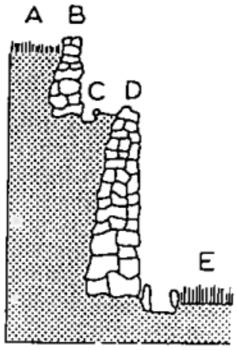


Figure 8 : Double terrace wall, Yucay, Peru (from Donkin, 1979)
A. Upper cropping surface. B. Upper wall (3.5 metres).
C. Intermediate level, canal, pathway. D. Lower wall (8 metres).
E. Irrigation ditch and lower cropping surface.

Figure 9 : Coca terraces in Bolivia (sketch by the author)

Terracing at higher elevations compensates for problems of frost drainage experienced on valley bottom sites. In deep gorges, terraced slopes can also provide favourable insolation as at Inty Pata (= sunny slope) in the Urubamba Valley, Peru. Terraces (Trincheras) were also developed across the channels of ephemeral streams (arroyos, quebradas), the stone structures serving as check dams (Herold, 1965). This facilitated the accumulation of deep, water-retaining soil (Figs. 10,11). Close relationships therefore exist between terracing and irrigation, just as they do between irrigation and drainage (e.g. Farrington, 1983), which warns against any attempt to rigidly compartmentalize these various agricultural strategies. Moreover, it is evident that 'terrace' has both functional and formal connotations and what we may term terraces, may on flatter terrain, grade into other kinds of field systems whose stone 'boundary' features may none-the-less have exercised a role in soil and water conservation. In the upper Grijalva basin of Mexico, Matheny (1982) describes 'linear, sloping, dry-field terraces' which for the most part are bounded by 'rows of stone set in earth at irregular intervals'. In a landscape incorporating other forms of conservation structure such as check dams this suggests an appreciation of the benefits even of limited containment along field edges.

Terraces were one component, rarely the only component, in the local agricultural economy (Fig. 12) and one reason for their widespread distribution was that their construction and farming required cooperation at no higher a level than that of the village community, in contrast perhaps, to elaborate systems of water control. For this reason it is probably no accident that terracing across the world as a whole substantially predates the widespread establishment of irrigation farming (Spencer and Hale, 1961). In the Maya area, terraces had, it is thought, seasonal use for tuber and grain crops to extend cultivation from lowland sites. At Tenam Rosario, in highland Chiapas, Mexico, where the major building complex occupies an entire hilltop site, terraces were found on the east, south and west, with the north aspect ignored, suggesting to Matheny (1982) that they had a seasonal use. It also becomes possible to visualise the north-facing slope (even at 18^{o}N latitude) as remaining in a wooded condition. In the Andes a pronounced vertical economy was related to simultaneous use of a number of ecological zones from 2000 to 4000 m. Maize was grown to a little over 3000 m while above this level the tubers, oca and ulluca and the chenopod grains were grown. Most of the better-known Inca terraces, built with labour drawn from each community, produced irrigated 'miska' maize (Figs. 6-8). Many communities thus endured Inca appropriation of their lands on the lower slopes of the main valleys, a

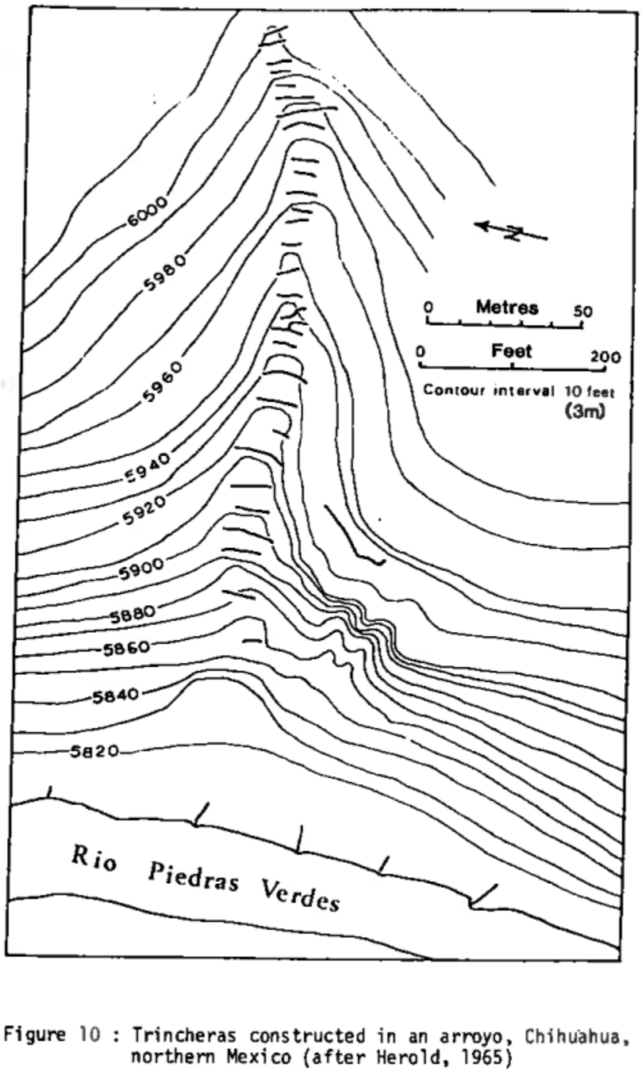


Figure 10 : Trincheras constructed in an arroyo, Chihuahua, northern Mexico (after Herold, 1965)

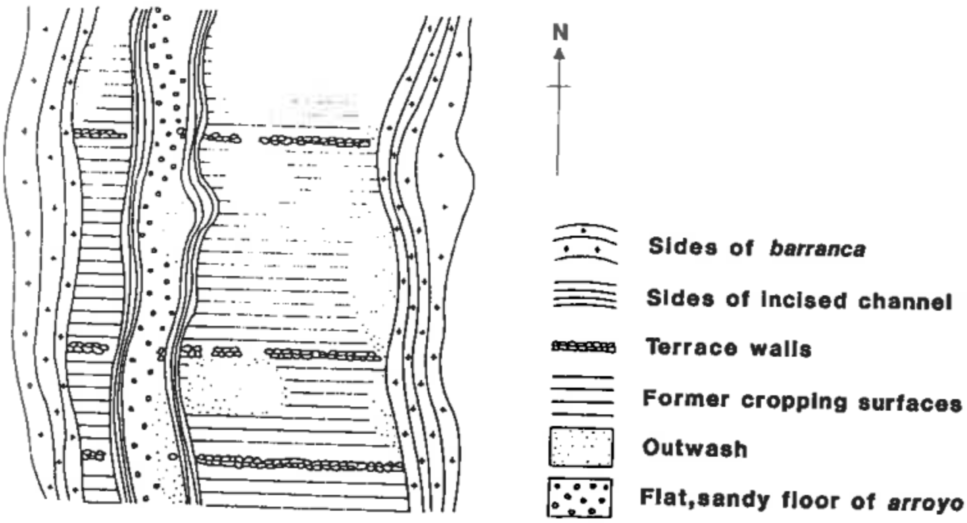


Figure 11 : Cross-channel terraces in a dry valley near Zapotitlán, Puebla, Mexico (from Donkin, 1979)

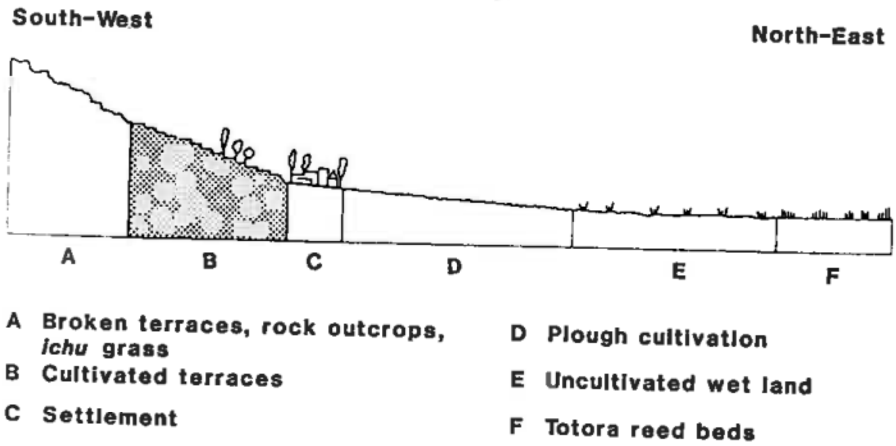


Figure 12 : Present land use zones near Chucuito, Lake Titicaca basin, Peru (from Donkin, 1979)

process merely to be perpetuated by the Spanish (Farrington, 1983).

Terraces may not always have had the same utilitarian purpose. Those on precipitous slopes at Machu Picchu, Peru, suggest site enhancement and stabilization quite as much as agricultural utility, the regularly broken contour of the hillsides evoking the step pyramid form and corresponding to an oft-repeated motif in native American art. While the symbolic significance of terraces will be a continued source of speculation, those at Sacsayhuamán, Cuzco, were for defensive purposes and are accompanied by stonework of cyclopean proportions. The remote site of Inty Pata presents a further problem, for high-grade Inca terracing at this site is not accompanied by much evidence of habitation, inviting speculation that this and perhaps other sites, were related to hermitages for priests of the Sun.

Terraces were normally constructed working uphill. On gentle to moderate slopes the dry stone wall merely prevented uncontrolled downward movement of soil and water. For example, outwash fans were modelled by excavation and forward filling to produce a succession of virtually flat surfaces such as at Pisac and Yucay in the Peruvian Andes (Figs. 7,8), where rivers were also straightened. On steeper slopes, excavation of hillsides was accompanied by importation of soil from elsewhere in order to create planting surfaces (Fig. 6). For these purposes pick and adze-like tools were used in which wood, stone and bone originally predominated, though bronze and copper later became used for the blades of hoes and adzes (Fig. 4).

We know little of the positive measures taken to ensure the fertility of terrace soils - these will certainly have been as varied as the environments encountered - but we can be sure that fallowing and rotation remained a central principle. The Incas had guano transported from the Chincha Islands by raft and, once on the mainland, this was brought to the highlands by llama train for use in the fertilization of maize fields. Llama dung was also used on fields of potatoes and other tubers at higher elevations. But there was also a realisation that planting particular crops at certain auspicious times, notably in relation to the moon's phases, ensured a better harvest and freedom from pests, and agricultural practices were, and indeed still are, accompanied by shamanic ritual (Farrington, 1980b and D.A. Preston, personal communication).

Irrigation agriculture

To say that irrigation began as a supplement to methods of farming already in existence is probably true but is like saying that farmers took some while to discover that plants benefited from water! Primitive methods of water supplementation were employed from the most remote times. One of these, pot irrigation, is still practiced today and involves the use of shallow wells with water drawn out by scoop or bucket and applied to plants set out in small depressions nearby (Fig. 13). On a larger scale too, is the more familiar well and furrow method. But it is only the more sophisticated and larger-scale irrigation structures, dating from about 1000 BC in Mexico and Peru, which have left lasting remains and it was floodwater farming and later, canal irrigation which were to make such a vital contribution to dependence upon agriculture and to the expansion of settlements throughout arid and semi-arid America. Indeed, irrigation was fundamental to agricultural development in arid regions such as the Peruvian coast. Here, a primary source of subsistence was fish, and possibly for this reason when irrigated agriculture expanded it was relieved of some of its more mundane pre-occupations and permitted the production of commercially valuable cotton around which a basis of prestige could be built.

Floodwater farming made use of a variety of impounding structures, remains of which are, for example, found in the Moche Valley near the Chimú citadel of Chan Chan on the north Peruvian coast (Farrington, 1974; Farrington and Park, 1978; Moseley, 1974). A number of deepened basins backward of the littoral zone on this coast may also have periodically served to impound flood waters. In drier uplands, cross-channel terraces (Trincheras - Figs. 10,11) were widely employed as a variant of flood water farming (Kirkby, 1973). In flood water agriculture, crops are planted on recession of the flood or in anticipation of it, and in this way maize, cotton, beans, squash, manioc, sweet potato, chile peppers, peanuts and many other crops were raised (Fig. 14). Flood water farming is, however, a high risk venture from the unreliability and erratic timing of the flood to its occasionally devastating effects. More sophisticated methods of water control were developed in time which allowed agriculture to expand in a more predictable context. The chief manifestation of this technological development was the long-distance, arterial irrigation canal.

Canal irrigation, while arguing for a higher degree of social organization, tended also to focus agricultural attention on the more dependable rivers

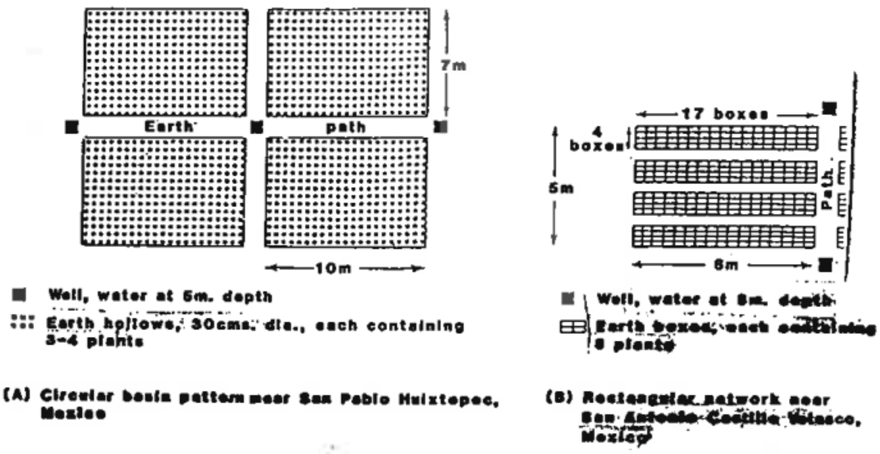


Figure 13 : Pot irrigated fields (after Kirkby, 1973)

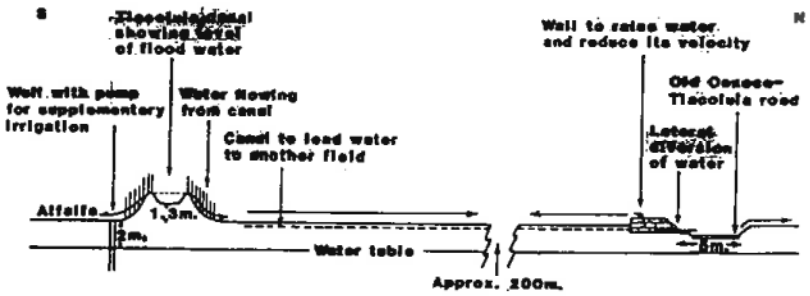


Figure 14 : Cross-section of floodwater-farmed area near Tlacolula
(after Kirkby, 1973)

(Pickersgill and Smith, 1981). Canals took water from higher up the course of streams and led it on a low incline around the contours of hillsides which would otherwise be too far from water sources (Farrington, 1980a) (Figs. 15,16). Canals therefore extended the benefits of irrigation away from the floodplain and brought large areas of previously underproductive or uncultivated land into production. It is easy to see why canal irrigation so often went hand in hand with terrace construction. Many of the more sophisticated terraces were provided with sub-wall drainage and spouts which allowed water to pass harmlessly to lower levels (see Figs. 7,8); both are associated with Maya and Inca works. Arterial canals sometimes depended on major engineering works and at Copán in Honduras the remains of a Maya dam have been found while reservoirs and associated canals occur at Edzna, Campeche, in Mexico (Matheny, 1982).

We should view the advent of canals for both drainage and irrigation as having an importance greater than simply the emancipation of agriculture. In reality the controlled abstraction of river water and the principle of the artificial canal permitted the flood plain environment to be tamed, with implications for the development of settlements and communications.

Drained fields

Drained and ridged (or raised) fields are to be found in three general localities; the moist lowlands, highland lake basins and sloping terrain in the central and northern Andean highlands. Very different climatic conditions attend these various manifestations. A great variety of form is encountered from fields divided by drainage ditches or channels to those elevated in different ways by construction. Thus ridges and platforms of many sizes and shapes, often forming intricate patterns, were created to produce what were essentially drained fields (Fig. 17). The significance of these fields is that in areas of markedly seasonal rainfall one of agriculture's orientations is towards maximizing use of the landscape in the one or more wet seasons while making a deliberate attempt to exploit wetlands for dry season crops, in which mode, drainage ditches can become a source of irrigation water (Fig. 18).

The creation of ridges and raised platforms has a number of potential agronomic and microclimatic advantages. In semi-arid regions it will facilitate concentration of salt above the level of plant rooting, one of the roles which ridges probably performed in pre-Hispanic times in the Titicaca basin. Pronounced ridging can generate shelter indirectly by interference with airflow and helps to control soil drift. It may, in particular instances, also assist in frost protection, all of which helps explain the occurrence of pre-Hispanic raised

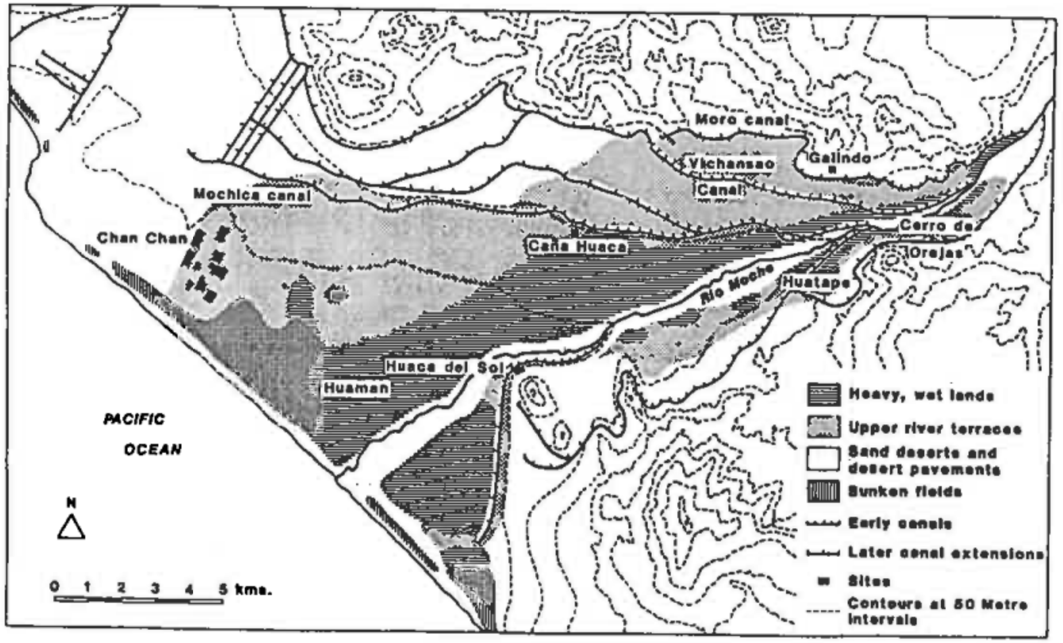


Figure 15 : The physiographic context of canal-irrigated lands and sunken fields at Chan Chan, Peru (after Farrington, 1974)

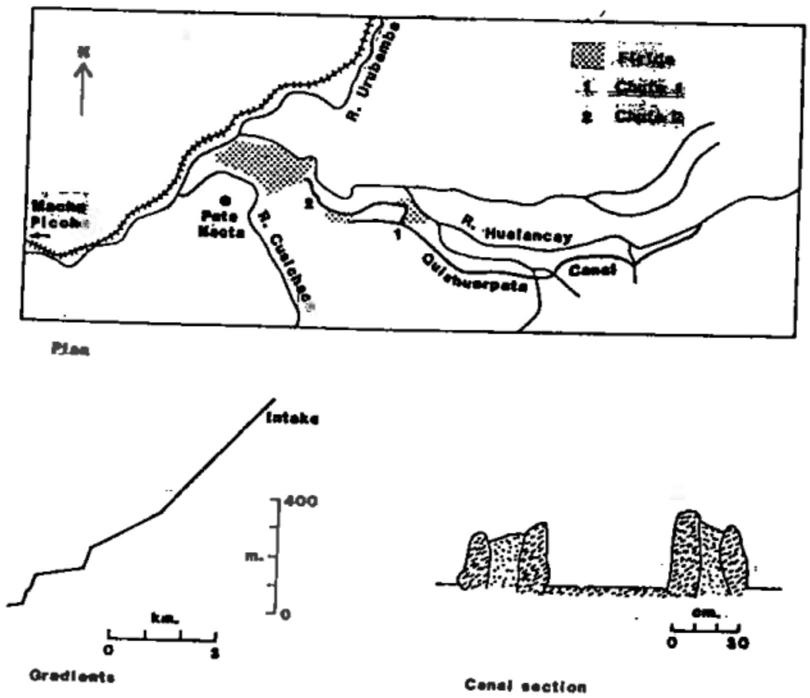


Figure 16 : Quishuarpata Canal, Peruvian Andes (after Farrington, 1980a)

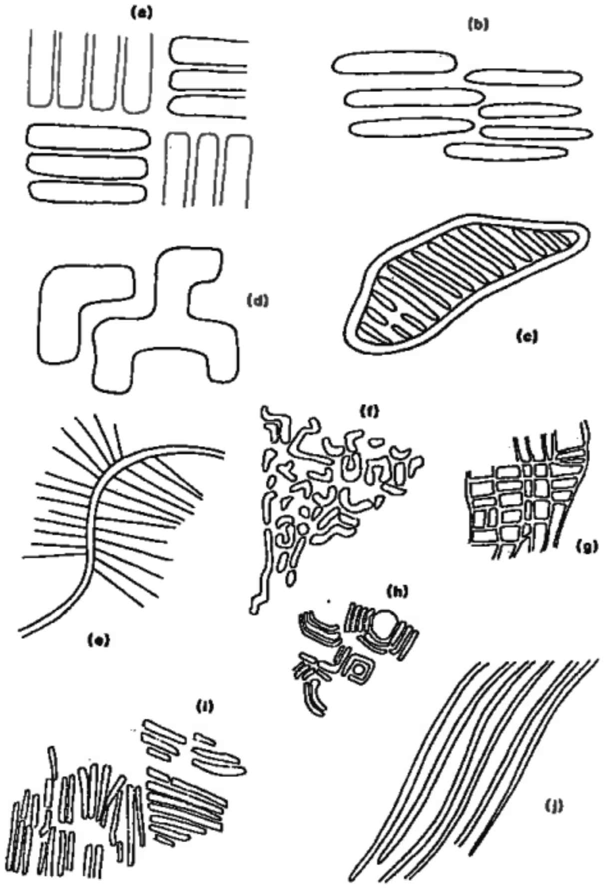


Figure 17 : Drained field patterns (based partly on Denevan, 1970; Denevan and Matthewson, 1983 and Siemens, 1982)

a) Regular checkerboard pattern; Chinampas, Valley of Mexico and parts of Titicaca basin
b) Ladder or echelon formation, e.g. Titicaca basin, Guayas basin, Ecuador
c) Embanked systems, e.g. Llanos de Mojos, Bolivia; San Jorge, Ecuador
d) Interlocking, e.g. Vera Cruz, Mexico; also Belize
e) Ditched fields in river levée zone, e.g. Campeche and Vera Cruz, Mexico
f) Irregular platform fields, Guayas basin, Ecuador
g) Ditched fields with canal network, Guayas basin, Ecuador
h) Platform fields, Samborodón, Guayas basin, Ecuador
i) Linear ridged fields, Guayas basin, Ecuador
j) Highland ridged fields, northern Andes. Form very variable.

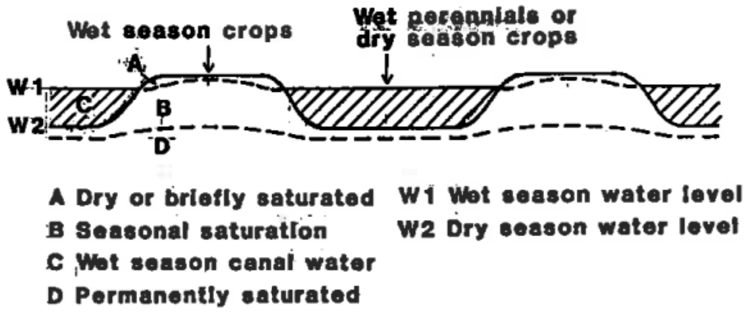
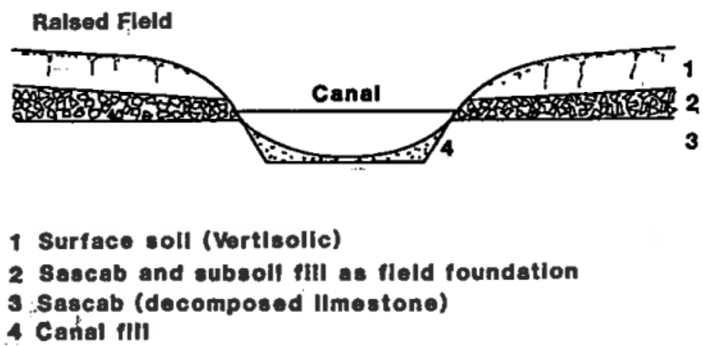


Figure 18 : Hypothetical water level fluctuations in lowland drained fields (after Smith, 1983)

Figure 19 : Section of Maya canal and raised fields, Pulltrouser Swamp, Belize (after Turner and Harrison, 1981)



garden beds not only in the American tropics and high Andean altiplano (Knapp and Rider, 1983) but in the Great Lakes region (Riley and Freimuth, 1979). But the most obvious value of raising the planting surface lies in drainage and the optimisation of soil biological processes in terms of temperature and aeration. Crop production would benefit from such a strategy in lowland and upland areas alike.

The Maya developed drained field systems, many of which first appeared in the Classic period (400-800 AD). The increase in their extent at this time may have reflected the deteriorating soil drainage of the Maya lowlands as much as the need for intensification itself while there is little doubt that such agriculture became, with terrace farming and milpa, a mainstay of Classic Maya subsistence (Darch, 1983; Flannery, 1982; Siemens, 1982; Turner and Harrison, 1981; Harrison and Turner, 1978). It was also developed locally within the Caribbean for example by the Taino Indians of Haiti (Dreyfus, 1981). The various configurations of drained fields in lowland mesoamerica relate clearly to morphological zones. For example, Siemens (1982, 1983) identifies linear, ditched or channelised fields extending back from the river levée tracts while truly raised fields of irregular pattern characterise back swamps. At Pulltrouser swamp, Belize (Turner and Harrison, 1981) it would appear that these raised planting surfaces were laboriously prepared by first stripping off swamp materials, laying a foundation of partially-rotted limestone (sascab) from canal excavation and then presumably returning the topsoil (Fig.19). These authors found some evidence for the use of hoes and mattocks in the construction and/or cultivation of these planting surfaces and, although subject to some qualification, there is evidence that maize was produced and also possibly cotton and amaranth grain.

It is likely that lowland drained field cultivation developed early, its progenitor conceivably being the type which Denevan (1982) describes as playa and levée agriculture. This latter involves temporary exploitation of sand bars, islands and river banks as floods recede. Development of such sites could have created a locus from which agriculture progressively gained control of back swamps. Siemens (1983) reports the practice among contemporary Tabascans of cutting hydrophytic vegetation and planting maize among the debris. After a week or so the field surface is cleared by burning which reduces pests, enriches the soil and leaves the maize largely undamaged. In this innocent practice we may see the origin of more sophisticated chinampa construction. In the second millennium BC, Olmec agriculture in the Gulf coast lowlands of

Mexico probably developed along these lines in conjunction with milpa, for major settlements and ceremonial complexes were developed at San Lorenzo and on the island of La Venta on land no more secure than that described above. It remains a possibility that adoption of aquatic-based agriculture in the lowlands led later to the transference of these techniques to the Valley of Mexico, to the vicinity of what was to become another island city, Tenochtitlán.

The most celebrated form of raised field was and is, the chinampa, built on the margins of lakes and into lagoons. It was constructed by placing layers of reeds and mud while trees were often grown along the margins; it thus constituted a raised but flat planting surface or platform. Parsons (1976) describes the vital contribution of these intensive horticultural beds for sustaining the tribute requirements of the Aztec capital, Tenochtitlán, now the centre of modern Mexico City. The latter lay in brackish lake Texcoco while to the north and south in fresh water at higher levels, chinampas were developed, particularly in the Xochimilco-Chalco lake bed (Fig. 20) where it is estimated they covered some 9500 ha. A considerable expansion occurred in the period 1426-1467, mostly to provide maize. Here, chinampas were of vital importance owing to the aridity of the climate and the vulnerability of rain-fed farming (see also Calnek, 1972).

It is understandable to regard swamps and aquatic habitats as marginal for agriculture yet we do well to note from Whittaker and Likens (1975) that the biological productivity of marshes and swamps can be up to 2.5 times higher than forest ecosystems and perhaps 5 times higher than conventional cultivated fields. The agricultural potential of reclaimed wetlands is very high indeed. Not only are the beds seasonally flushed with nutrients but organic, nitrogenous material can be dredged from adjacent ditches and canals to build and enhance soil fertility. It can scarcely be argued that, with primitive tools, soft muds and sand presented any more awesome a task than did breaking into hard dry turf, while the rivers and canals around the fields were a source of fish and a variety of other protein (Smith, 1983). Semi-aquatic drained fields have arguably the greatest capacity of any single agricultural system to sustain production year after year in marked contrast to milpa and other more extensive, rainfed systems. In this respect it resembles contemporary rice paddies, although cultivated rice was unknown in pre-Hispanic America. Tropical lowland drained fields grew many of the crops of the rain forest such as manioc and, as drainage systems became more sophisticated, as in the Maya lowlands, year round cropping would have become possible, with the spatial and temporal water regime determining the pattern of crops. As Siemens (1983) comments, raised fields may have provided 'a seasonal complement to the wet season milpa and

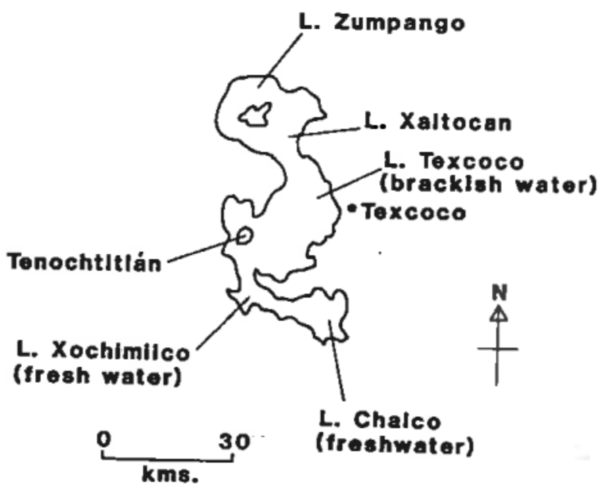


Figure 20 : The pre-Hispanic Valley of Mexico; context of Chinampa agriculture

other subsistence activities' while in areas where fields were, or could be made to be, above flood levels 'the system might also have been the crucial element in the support of nearby population concentrations'.

In the central and northern Andes, ridged or ditched fields cover very large areas, with notable concentrations occurring in the highlands of Ecuador (Knapp and Rider, 1983) and Colombia (Bray, 1983; Broadbent, 1968; Bruhns, 1981), in the semi-arid Lake Titicaca basin of Peru (Smith, Denevan and Hamilton, 1968) and in the seasonally-inundated Bolivian *llanos* (Denevan, 1970, 1982). These features are generally at least two metres in width and distinct from the individual soil ridges associated with the planting and ridging of rows of root crops. The form of ridged fields shows variation regionally and their widths and individual topography also reflect to some extent the angle of slope of hillsides. The object of these fields appears to have been the expansion and intensification of wet-season cultivation mainly of the eminently-storable roots and tubers, the latter having been grown up to heights of 4500 m. At the higher elevations potatoes, quinoa and cañihua were the main cultigens while greater diversity would have been encountered at lower altitudes with maize and the coca bush being widely grown. In this context as elsewhere, the diversity of plants would have been greatest around settlements with medicinal herbs and flavourings being grown as garden crops (Johnson, 1983). The instruments used for field construction and cultivation are likely to have been forms of the coa and chaquitaccla (Fig. 4), the latter being particularly well adapted to and indeed probably designed for breaking through dry soil which has developed a turf cover. An historical account from the Orinoco llanos of Venezuela refers to construction of ridged fields with macanas, which again were essentially specialised digging sticks (see Donkin, 1979). In any event the widespread regularity of field strips suggests that teams of labourers worked to pre-arranged plans determined by principles of land division as well as by topographic constraint.

The obvious contrast with terrace agriculture is that in areas subject to wet seasons and tropical storms, or simply a high water table, a moisture-shedding rather than a moisture-conserving role is the priority and this, irrespective of the duration of the wetness. It was stated earlier that terrace farming was associated chiefly with moisture-deficient areas and that it probably superceded tlacolol systems. Much the same temporal relationship may have applied in the case of ridged fields. One may suppose that agricultural intensification in the wetter areas likewise involved the exploitation of increasingly steep slopes on which primitive sectoral agriculture would have tended to invite soil instability, from soil wash to larger-scale earth slips. Such risks do of course depend on a variety of circumstances, important among which are the depth and texture of the soil and the permeability of the subsoil and subjacent rock. Hence, a view recently put forward (Botero, 1983) is that ridged fields on slopes were designed to circumvent slope failure. The combination of ridge and ditch facilitates surface runoff and generally improves soil drainage. But in particular circumstances, as where ash deposits overlie impermeable subsoils, ridging increases the capacity of the cultivated areas to absorb moisture while drainage lines permit excess water to drain from above the impermeable base, thus reducing or even avoiding the risk of soil slips through lubrication.

The fact remains, however, that slope soils are frequently lacking in depth, a problem which is likely to have been perceived as especially limiting in the case of roots and tuberous crops. Measures taken to artificially thicken the soil would improve productivity notably through increasing the amount of water and nutrient accessible to the growing crops. Furthermore, any tendency, however brief, for saturation to occur would be confined to levels below the main rooting zone. There can be little doubt therefore, that ditching and ridging conferred both stability and agronomic benefits to the cultivation of sloping terrain in wetter areas of tropical America. Ditching was probably always the primary objective. Ridging in the highlands sometimes depended upon topographic circumstances, as in the lowlands, but was probably always mainly a function of field width and soil type. The latter are likely to have been interrelated. For example, the less able was the ditch to maintain cut sides, the broader it may have become and the more soil may have been placed onto the field surfaces.

The up-and-down-slope orientation of so many ridge field systems might have seemed certain to lead to soil loss and gullying through excessive, rapid runoff along the inclined drainage lines. It certainly did so in some localities yet the system is so widespread that one is forced to conclude that it was basically sound. For example, it is now clearer to see why, had these fields normally been arranged in bunded fashion around the contours, serious build up of subsoil water could occur thus destabilizing large areas. It needs also to be appreciated that, following initial excavation of the ditches there will have been a natural tendency for these to become overgrown with a durable turf dominated by grasses. Initially this process will have taken place during the drier intervals. The latter is, of course, reminiscent of the use of sod channels and terraces in modern soil conservation practice. The greatest runoff would always have occurred when the first heavy rains encountered hard, dry soils, thereafter, the soils would improve in their ability to transmit and to hold moisture. Additionally, cultivation almost certainly did not take place at all points along each ridge at any one time and would have been confined to the convex top of each ridge if only to allow better access for weeding and harvesting. It seems equally probable that rows of plants were cultivated at right angles to the orientation of the field, i.e. with the contour. This superficial soil management would have again reduced downslope soil losses. These various assumptions have been built into the idealised model of a prehispanic ridge field in figure 21 and help to explain why such inclined field systems were viable and have become such an enduring expression of prehispanic agriculture.

There are, needless to say, substantial dangers in assuming that all the above arguments and explanations are applicable to every ridged field group or that prehispanic peoples made their decisions exclusively in response to physical processes. It has to be recognized that these fields represent the distal portions of divisions of land which were related to settlement, mostly of valley rather than hillside location. We are thereby compelled to see the logic of an up-and-down arrangement as it relates both to access and to the management of individual units of the pattern.

As one examines further the context and relationships of drained fields it is possible to see how sloping field agriculture was complementary and gave way to the swidden type of agriculture in the humid lowlands. The time is approaching when it will be possible to attempt the reconstruction of archaeological landscapes, for even where field systems are not in evidence the soils near to concentrations of riverine settlement are often characteristically anthropic (see e.g. Eden *et.al.*, 1984). It is of interest to note in this context that sites on low terraces which are close to and have good views of navigable waterways are often characterised by their organic, *terra preta* soil horizons. Here, the benefits of free drainage are apparent and such sites were clearly the sophisticated tribesman's answer to playa and levée agriculture. Riverine sites were not only the loci of tropical lowland settlement but were, as is now well established, the typical settlement sites for the Adena and Hopewell and later Mississippian woodland peoples of eastern North America whose original resource base could be very favourably compared with that of the tropical lowlands.

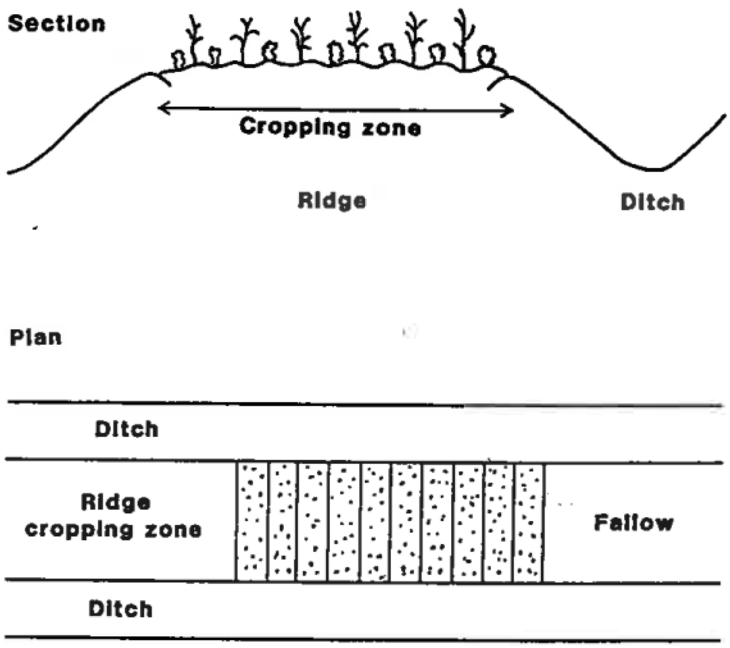


Figure 21 : Possible relationship between ridged-field topography, a cultivated zone and rows of crops.

Sunken fields

The most geographically-restricted form of indigenous agriculture is that of the so-called sunken fields of the desert coast of Peru (Moseley, 1969; Parsons, 1968; Parsons and Psuty, 1975; Rowe, 1969). These consist of elongated depressions excavated in sand and their close association with a fresh water table suggested that they were dug to exploit the capillary fringe (Smith, 1979, 1984). However, it is argued that the system would not have been viable without use of surface-applied water derived from wells. The few sunken gardens which remain in use for crop growing at present, notably at Chilca to the south of Lima, rely on irrigation water pumped from wells and this must in any case have formerly been the local source of domestic water (Figs. 15,22). In addition, there are grounds for believing that some sets of integrated basins were suitably located for receiving flood water (Knapp, 1982; Smith, 1979). This has led to some controversy (Knapp, 1983; Smith, 1983a) which Moseley and Feldman (1984) assume to be resolved in terms of the evolutionary history of these sites and of the coastal plain as a whole. The basins are quite distinct from walk-in wells (Day, 1974; Flannery, *et al.*, 1967) or sites associated with simple 'pot' irrigation (Kirkby, 1973) and are surrounded by steep-sided mounds of mineral and organic refuse from field surfaces. Nevertheless, fig trees are today grown in individual pits which no doubt reach towards a moist zone but also provide for pot irrigation if required. These fields formerly produced crops for food and industrial purposes, many of which are inherently salt-tolerant or suited to a high water table; they include beans, maize, sweet potatoes and a wide range of other vegetable and fruit crops including the sulphur-demanding peanut. There are also abundant remains of cotton, gourds, squash and reeds, the latter being grown to this day in brackish, water-filled depressions. These were the raw material for boat-making, and for house construction in association with adobe. The unique character of this region means that analogues elsewhere are limited (Smith, 1984; Soldi, 1982).

Various attempts have been made to place sunken fields into a spatial and community setting (Kautz and Keatinge, 1977; West, 1979). At Chan Chan, at the mouth of the Rio Moche, sunken gardens were clearly tributary to a major dependence on irrigation farming associated with the Imperial Chimú domain. On the other hand, at Chilca there is no equivalent urban development and here, the large extent of sunken fields is intriguingly related to the ephemeral nature of the Chilca stream.

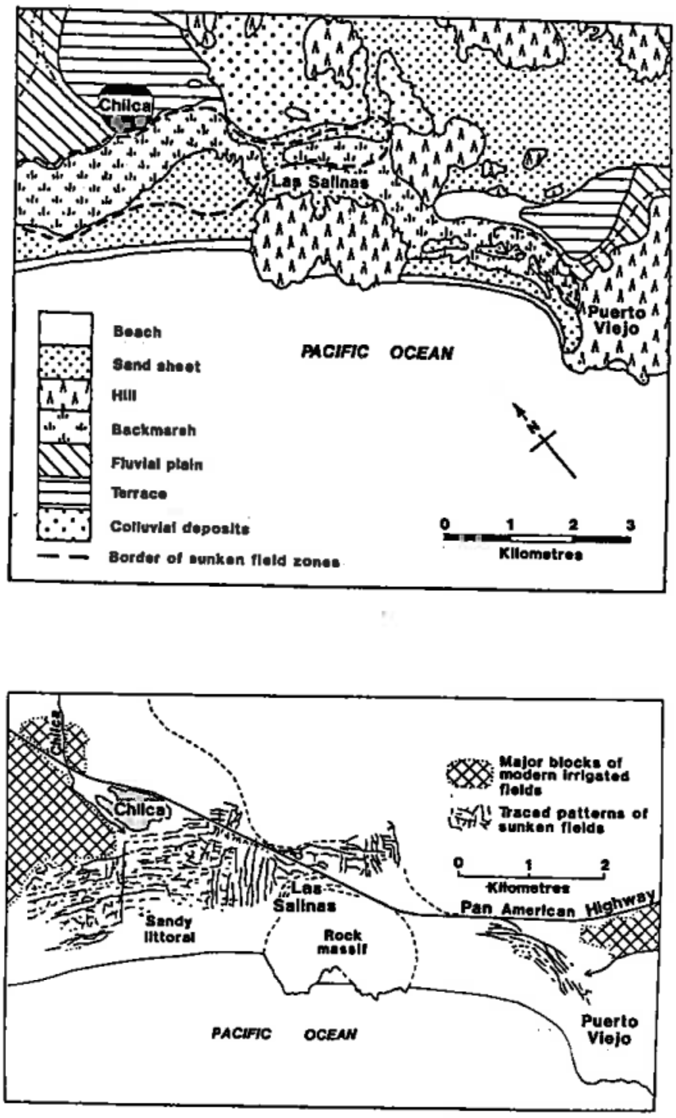


Figure 22 : The distribution and physiographic context of sunken fields at Chilca, Peru (after Parsons and Psuty, 1975 and Smith, 1979)

The field systems at Chilca have very largely been constructed where the dry Chilca river mouth reaches, but fails to cross, the littoral zone. Although floodwater is said to be available on occasion it seems reasonable to surmise that where surface water supplies were unreliable, ground water-based agriculture would have tended to proliferate. But why so large an extent of sunken fields even so? It would seem a virtual certainty in view of traditional contacts between highlands and coast (Murra, 1968) that this development and others like it, took place at the instigation of highland chiefdoms anxious to broaden and strengthen their resource base. The coastal sites provided abundant fish and other materials including guano. It is the writer's contention that such forms of subsistence were not initiated by external influence but their organised expansion - so evident at Chilca and elsewhere - resulted from Tiahuanaco and Huari highland expansion in the early centuries of the Christian era, such a timing being borne out by radiocarbon dates (Parsons and Psuty, 1975).

POST-CONQUEST CHANGES AND THE CASE FOR TRADITIONAL AGRICULTURE

The spread of Spanish rule throughout the greater part of Middle and South America caused considerable upheaval. First and foremost, the indigenous populations declined dramatically, not least through succumbing to the Europeans' diseases such as the common cold and those of childhood. Under circumstances of abject native debilitation the Spanish were able more readily to exploit their new territories and establish a new religion and characteristic urbanised life. As with the spread of the Roman empire, this process was facilitated by the existence of a developed agriculture and a system of established portage routes. Large scale abandonment of native agricultural lands was to result, this being reinforced by policies of *reducción* or *congregación* in Peru about 1570 and in Mexico after about 1590. Abandonment of terraces led in some cases to their degradation and eventually to gully erosion. The introduction of plough technology saw the rapid extension of agriculture into moist but fertile valley sites, many of which had previously been beyond the scope of hand tools. In these locations *haciendas* typically were established which had the effect of forcing native agriculturalists to make do with the steeper slopes and more remote areas at higher elevation (Donkin, 1979; Knapp and Rider, 1983). The Europeans introduced a range of exotic crop plants to different parts of tropical America including date palms, citrus, figs, grapes and wheat (Marcus, 1982). Exchanges became more frequent between North and South America and the dessert banana and cooking plantain became widely grown. Later the eucalyptus and other exotic trees made their appearance. The horse, which had so terrorised the defending Aztec and Inca warriors was soon joined by its small cousin the donkey, together with cattle, goats and pigs. While the donkey largely replaced the Andean llama as a general purpose delivery van, the introduction of new grazing animals was to have major implications for the provision of pasture. This led even more to a restriction of indigenous subsistence to *tlacololes* on the steeper slopes and it is probably from the sixteenth century that a major decline in woodland resources set in. Indeed, recent increases in the extent of tropical grassland are a further illustration of the role of animals in landscape change and it is to be wondered to what extent the grazing of native grasslands and scrubland in the colonial period by exotic cattle and goats, brought about environmental deterioration, particularly in drier areas.

It would be wrong to assume that prior to European contact there had been centuries of virtual homeostasis in the forms and products of agriculture for, as Brush and colleagues (1981) indicate for potato culture, the situation appears to have been one of continuous selection and change. Nevertheless, at the present time, economic imperatives manifesting in scale of enterprise and choice of crops, threaten to undermine indigenous farming as never before. In the first place there has been a marked increase in the scale of commercial farming or agribusiness from bananas to henequen and from sugar cane to cotton. This has led to the extermination of native agriculture either by taking its land, its people or both. Gudeman (1978) describes the transition some twenty years ago in a Panamanian village from a subsistence rice and maize system to cash cropping of sugar cane. While the change if basically an ecological one, Gudeman is also concerned with the attitudinal change among *campesinos* which accompanies the changing type of production and it is clear that changes of this sort are even more irreversible than are those of ecology. Developments of this kind in the tropical lowlands have at the very least led to pressure on the remaining peasant lands, the response to which has been the adoption of permanent settlements with resulting land degradation as mentioned earlier, a sequence splendidly documented in a recent study from Brazil (Gross *et al.*, 1979). In recent years it is of course the large who have gained at the expense of the small at all the various scale levels in farming, a situation so well encapsulated by Time magazine (Nov.6, 1978) as 'Get big or get out'.

Advances in plant breeding associated with the so-called 'Green Revolution' only seem to have endorsed this situation for, as Greenland (1975) observes, "the technology required for high yields - fertilizers, pesticides, machinery for tillage and harvesting, proper irrigation control and access to markets - is not available to the small farmer nor (in Developing Countries) is it adapted to his level of education and normal scale of operations. Furthermore, the small farmer usually does not have the capital or access to credit needed for this type of operation which in any case does not give him any greater guarantee of a minimum, secure level of production". The introduction of higher-yielding varieties into areas of indigenous subsistence farming, though it may improve the economic prospects for well placed *campesinos*, also carries its own set of problems. Andean potato culture provides a good case study (Brush, 1980; Brush *et al.*, 1981). Until recently, approximately two hundred varieties of indigenous potatoes of various land races were in use throughout the Andean potato heartland. At the present time, however, improved hybrid varieties are grown increasingly as cash crops, are 2-3 times more productive than native varieties, are resistant to potato blight and respond well to fertilizer. This trend inevitably affects patterns of exchange established over many hundreds of years and Ochoa (1975) claims that 'genetic erosion' or loss of genetic diversity is taking place rapidly and is most serious on the margins of the potato heartland. The risk is not that native varieties will disappear altogether, for people living in the Andes generally prefer eating the tastier indigenous types to the introduced ones and they also store better; it is simply that many different races of *Solanum* are suited to different land types and should failure attend either the introduced potato or its market, the native *campesinos* would no longer have suitable alternatives to fall back on (see also Bayliss-Smith, 1982; Harris, 1978). It is not only potatoes which are affected in this way in the Andes for wheat and barley are spreading in popularity for similar reasons, threatening especially the indigenous chenopods, quinoa and cañihua. Likewise, European broad beans (Vicia faba) are seriously displacing the indigenous *frijol común* (Phaseolus vulgaris) and tarwi (Lupinus mutabilis) in the Central Andes. It has furthermore been traditional to grow potatoes for up to 2 years, then have a short rotation of crops such as oca (Oxalis tuberosa) with the chenopod or amaranth grains but not returning to potatoes for at least 6 years in order to avoid eelworm (golden and cyst nematodes). Interference with individual crops or the rotations as a whole could have important consequences.

So must we be faced with the relentless tendency towards monoculture and should we be content to merely record the passing of native agriculture as today we also witness the inexorable elimination of the rain forest? Such conservationist questions are perhaps symptomatic of those distanced from the reality and enjoying superior material living standards. Indeed it would be morally reprehensible to suggest on purely conservational grounds that farmers ought to continue with practices which currently register as bare subsistence (Brush,1980; Clarke, 1976). But it is equally the moral responsibility of those able to foresee agro-ecological crises to help others plan their development in a way which does not compromise the future in general and theirs in particular. In the face of contemporary trends there may appear to be no substantial case for preserving traditional farming. Indeed, the plural society (and largely dual economy) has ensured native agriculture would never be more than an economic backwater. It is also well to realise that the major achievements of indigenous farming, in terms of monumental remains, are as much a testimony to the coercive nature of pre-Hispanic societies as to their technological and agronomic prowess. Indigenous peoples may now be subject to cultural erosion but, despite hardships, have arguably gained a freedom of action which did not exist in former times and it is this which now constitutes an important factor in the future viability of traditional agriculture.

If we argue for the preservation of indigenous agriculture we will probably have in mind the fact that this alone appears able to utilize a range of extraordinarily hostile and isolated terrain and the fact that modern technology has little place among lowland rainforests or over vast tracts dominated by steep slopes. In this respect countless numbers of holdings in the American tropics are below 2 hectares and as energy costs continue to rise, mechanisation, except in terms of intermediate technology, appears increasingly doubtful. Under these circumstances, with access to markets being a crucial factor, self sufficiency and local exchanges can be presented as a logical solution. It should also be recognized that small horticultural plots are proportionally far more productive than large-scale mechanised systems (Dahlberg, 1979; Schumacher, 1974; Wortman, 1980) for, as Clarke (1981) somewhat weightily explains, "the subleties of good husbandry can be harmonised with micro-environmental variation".

As indigenous farming and farmlands are increasingly abandoned we should try to identify in what respect the loss is most serious. Regrets about the possible under-use of land are valid, sentimentality understandable but the passing of rich ethnobotanical inventories and agricultural traditions is a serious loss to humanity as a whole. Indian practices are adjusted to maintaining the fertility of the land and to maximizing yields albeit of indigenous crops. The practices of planting mixtures and of adopting particular sowing calendars, e.g. according to the moon's phases (Farrington, 1980b) have much in common with Biodynamic Agriculture (Koepf, 1974; Kolisko and Kolisko, 1978; Soper, 1983; Thun, 1976), a more holistic form of ecologically-orientated farming. These are ultimately the most tragic losses and in this author's view future study must be concentrated in this area so that, at the very least, indigenous practices may beneficially infuse themselves into contemporary farming systems. It is encouraging to note that a training centre for sustainable agriculture has recently been established in the Dominican Republic (Mark Feedman, personal communication).

INDIGENOUS SYSTEMS AND THE FUTURE

The case for indigenous farming is based on its careful adaptation to environment and its maintenance of biological diversity and cultural stability. Its methods are relevant to a world of declining resources and to increasing costs of raw materials, particularly energy. Although associated with low per capita output, indigenous systems are nevertheless labour-consuming rather than labour-shedding. For this reason, especially when world markets are in recession it should be the aim of national governments to stem the tide of *campesinos* (small scale farmers) moving away from rural areas to what they so tragically see as a better life elsewhere. Traditional rural agriculture produces food for the family and community while modern mechanized agriculture is geared to the urban and overseas market place. The fact is that rural populations over wide areas, together with workers actually employed in commercial agriculture, lack the income to buy food produced by this expanding agricultural sector. The problem is highlighted by the production of grain and the irrigation of pastures for the purpose of feeding high-value livestock rather than people. In face of these problems, traditional agriculture, far from being an irrelevant sideline, is a vital and potentially stabilizing force in an otherwise precarious scenario. But to what extent can native methods be buttressed, adapted or even reintroduced?

In the tropical lowlands, shifting cultivation needs assistance in order to enhance living conditions and protect the environment. Agricultural extension should ensure that appropriate, improved-yielding crop varieties are available and at an affordable price but this also depends on provision of fertilizer, pesticides and even certain low-energy tools. Diversification is also an obvious direction in which to go in order to avoid land exhaustion yet increase per capita output. In this connection one might advocate incorporating livestock into crop-grass and crop-legume alternations and planting arboreal fallows for commercial timber or varieties of fruit. While it may be argued (Gomez-Pompa, 1972) that pieces of original forest should be retained as they provide the only means by which forests can be reconstituted in future, there nevertheless does seem every reason ecologically and economically to encourage controlled and diversified tree cropping which in particular areas may help reduce erosion. Many tropical trees are candidates both for subsistence and commercial use. Cacao, oil palm, rubber and various timbers are examples of the latter while for subsistence purposes, the ramón or breadnut could be developed as has the breadfruit in Africa (Miracle, 1967) and Hawaii, and the Pandanus nut and nitrogen-fixing Casuarina in Papua - New Guinea (Brookfield and Brown, 1963). Indeed there is little doubt that the Mayas, for example, laid great emphasis on the produce of planted tree species (Marcus, 1982). As far as agriculture is concerned, there is no doubt that the traditional system of creating a miniature forest of mixed cultivars offers a more varied diet, an increased period of harvest, better nutrient utilization and improved protection against pests and diseases. Nowhere on earth is it more important than in the tropical lowlands to create an artificially-structured ecosystem for the optimum working of agriculture. Minimum or zero tillage has recently been recommended (recalling previous remarks about intermediate technology) together with the use of crop and weed residues as a mulch for weed suppression and maintenance of soil fertility (Lal, 1975). Prehispanic agricultural tools were very simple in design which further suggests that our temperate concept of freshly-ploughed soil is alien to indigenous tropical systems.

In the wetlands, intensive horticulture offers scope for community development and has attracted much interest in Mexico. Here, experimental chinampas have demonstrated their capacity for multiple cropping (Gomez-Pompa *et al.*, 1982). In a matter of weeks, crops of manioc, rice, corn, beans, melons, tomatoes, alfalfa and many other vegetables have been raised. But publicly-sponsored schemes must eventually be handed over to local people and allocated ideally to private family ownership for which they are well adapted. In Mexico, the *ejido colectivo* may be capable of providing a framework within which this can occur. Nevertheless we may wonder whether such developments will prove to have long-term viability in a market-orientated economy. In prehispanic times we assume that such systems developed by centralized influence rather than through local initiatives. The success of rural enterprises certainly depends upon the existence of markets but ironically, as proximity to urban areas increases, so also do alternative forms of employment present themselves. In the Mexican lowlands the oil industry inevitably proves an attractive alternative to being a landless *chinampero*.

In the highlands a continuing problem has been the quality of nutrition as well as the quantity of food produced per unit area (Bastien *et al.*, 1978). The latter is brought about through a combination of high elevation, aridity and local salinity. The best prospects lie in diversification, employing mainly indigenous rather than exotic biota for reasons already discussed. On the grounds of environmental management one may therefore advocate the de-emphasising of sheep and cattle in the Central Andean altiplano (Browman, 1980) while a variety of measures including culling should be taken to improve the productivity of herds of llama and alpaca. Improved utilization and integration of water resources could do much to raise the aspirations and even the standard of life in the highlands albeit within the context of largely collective ventures. The Cusichaca project in the Urubamba valley of the Peruvian Andes, initiated by Dr. Ann Kendall in conjunction with the Instituto Nacional de Cultura Peruana, has recently contributed to the re-establishment of Inca irrigation canals. While one hopes similar initiatives will be taken elsewhere there remain problems of land ownership and the collective will in isolated communities to develop markets for sale of produce, surplus to local needs. In the Lake Titicaca basin,Browman (1980) advocates the reintroduction of nutritious aquatic plants known to be acceptable to the local population while the rehabilitation of relict ridged fields growing a wide variety of salt-tolerant crops could bring a large area into production once again.

The object of external aid to indigenous agriculture should be to create a momentum of production which can be sustained. While the initial success of developments depends on a process of education and genuine involvement of local people the long term future depends on market opportunities being made available. Without this realisation the process merely becomes one of giving with one hand and taking away with the other. The ultimate constraints against proposals for the envigoration and diversification - even reintroduction - of indigenous agriculture are then economic, social and political rather than physical or biological; in the words of Denevan (1982) "there are no environmental limitations to the development of agriculture only cultural limitations". It has not been the purpose of this essay to discuss in detail such constraints, which in any case vary substantially in type and degree from region to region. Yet failure to solve the agriculturally-based problems of rural areas - by far the most widespread in the world today and reflected in increasing revolutionary activity - will only exacerbate the growing urban deprivation so manifest in the *barriadas* of major Latin American cities. It is here that the failure of successive governments to treat seriously and sincerely the needs of rural areas is most tragically manifest.

SUMMARY OF PRINCIPAL SOURCES

This article has attempted to tackle the interfaces between environmental history, archaeology, agriculture and Third World problems and is based, not surprisingly, on an extensive list of primary sources.

On the environmental side, the statements by Flenley (1979) and Street (1981) provide a context for more detailed study backed up by material listed in Graham (1973, 1979) and Smith (1982). For plant domestication the essay by Pickersgill and Heiser (1978) is essential reading while the chapter by Marcus (1982) discusses the inheritance of pre-Hispanic plants in the colonial context. For South American cultigens Towle (1961) is remarkably comprehensive though now dated while useful insights into particular crops are provided by Gade (1970) and Brush (1980). On the origins of agriculture the recent work by Rindos (1984) should be consulted as should the chapter by Smith (1977). On general archaeological topics a number of excellent texts have been produced among which are those by Browman (1978), Cleland (1976), Flannery (1976), Sanders and Price (1968) and Weaver (1981) while approaches to site investigation have recently been covered by Eidt (1984). On early agriculture it will be worth consulting Darch (1983), Donkin (1979), Denevan (1980, 1982), Farrington (1984), Flannery (1982), Harrison and Turner (1978), Kirkby (1973), Siemens (1983) and Smith (1979). Problems of contemporary land use are comprehensively discussed by Clayton (1984) while specific aspects of land use and soil management are covered by Arnason *et al.* (1982), Brush *et al.* (1981), Clarke (1976), Dahlberg (1979), Spain (1975) and Lal (1975).

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