Plant Transfers in Historical Perspective: A Review Article

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ABSTRACT

This paper explores some routes into the history of plant transfers, especially during the period of European imperialism. It attempts to draw on different bodies of research, which are not usually juxtaposed, and weave together perspectives from contrasting disciplines. It does not pretend to offer a history, which is a much more complex task. We have deliberately tried to include cultivated crops, garden plants, weeds and plant invaders within the same frame of analysis, because it is so difficult to define some species within any one of these culturally constructed categories. The paper develops three main points. Firstly, it raises questions about the asymmetrical pattern of plant transfers during imperialism, thus challenging some of the propositions offered in Crosby's *Ecological Imperialism*. Secondly, we evaluate recent literature on the history of botany and botanical institutions and suggest that a broader range of human agency needs to be considered, as well as accidental transfers, if the global trajectories of plant species are to be mapped and comprehended. And thirdly, we argue that in pursuit of generalisations about patterns of transfer, scientists have concentrated too much on plant properties, and historians on understanding political economy or institutions. A global history, as well as particular plant histories, requires a combination of insights and research from sciences, social sciences and humanities.

KEY WORDS

Plant transfers, invasions, environmental history, ecological imperialism

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INTRODUCTION

Plants have been central to world history. Human demographic growth over the long term, and the development of complex societies, has often been linked to the domestication of plants and animals. Jared Diamond's recent popular overview places domestication of wild species as a first and necessary stage in the early intensification of agricultural production.[1] Equally important in world history has been the transfer of domesticated plants and animals from their core area to new zones. Such transfers have been fundamental in facilitating major expansions of people, agrarian complexes and empires. Given that domestication of the limited number of key staple crops and vegetables is likely, originally, to have been highly localised, it may be true to say that most agricultural development has been dependent on plant transfers. Even where agricultural systems, such as those in the Middle East, China, the Americas, and pockets of Africa, are still based partly upon plants that were domesticated locally (wheat, rice, maize and millet respectively), the regional spread of these crops requires explanation.

Agrarian complexes in northern Europe, north America and the southern hemisphere, which are now amongst the most productive in the world, resulted from the migration or adoption of a wide range of plant species, totally new to these areas, in relatively recent times. As Alfred Crosby argued in *Ecological Imperialism*,[2] it is difficult to conceptualise European imperialism adequately without an understanding of the plants and animals that facilitated and shaped it.

Difficult historiographical questions arise from such an argument. On the one hand, species transfer during the imperial era was intimately connected with expansive, capitalist, European social formations, and the migrations, markets, technologies and sciences that they spawned. European knowledge about the qualities of plants in turn drew on and systematised local knowledge. On the other, the properties of species themselves, from sugar cane in the tropics to sheep on the great antipodean plains, played a major role in shaping the pattern, scale and success of transfers. The tropical American empires took their shape not simply because of capitalism, sea power and the dismal development of the Atlantic slave trade, but because of the opportunities and constraints inherent in the botanical characteristics of sugar-cane. Settler colonialism in Australia, New Zealand, South Africa, Argentina and Uruguay was profoundly affected by their suitability for domesticated livestock from the northern hemisphere. Certainly the limits of domesticated species were greatly extended by the application of human knowledge and investment. Yet an analysis of such adaptability requires recourse to ecological and scientific, as well as social, approaches.

By reviewing a small range of readings on a vast topic, this paper asks how we might reach generalisations about plant transfers. It illustrates some of the lines that have been explored, and indicates others could be usefully pursued. It draws on a range of recent literature that greatly enriches an understanding of these processes, but is seldom considered together. Although our concern here

is with plants rather than animals, we recognise that the transfer of the two, not to mention of insects and germs, were sometimes closely connected. The *Jardin d'essai* in Algiers, for instance, although primarily a horticultural institution, experimented with combinations of insects and their host plants: silkworms and mulberry trees, and cochineal insects and prickly pears.[3]

Our focus is on four interconnected questions. Firstly, how useful is Crosby's idea of botanical or ecological imperialism? Has there been any overarching pattern of plant transfers from one region to another, and, if indeed there has, how might it be explained? Has the asymmetry an ecological basis? Have strong species emerged from a particular zone of the world? Are some regions susceptible to rapid transformations of their indigenous flora? Or are asymmetrical geographic patterns of transfer, if these can be detected, better explained within political economy and cultural frameworks?

Secondly, the historical literature focuses on scientific specialists, notably botanists within Europe, as well as on the institutions for which they worked. By implication as much as direct argument it suggests they had a very significant place in the history of plant transfers. But how should we conceive of their role relative to that of more informal practices and local knowledge? Should we use Diamond's arguments about domestication as an analogy: this was a very diverse process, the result of a multitude of daily practices and experiments, rather than of easily dateable major 'discoveries'.

Thirdly, is it possible to make a useful distinction between human agency in plant transfers, and other forms of plant spread? When does an intentional and apparently controlled transfer become an invasion? What is the borderline between useful plants and those seen as weeds?

And fourth, as a corollary, are there general points to be made about the human acceptance and encouragement of botanical change and plant introductions? Which forces operate towards an acceptance of plant transfers, and which against? And how do African experiences on this front contribute to analysis of asymmetrical models?

Scientists and historians, even those who define themselves as environmental historians, tend to start in different places in order to answer these questions. Scientists are primarily interested in the particular characteristics of plant species and natural habitats that lend themselves to transfer or biological invasion. For most historians, almost the opposite is the case. They tend to see human agency as the major factor, and are less concerned with the opportunities and constraints inherent in particular plants.[4]

It would be wrong to oversimplify. Scientists such as Diamond and Flannery, to whom we refer in this essay, write ambitious, well-informed works that draw on a range of historical sources and take a global view of historical processes. They try systematically to answer questions about the development of human cultures and their interface with the natural environment over the long term. Historians of the environment in their turn are paying increasingly close attention

to natural science disciplines and scientific research – at least to research done in the past.[5] At a theoretical level, Edward O. Wilson, among others, advocates a unification of scientific and humanist approaches.[6] Nonetheless, in respect of plant transfers, the historical and scientific literatures still remain to a large extent separate. And in practice, it is difficult to combine the different methodologies and research priorities of science and history.

This overview essay stems from a comparative project on the history of meso-American *opuntia* species (prickly pear or cactus pear) in Madagascar and South Africa. Although we will not focus on *opuntia* here, their spread to our areas of investigation, and to other 'Mediterranean' and semi-arid environments, has shaped many of the questions we ask. *Opuntia* travelled in multiple directions during the imperial era, against the tide of the flows identified by Crosby. Although *opuntia* species were usually transferred deliberately, some also had the capacity to spread rapidly beyond the zones that humans designated for the plant. Although some species were considered useful, providing hedging, fodder for animals and fruit for people, on occasion prickly pear became condemned as a pernicious weed and invader. *Opuntia* trajectories have alerted us to the multi-faceted features of plant transfers, to the interplay of human and non-human agency, and to the difficulty of distinguishing between domesticates, wild plants and weeds.

PLANT FLOWS: CAN GENERALISATIONS BE MADE?

Crosby contends that exported Eurasian species including domesticated and wild plants, as well as animals and germs, not only facilitated settler colonialism, but proved more powerful than those originating in the Americas and Australasia. He distinguishes sharply between the deep history of the interconnected 'old world' continents of Asia, Europe and to a lesser extent Africa, and the isolated 'new world' continents. And he sees a clear flow of plant species from the former to the latter.

A high number of 'old world' plants had naturalised in the Americas; roughly 50 per cent of farmland weeds in the United States, 258 in all, and 60 per cent in Canada were of Eurasian, largely European origin.[7] By contrast, he argues, relatively few American species had established in Europe. Australia and New Zealand demonstrate a similar pattern and there was a significant overlap between the new weeds of all these zones.

Charles Darwin recognised this asymmetry, and teased an American botanist: 'does it not hurt your Yankee pride ... that we thrash you so confoundedly'; his respondent agreed about the 'intrusive, pretentious, self-asserting foreigners'.[8] Crosby gives vivid examples of self-spreaders that took advantage of Europeanised landscapes and further transformed them. Some were regarded as useful, such as white clover in Mexico, red-stemmed filaree in California,

and Kentucky bluegrass in the eastern United States; some were destructive, such as thistle in Argentina. His notion of plant imperialism is extended in a metaphorical sweep: 'the sun never sets on the empire of the dandelion'. He sees the capacity to reproduce rapidly as one factor in the success of European plants; another was the similarity in climate.[9]

If climate was the key factor, then one would expect a more reciprocal exchange. With respect to the idea that European plants may be more powerful colonisers, indirect support can be found in some scientific overviews. Cronk and Fuller, in *Plant Invaders*, also invoke a contrast between 'old' and 'new' worlds, but on a geological time-scale.[10] Much of northern Europe was relatively recently covered by glaciers. Its soils were more freshly exposed and generally richer for plant growth. Permanently glaciated areas were mobile, depending upon long-term climatic changes. They suggest that in order to cope with this 'frost heave', some plants evolved invader and opportunist strategies. Natural selection on this mobile frost frontier favoured plants that reproduced and spread rapidly. While they emphasise these points in relation to the apparent lack of invaders in this cool temperate zone – the endemic plants were 'inherently resistant' – such characteristics may have given flora from Europe an advantage in new environments.

Support for this approach may be drawn from Tim Flannery's environmental history of Australia.[11] He challenges concepts of 'old' and 'new' worlds, not only because they are culturally loaded. Viewing the question from the geological and botanical point of view, Flannery would prefer to invert the terminology. Geologically, the southern hemisphere, and especially Australia, is the older world, not the newer world. Its long exposed soils had become leached, eroded and poor. This was a world characterised by resource poverty. The ancient mammals of Australia tended to be smaller than those elsewhere. Many Australian plant species (and this argument could apply equally to semi-arid South Africa and southern Madagascar) were also geared to scarcity; they were restricted to highly specific areas and did not spread easily.

Cronk and Fuller draw on social as well as ecological explanations for the apparent asymmetries in plant invasions: centuries of intense land use and environmental management in Europe, as well as the lack of 'wild' spaces, may have diminished the chances for alien species to establish. A corollary of this argument, which they do not explore, would be that the decimation of the native Americans facilitated vegetation change.[12] They also note the converse possibility that warmer zones may be particularly prone to colonisation by exotics. Plants from areas of sharp winter frosts, as well as those from other sub-tropical areas, can prosper in such conditions. By contrast, plants from frost-free areas are very unlikely to survive frequent frost, especially when accompanied by long periods of low temperature. Frost-free islands such as Hawaii, the wetter Canaries and Madeira, have provided particularly hospitable habitats. Some

coastal stretches of South Africa and Australia share these characteristics and have also been botanically porous.

These arguments may lend substance to Crosby's impressionistic conclusions. However, we need to be cautious asking how directional flows may be judged. Is the key index the number of species that are transferred, or is it the number that become useful, or naturalised, or invasive? Is it the area covered by exotics, even if they are few in number? Is it the volume of production of different transferred crops? Are quantitative criteria necessarily the best way to approach the issue? Should we rather attempt to identify the scale of social impacts? What are the regions and time periods of relevance?

Even in the period from 1500–1900, plant transfers may have been more evenly balanced than Crosby suggests. Ships sailed both ways and from the earliest phases of European expansion there was a significant washback. Agents of European empires were highly alert to plant potential. Many plant species were deliberately brought back from the tropics and southern temperate zones; accidental transfer was always a possibility. It is possible to point to successful colonisers from 'new' worlds including semi-arid zones with long exposed soils. Eucalypts, highly adapted to the specific conditions of Australia, have flourished elsewhere – both in plantations and as naturalised self-spreaders – including areas where few if any indigenous trees could grow. (Crosby admits to this exception.)[13] Pines from North America are widespread. Prickly pears from apparently unpromising semi-arid American environments have proved to be highly adaptable throughout the Mediterranean, South Asia, the Indian Ocean, and parts of Africa and Australia. In some places they became invasive.

Acquisition of Amerindian crop plants had a dramatic impact on 'old world' economies and social histories, as Crosby later recognised.[14] The picture becomes more complex if Africa is considered part of the 'old world' – and south–south flows are taken into account. Sub-saharan Africa over the last three centuries came to depend largely on New World domesticates. If a wider range of food and useful plants, rather than a few staples, is taken into account, and a global rather than European perspective adopted, then plant flows may look more multi-directional. American plants such as maize, potatoes, cassava/manioc, sweet potatoes, tobacco, bean varieties, peanuts, cocoa, avocado, cinchona, chili, rubber, agave, prosopis, as well as prickly pear are important and widely grown. It is difficult to conceive of species that have had more culinary and social impact than potatoes in Europe.[15] A similar argument could be made about maize in Africa or chilli in India.

A longer timescale may raise further doubts. Over the last few thousand years, there have been other major plant movements within the old world: from the Middle East to much of the rest of the temperate world; from the Mediterranean to northern Europe; and the transfer of rice, sugar cane, citrus and bananas from East Asia. The Arab empires played a key intermediary role here and pushed the cultivation of sugar cane in the Mediterranean to its northern limits.[16] Even

if it is analytically useful to consider Eurasia as a single zone for the purposes of disease patterns, it is far less so with respect to plants.

If the time-scale is extended to the present, and gardens, houses and nurseries included, Europe may be a net receiver of plant species. Tomlinson notes with respect to Australia that 'ten per cent of the current flora have been introduced since European settlement, with up to twice that figure in the most densely settled regions in the south-east of the continent'.[17] But Britain houses a higher proportion of non-indigenous plant species – if that is to be the measure of plant flows. A seemingly insatiable desire to acclimatise exotics and to hybridise new cultivars has made British garden flora one of the most varied in the world. In the nineteenth century this enterprise was supported by a large published output, some of it beautifully illustrated, not least by women.[18] A vivid pictorial culture helped to make exotic plants an object of interest and desire, just as botanical drawings had stimulated Tulipomania in Holland.[19] Increasing literacy and print cultures were critical in Europe for the growth of interest in botanical gardens, natural history, and plant transfers. A wide variety of trees were absorbed, then and since, in forests, arboretums, public spaces and on private land. There have been successful invaders such as rhododendron, knotweed and an introduced species of speedwell that challenge the assumption of native British flora presenting a 'closed' habitat which few penetrate.[20]

Williamson, a leading British authority on biological invasions, is sceptical of attempts to generalise about the typical characteristics of plant invaders, or of the environments they invade, or of the environments in which they originate.[21] His review finds little evidence to show that species from particular areas, such as Europe, are more successful self-spreaders than those from North America or the southern hemisphere. He doubts that there is typical profile of a successful invader. Some successful invaders have rather low rates of increase. Their success may have more to do with the changed habitat, or absence of predators. Moreover, plants can to some degree change their biological characteristics or hybridise in new environments: Australian *Acacia longifolia* and *Hakea gibbosa* have been found to produce more seeds in South Africa than in their native habitats.[22]

He is similarly uneasy about arguments that emphasise the role of climate in facilitating biota transfer. He recognises that those plants with a wider domestic range of temperature and climate seem to have more adaptive potential. But he finds 'plenty of exceptions' to intuitive generalisations about climatic matching and sees it as a 'rather weak indicator or predictor' of successful transfer.[23] There is a potentially huge geographic range into which many plant species can move.

Elton suggested that the more diverse a plant community, the less invasible it is likely to be.[24] Reviewing the old-established literature on island ecologies, Williamson suggests these may be more vulnerable because they are likely to have a smaller number of well-established native species; their isolation has

tended to mean a high degree of endemicity and internal speciation but a lower degree of historical reception. Islands, it may be added, were important ports of call on shipping routes in the early European maritime empires and they were also favoured for environmentally destructive plantations. Yet islands may not be exceptional. The Cape, which had one of the most diverse floral kingdoms, has been very hospitable to new cultivars and highly susceptible to invasion, especially by alien shrubs and trees.[25] Continental tropical forests are commonly regarded as resistant to plant invaders, but low levels of plant invaders may, at least in part, be due to history as much as ecology. Williamson insists that all systems are potentially invasible.[26]

Yet Williamson, in an aside, is also open to the idea of asymmetries in plant transfers. Without referring to Crosby's thesis, he agrees that in 'the nineteenth century the pattern of colonisation and trade meant that introductions were predominantly from Europe'.[27] 'Nowadays', he continues, 'the flow of commerce is much more widely spread, and faster, and species travel in all directions'.[28] We have already noted that the flow of plants may not simply follow the flow of power. Moreover, a central weakness of Williamson's approach is that, while he admits the significance of human agency in transfer, he does not then develop a theory or methodology that takes full account of that agency. The explanatory value of his models, dependent as they are on interrelationships between plant characteristics and natural communities, is limited. In ascribing the historical asymmetry to trade and imperialism, Williamson lets an important facet of the phenomena slip beyond the scope of population ecology into the domain of history, and thus unintentionally makes the case for detailed social and economic research in understanding transfers, invasions and their longer term impact.

The idea of global historical asymmetry in biota transfer clearly remains attractive to natural scientists and environmental historians, and warrants further scrutiny by both. It would be interesting to know whether plant species endemic to particular parts of the world, or plant invaders in general, do reproduce more quickly than others, or by a greater variety of strategies. But Crosby's conceptual and geographical map of biota transfer is partial and Williamson's brief lapse into social history unhelpful. Empires undoubtedly facilitated plant transfers on an extraordinary scale, but we need to be very cautious about accepting either a plant power bloc, or an overall asymmetry in movement over the longer term. What is more evident, however, is the importance of combining botanical, ecological and social factors in analysing plant flows and their outcomes.

HUMAN AGENCY: WHO SPREADS PLANTS AND WHY

It is essential to understand plant properties in explaining their spread and utilisation but not enough to do so. A wide range of texts touches upon human agency in plant transfers. The socio-economic history of particular crops, and

the agrarian complexes which grew up around them, have attracted illuminating studies: Salaman on potatoes; Mintz on sugar; Miracle on maize in Africa.[29] Comparative studies of this kind provide some opportunity to tease out the interface between plant properties, particular ecologies, and socio-political contexts. 'Biographies' of plants that became important commodities, such as the tulip and coffee, are multiplying.[30] Allowing coverage of both natural and social history, this genre is linked to popular interest in the history of science. Histories of food and of gardens document the spread of cultivated plants of all kinds.[31] A rapidly expanding literature, both academic and popular, on scientific travellers – including annotated editions of their works – is another fertile source for plant history, even when this is not the major focus.[32] Classifying, identifying, collecting, and transferring plants was often a major motive for imperial scientific expeditions, official and private.

One of the most important strategies in writing about plant history has been to follow western botanists, and institutional developments in the spread of economic plants. Lucile Brockway's *Science and Colonial Expansion*, focused largely on Kew Gardens and its Directors – Joseph Banks, William Hooker and his son Joseph – as they assembled resources and cultivated global connections to facilitate key plant transfers: tea from China to India, cinchona and rubber from Latin America to south-east Asia; sisal from Mexico to East Africa.[33] Botanical knowledge was an integral part of imperial expansion. Skills and institutions were required to identify the most suitable species, acclimatise them in new surroundings and breed them to increase yields. New technology, such as Wardian cases – protective miniature glasshouses that also minimised the need for fresh water – greatly improved plant survival during transit by sea and land.

Brockway is well aware that Kew's eminence was preceded by other botanical gardens, both in Europe, such as Leiden, and overseas; some dated to the seventeenth century. Subsequent authors have developed a finer-grained focus on these. Richard Grove's general argument about the significance of the colonial periphery in the origins of conservationist thinking might be adapted here to botanical innovation; the Dutch East India company gardens at Cape Town 'drawing on a global range of plants, some of them intended specifically for medical or commercial use, represented an accurate analogue of the current state of botanical knowledge and endeavour'.[34] Although he would differ from Grove's stress on the centrality of the periphery in environmental thinking, Richard Drayton concurs that colonial botanical gardens became centres for 'harvesting of specimens and information' in the search for useful or rare plants.[35] The establishment of Kew as a national institution depended greatly upon the requirements of empire for a centre of knowledge, bridging colonial establishments, as well as a particular conjuncture of Royal patronage and scientific development.

Private botanical gardens in Italy – for medical as much as agricultural experimentation – preceded those associated with the Dutch and British empires.

Mauro Ambrosoli emphasises the centrality of botanical knowledge, and texts, in the intensification of farming in Europe, and especially in the spread of fodder crops during the late medieval and early modern period.[36] Lucerne, a perennial fodder crop, was a case in point. Gradually extended from Iran and Central Asia, through the Mediterranean littorals, as far as northern Europe, and later into colonial empires, it saved considerably on labour and facilitated more concentrated mixed farming at a time when intensification required animal power.

Ambrosoli's emphasis on knowledge and text differs from Crosby's concern with biological processes of plant spread and displacement. While his stated aim is to explore relations between wild and cultivated plants, and between local and foreign species, he largely neglects the exotic plants that were arriving in Europe from the New World in favour of following the single strand of lucerne.[37] His work is not a mirror image of plant transfers to Europe that can be set against Crosby's tapestry of American transformations.

Grove, Ambrosoli and Drayton all adopt the approach of intellectual historians. Drayton pays close attention to the circuits of patronage and knowledge that underpinned Kew – especially the Whig grandees and landowners, improvers and experimenters on their own estates, were also advocates of imperial progress. After the gardens were transferred from Crown to the state in 1840, he argues 'the informal empire of economic botany which Banks had created' became 'a formal bureaucratic instrument for efficient utilitarian colonial government'.[38] For those seeking discussion of botany, plants, or the impact of plants transfers, however, Drayton's book is limited. We hear more about political elites than about professional botany or the popular natural history craze of the nineteenth century that drove botanical interest.

Forestry, a related European scientific specialism, also fostered species transfer. European species were introduced to colonial outposts from the seventeenth century to provide fuelwood and timber. Islands that served as refuelling points on imperial shipping routes were soon denuded and by the eighteenth century plantations were one response. Australian eucalypts and northern hemisphere pines were identified in the nineteenth century as quick growing species suitable for plantation cultivation in a wide range of settings from Uruguay and California to the Cape and India. Scientific forestry techniques evolved in eighteenth-century Germany and France for local species were reproduced in extra-European contexts such as India, and subsequently facilitated the transfer of a wide variety of exotics into colonial lands.[39] Colonial state forestry departments, followed by private forestry enterprise, helped to transform the vegetation of many of the higher rainfall zones of the British empire.

Michael Osborne argues that France and its empire in the nineteenth century, rather than the empires of Great Britain or Germany, sat at the international epicentre of the acclimatisation movement.[40] The *Société zoologique d'acclimatation*, formed in 1854 to pursue 'the introduction, acclimatisation and domestication of useful or ornamental animal species', extended its activities to the transfer of

exotic plants, and over the course of the Second Empire became the most successful of national scientific societies. It was especially active in Algeria, where Auguste Hardy, Director of the *Jardin d'essai* in Algiers, described 'the whole of colonisation [as] a vast deed of acclimatisation'.[41] This garden devoted much of its budget to investigating the transfer of Asian and Latin American plants to North Africa, notably, bamboos, Indochinese sugar cane, avocado, coffee, cocoa, and breadfruit. The aim was to identify tropical colonial products that would complement rather than disrupt the French agricultural economy, and replace the lost Caribbean colony of Saint-Domingue (Haiti).

These authors have opened exciting new areas for research in environmental history, agrarian history and the history of science. Yet historians are often attracted to institutions, and texts that leave a strong documentary trail and explain themselves clearly. While a focus on systematic knowledge, governments and institutional history is interesting in its own terms, these may be the tip of the iceberg in relation to long term patterns of global plant transfers. Companies, settlers and plantation owners, rather than the state or scientists, often took the initiative in institutional development; prior to the late nineteenth century, most British colonial states had shoestring bureaucracies with few specialists. Storey argues that Mauritius became a centre of sugar production in the first half of the nineteenth century not because of British officials and Kew, but because the Franco-Mauritian estate-owning elite took a great interest in plant research and breeding.[42]

Orthodox narratives of 'botany as instrument of plant transfer' are open to challenge. Dean has rewritten the story of the successful development of commercial rubber in Malaysia, shifting the emphasis from Kew and the imperial appropriation and development of plant material from Brazil. He argues that the success of rubber owed much to the existence of a virus that prohibited the parallel development of a competitive plantation economy in the plant's native habitats.[43] Like others, he also notes that private plant collectors collected the best cinchona seed; Kew's attempts were a dismal failure.

In South Africa, the Cape botanical garden from the seventeenth century, von Ludwig's private establishment in the early nineteenth century, and subsequently the Grahamstown and Durban gardens, certainly helped in the spread of exotics. The forestry authority also played a major role in planting exotics.[44] But many of the key transfers were made outside of institutional contexts. Settlers evolved their own intermediate, non-professional, botanical intelligence and technology that informed their decisions about which exotics were useful and desirable – and how they could be grown in a hostile environment. Prickly pear was taken to the farthest reaches of the eighteenth century frontier in the eastern Cape, where a century later it became an invader; jointed cactus (*Opuntia aurantiaca*), introduced privately as a garden plant, was judged an even worse pest.[45] Settlers in the Western Cape helped to create the 'Mediterranean' floral kingdom, an amalgam of exotics, valued for their perceived beauty and

their capacity to acclimatise. This hybrid plant complex is discernible through many similar climatic zones. 'Colonisation by gardening' was a ubiquitous, everyday settler activity.

Informal links were even more central to plant transfers of exotic food species in indigenous African societies.[46] In Madagascar, which became a French colony much later than Algeria, state botanical gardens were a relatively late development, although private botanical gardens existed by the late nineteenth century. At the Jardin de Nampoana, near Fort Dauphin, for instance, trials were undertaken for many plants from tropical and temperate climes, including coffee and fruit trees. But the introduction and spread of key field crops in southern Madagascar – maize, manioc, sweet potatoes, and, from the late eighteenth century, prickly pear – took place much earlier, and went largely unrecorded, referenced only intermittently in European travellers' and traders' reports.[47] The transfer of a typically 'Southeast Asian' culture complex based on rice cultivation to the highlands of Madagascar took place under similar circumstances.

There is a history to every transfer, even if specialists were not involved. Ordinary people travelled with seeds as well as possessions and livestock. American pioneer women took them as part of their baggage in the wagon trains going west.[48] Afrikaner trekboers – often thought to be obsessed by their livestock – were able to establish kitchen gardens and fruit orchards within a few years of settling on the remotest Cape frontiers, wherever they could find an adequate water supply. African travellers, former slaves, sailed home across the Atlantic with cocoa seeds.[49] For both settlers and indigenous people migrating to new areas, survival could depend upon successful transfers.

Amongst the historians of botany, Brockway perhaps evinces the clearest sense of these longer and more informal histories. 'Seeds', she notes, 'have been one of the most precious and easily transported cultural artifacts'.[50] She is particularly aware that what Crosby characterised as the Columbian exchange was so quick, and largely preceded botanical specialisation. As one food historian notes, there were 'imperialist cereals' well before European imperialism.[51] The role of earlier Arabic and Indian trading networks has perhaps been recognised in relation to food crops, particularly sugar.[52]

An exploration of informal forms of knowledge and experimentation is essential in understanding human agency in plant transfers, but not easy. Kreike has revealed the role of rural peasants in spreading the partially domesticated marula tree to non-native districts of Namibia during the twentieth century through the extensive use of oral histories.[53] Recovering plant histories for earlier periods is more difficult, at least for environmental historians using conventional research methods. Archival references to plants are often confused and unreliable.[54] A combination of methodologies may be called for. In a classic piece of detection, aspects of the history of Amerindian maize were pieced together by research in anthropology, cytology, and archaeology, each discipline supplying data the others could not.[55]

The sheer variety of transfers makes it very difficult to evaluate the role of botany and institutionalised science. Plants can be highly mobile, and widespread experimentation makes it difficult to generalise beyond specific case studies. Investigation of the history of botany and of institutionally led plant transfers is less likely to tell us about food and fodder crops or garden plants – at least before the age of commercial nurseries (themselves under-researched). And it is least likely to explain accidental transfers – at least before states and botanists became interested in the suppression of weeds. Science clearly penetrated into previously informal domains during the nineteenth and twentieth centuries. Yet even then, informal and accidental transfers may have predominated on a global scale.

UNINTENTIONAL SPREAD, WEEDS AND INVADERS

Recent historiography may be stronger on formal involvement in plant transfers than on informal human agency. But how do we evaluate both of these processes against a backdrop of unintentional or accidental transfers and plant spreads? Ecological dynamics are clearly central here: seeds and plants can be carried along ocean currents or rivers, by wind, or by animals. Yet human agency can be directly responsible for unintentional transfer. Human disturbance of environments can unintentionally facilitate the spread of particular species by other natural forces. Posing this question suggests a range of problems and literatures. What is the boundary between informal agency and unintentional spread? When does an intentional and apparently controlled introduction become an unplanned, uncontrolled invasion. The literature on biological invasions, as well as commentary on the concept of weeds, is a useful way to explore some of these questions.

Natural forces did not disappear with the rise of recent empires but ecological relationships could be radically reorganised on imperial frontiers. Crosby relates the unintentional spread of exotic plants in neo-Europes to the contemporaneous deliberate introduction of domesticated livestock breeds. The scale of growth of introduced animals is worth emphasising: sheep on the great plains of the southern hemisphere, for example, increased from perhaps a few million in southern Africa alone in 1800, to 250 million in Australia, New Zealand, Argentina, Uruguay and South Africa by around 1930; cattle from even fewer to perhaps 50 million. European burrweed and thistle as well as *opuntia* species were spread by livestock, in that they transported seed and cladodes, ate and deposited seed, and disrupted the indigenous vegetation. It may be the case that alien plant migration was particularly rapid in these regions because of this huge build up of mobile livestock. Once new seed was established, indigenous wildlife could also disperse it.

Cultivation, van Sittert notes, similarly 'cleared the way for the unwanted "dump heap" doppelgangers of humanity's chosen crops to compete for the newly broken earth'.[56] For South Africa, it has been suggested that alien plants were often introduced accidentally with agricultural crop seed, and that bulk sowing of grains favoured the unintentional spread of their fellow-travellers.[57] Khakibos (*Applopappus* sp.), ubiquitous in the post-harvest fields of commercial farmers and African smallholders, probably arrived with grain around the South African war (1899–1902). Gardening could be seen as a subset of cultivation, but often created different conditions. Whereas arable activities probably favoured accidentally introduced seeds that germinated in complementary cycles, gardening may have encouraged plants which tolerate disturbance, and reproduce especially from their root systems.[58] For this reason, van Jaarsveld suggests, Eastern Cape plants have become ubiquitous in pots and gardens globally. Pastoralism, arable farming, and suburban gardening could all privilege different kinds of unintentional introductions. New patterns of fire can also help some species and hinder others; weeds or grasses may themselves become fire hazards.

In considering unintentional transfers, it may be unproductive to focus on the process of initial introduction. Plants that remained confined to a few gardens or die out can offer useful insights into failure; but most transfers become important, historically and ecologically, if they spread. Terms such as 'weed' and 'useful plant' are essential but problematic categories in exploring processes of accidental spread. It is interesting that scientists have unselfconsciously adopted culturally loaded terms such as 'invader' and 'colonisers'. The case of prickly pears highlights the difficulty of distinguishing between these categories and evaluating human and non-human factors in the dynamic of specific plant transfers. In both South Africa and Madagascar, species of *opuntia* were intentionally introduced. In both, a degree of human intervention has been central to the process of selection and propagation**.** Yet prickly pear species were able to reproduce quickly by both sexual and asexual modes (when the succulent cladodes became detached), and spread to areas where at least some people did not want them. They also displaced indigenous vegetation.

Given these difficulties, how might we generalise about accidental transfers and invasions? The terms used are bewildering for the scientist, and more so for laypersons.[59] It is not simply a case of mastering a scientific vocabulary that differs from everyday use; scientists themselves do not share vocabulary, and therefore we need to be careful to understand the sense in which the particular author uses a term.

Elton's use of the term 'invasion' corresponds closely to popular usage, partly because he focuses on the dramatic explosions.[60] By contrast, Williamson's terminology is more idiosyncratic: 'Biological invasion happens when an organism, any sort of organism, arrives somewhere beyond its previous range.'[61] Williamson's concern here is to highlight the important element of failure, and to make it central to any explanation. He argues that to grasp the dynamics of

invasion, we need to see the dramatic phenomena that Elton describes in the context of a fuller range of examples.

Williamson's definition might also cover crops. As Allard notes, 'If abundance and world-wide distribution in many diverse habitats are criteria of success in colonisation, many crop plants can be regarded as notably successful colonisers. Barley, for example, is a dependable species in a vast range of habitats between the limits of cultivation marked by desert on one extreme and tundra on the other extreme'.[62] In some senses, crops have invader qualities because they are bred for strength and adaptability, that is, for qualities that ensure success beyond their natural range. Yet to class them as invaders seems paradoxical since, in contrast to 'true' invaders such as thistle or prickly pear, crops generally remain dependent on human agrarian practices. A commonsense view would prefer to consider crops or plantation species as invaders only when they escape cultivated, managed domains and pioneer their own routes of occupation. Cronk and Fuller would agree: they exclude the human factor *a priori* since they define invasive plants as those that succeed outside their native domain without human assistance.[63] As the case of prickly pear illustrates, that may also be too restrictive a definition.

If scientists disagree about definitions, they tend to agree that 'weeds', 'invaders', 'pests' can be measured in relatively objective ways. Others stress the importance of economic interests and cultural perceptions in determining whether species are defined as useful plants or as weeds. Certainly, attitudes to prickly pear in Madagascar and South Africa varied sharply. Richer white livestock farmers, who wished to protect their pastures from an invader, even if it was useful in some circumstances, agitated for its control. Poorer white tenants and black workers, who ate the fruit, brewed it, made syrup, and used the leaves for fodder and medicine, were beneficiaries of its spread. In 1920s Madagascar, where prickly pear was an important resource for southern Malagasy dryland farmers and herders, the plant became the subject of fierce controversy. Colonial debates went far beyond consideration of its economic value to moral and political issues such as the purpose of French colonialism, and the perfectibility of man.[64]

Historians tend to accept that the definition of a weed is subjective. The term describes plants that are not useful to people, that 'outcompete others on disturbed soil', and are usually, but by no means always, alien to the area in which they are found.[65] This cultural definition allows the same plant to change status in the context of historically dynamic socio-ecological systems. The American domesticate amaranth became a weed elsewhere and rye became a crop.[66] Cultural values may compete with utility; botanical nationalists agitate against undesirable 'aliens' even where these have uses. In some cultural systems, plants occupy more fluid positions between weed and cultivated plants. The gathered self-seeding 'greens' in African arable plots are a case in point. In parts of southern Madagascar, prickly pear is classified simultaneously as both

'cultivated' and 'wild'.[67] African literature suggests that many environments are managed as much by leaving, thinning or lopping indigenous species as by cultivating, and that people adapt to the plants that thrive – for example in collecting firewood.

The very categories 'wild', 'domesticated' and 'cultivated' are problematic: it cannot be assumed that other societies classify the world in ways that correspond to western cultural constructs.[68] In South America, Lévi-Strauss observed fifty years ago, 'there are many intermediate stages between the utilisation of plants in their wild state and their true cultivation', a point subsequently developed by anthropologists, ethnobotanists, and historical ecologists for Amerindian agroforestry practices in various contexts.[69] It is also implicit in Diamond's representation of domestication as a slow, gradual process of selection, largely a matter of happenstance, as hunter-gatherers picked, ate and gradually spread bigger ears of what became grain. In Ecuador, the Huaorani 'view of the environment does not discriminate between what is wild, tame or domesticated but only between what grows slowly and what grows fast'.[70]

A linked question is whether there is any botanical definition or phytological characteristic of weeds. Here Ambrosoli agrees with Crosby that 'there is no botanical difference between cultivated species and weeds, it is man who makes the selection'.[71] But a constructivist position can mask actual biological processes taking place. As Ambrosoli notes, contradicting his earlier assertion, cultivated plants develop distinct phytological characteristics through propagation, experimentation and cross-fertilisation.[72] The passage between weed and cultivated crop may not be through a gateway that is equally open to traffic in both directions in that plant-breeding usually diminishes the plants capacity to compete without careful human attention. Both historians and scientists tend to be inconsistent and if it is important to recognise that terms like 'weeds' are social artefacts, it is equally important to challenge the commonplace observation that there is no difference between weeds and cultivated plants.

Definitions, and their epistemological bases, help to shape theoretical and methodological questions in the study of plant transfer, and call for further interrogation by historians and natural scientists alike. While social anthropologists are well aware of the importance of local categories, these are often ignored or assumed. Ambrosoli (and his translator) gloss vernacular terms freely into Italian and English as 'wild' and 'cultivated', without indicating how the terms or their uses might have differed. 'In the fifteenth century', he writes, 'plants were classified as wild or cultivated, more or less as they are now'.[73] Lucerne is perceived in texts at some periods to be growing wild, when a peasant, more familiar with local ecology and local practices, might have known it to be partly cultivated. Ambrosoli talks of plants being 'rustic', 'growing spontaneously', 'in the wild', without allowing for the complexity of agricultural practices on the peripheries of demarcated fields, or in the interstices of formal agrarian systems.

Definitions also matter, as we have argued, if we are to get further in respect of assessing the directions of plant transfers and invasions: a commonsense view of geographic scale, comparative global spread, and impact on local plants and societies are critical. Such knowledge, as well as cultural constructs, shapes political decisions and remains essential in debates about biodiversity and the control of weeds.

WHEN AND WHY DO PEOPLE ACCEPT PLANT TRANSFERS?

Underlying many of the points raised in this review is the question of when and why people welcome alien plants. We asked, for example, whether the demise of Native American people facilitated botanical transformation; would the pace of change have been different if they had remained demographically preponderant and in control of their land? Yet indigenous people do not necessarily favour indigenous plants. African experiences, which are not addressed in the models of asymmetrical plant flows that we have outlined, can be instructive. This concluding section focuses largely on Africa, and on one aspect of human choice – crop innovation, including prickly pear. We cannot generalise comfortably about the overall implications for plant transfers, but we can discuss some of the dynamics involved.

Crosby, following Boserup, suggests that people are mostly conservative, but are driven to adopt alien plants by practical necessity: for instance, demographic pressure on land.[74] With respect to Africa, some authors who develop an anti-colonial position emphasise the resistance of African peasants to colonial introductions. New cash crops, encouraged or forced upon peasants by governments, were seen to intensify labour demands or result in a loss of land and labour for food crops. Cash crops at times contributed to intense food insecurity and even starvation; in West Africa, the interior savannah regions were more susceptible to such costs than the wetter forest zones.[75] Forced cotton cultivation was resisted in Mozambique for similar reasons.[76] Malnutrition has been linked to the gradual spread of maize and cassava, because these American cultivars displaced the more nutritious African staple crops of sorghum and millet.

Fiona MacKenzie suggests that maize types favoured by the Kenyan agricultural officials were unsuitable for local conditions, and that peasants, particularly women, often preferred their own, older varieties, which were seen as either better adapted or more reliable for seed. Official initiatives were frequently resisted, as part of a broader struggle against colonial environmental and agricultural regulation and intervention. The particular importance of her analysis is its illustration of gender relations as an element in rural responses and strategies.[77] The implication of such arguments is that Africans wanted to cultivate familiar species, or that they did not benefit from innovation.

Some African systems have also experienced extended periods of involution or stasis following phases of rapid innovation. In the Eastern Cape, for example, black South Africans adopted ploughs, ox transport, maize, oats, wheat, beans, pumpkins, and woolled sheep so that, between about 1820 and 1900, their agricultural system changed fundamentally. Crops were marketed through a region-wide trading network. But over the next 80 years, innovation was less common, despite the fact that neighbouring white farmers were growing an increasingly diversified range of crops and fruits. This closing down is difficult to explain but it coincided with the extension of migrant labour, restricted access to markets, and decreasing dependence on domestic food production; the survival of forms of communal tenure could make it difficult to isolate and control land for new crops.

Yet, as noted above, Africans adopted many American species. Over a few centuries, these have become amongst the major food plants of Africa, and are now often seen as indigenous or naturalised. It is barely possible to conceive of African food systems without maize, cassava, chilli, tomato, American beans and groundnuts, not to mention prickly pear and tobacco. Cultivars from the east such as sugar, citrus, mangoes, types of rice, and especially plantain and banana, have also been important. So have, more recently, vegetables such as onions, cabbages and potatoes.

Maize is so widespread, and so widely considered by Africans as an African crop, that it is difficult to see its adoption, and subsequent infiltration to the heart of many production systems, as enforced. The earliest varieties may have been introduced by sixteenth-century Portuguese traders seeking to expand supplies for slave ships, and colonial regimes encouraged its cultivation more recently.[78] But the crop spread not least in the nineteenth century, between the era of slavery and colonial rule. It presented many attractive properties to smallholders: a covered cob which diminishes labour required for guarding against bird predation; high yields, given certain water-soil conditions; amenability to plough agriculture and storage; disease resistance; and clearly an attractive taste.

Cash crops such as coffee and cocoa have been widely adopted and brought considerable wealth. Many authors, following Polly Hill's famous study of rural capitalism amongst Ghanaian cocoa growers, have celebrated such innovation as a critique of colonial stereotypes of African backwardness.[79] Laissez-faire policies adopted by the British in their West African colonies encouraged African entrepreneurship. In East Africa, colonial governments were more restrictive in respect of cash crops up to the Second World War. Subsequently, Kenya has increasingly been seen as a hive of innovation. Price-responsiveness is often cited as a key factor in decision-making in both conventional economic models and in radical analyses of peasant innovation. Prices for primary commodities in general and for cocoa in particular were attractive at the turn of the twentieth century and this helps to explain the rapid spread of cash crops in West Africa at the time.

Price incentives help to explain innovation in key cases, but the relationship is seldom straightforward. Some critical periods of expansion of cash crop planting have taken place when prices were no longer favourable, especially in the inter-war years of the twentieth century. Producers had to sell more in order to pay taxes and debts, or for imported commodities and education. Boserup emphasised demographic pressure and the erosion of old agrarian systems, rather than prices *per se*, as a powerful stimulus to innovation. Globally, a very limited number of rural communities have responded to past peaks in commodity prices by adopting new cultivars. Perhaps most importantly, a vast anthropological and historical literature suggests that 'economic' models are too simple. Africans and Asians often failed to respond to price incentives, because of their constructs of the traditional or sacred, as well as risk-aversion and local understandings of ecological processes.

Berry argues that even in West Africa, where the embracing of new agricultural opportunities and crops has been most sustained, there is a 'very weak link with price responsiveness'.[80] She develops a sophisticated model of agrarian innovation, which contextualises price responsiveness in complex interactions between multiple social, economic, and gender influences, both local and external. The idea of social capital is one means of explaining agricultural innovation: the availability of networks, communities, extended family, subordinate groups, as well as capital and land. While her theoretical route is attractive to anthropologists and historians, there are problems in invoking so generalised a set of relations. What should we understand as a high level of social capital? The survival of strong kin and community networks can also be associated with resistance to innovation. Case studies have linked religious conversion, and individualisation, with crop innovation.[81]

Capital as well as social capital can play a major role in crop transfers. Previous opportunities for accumulation and the honing of entrepreneurial skills and knowledge were clearly important to crop innovation in West Africa. Arhin suggests that social framework of production and the organisational methods developed through Asante experience with the kola and wild rubber trades laid the basis for the successful introduction of cocoa cultivation.[82] But not all accumulation of capital and knowledge necessarily goes into crop innovation. In southern Madagascar, the wild rubber boom did not have the same outcome. Income was invested in cattle or was spent in purchasing imported western trade goods, chiefly cloth, guns, and mirrors. After 1900, colonial poll and cattle taxes became priorities. This same people had embraced prickly pear a century before. In many African contexts, successful cash crop producers have chosen education or non-agricultural enterprises as their key investments. A culturally infused analysis of risk is essential in explaining such choices.

In the case of prickly pear, price had some indirect relevance for South African commercial farmers in that it was used as drought fodder, especially for ostriches during the great feather boom from about 1880 to 1914. Like lucerne

in Europe, *opuntia* was implicated in a general intensification of pastoral production in parts of Madagascar and South Africa. However, over the longer term, the plant helped to underpin subsistence as much as an export economy.

Approaches that emphasise factors such as relatively free land and labour, rather than simply external price stimuli, have been used in explaining cash crop exports.[83] They can also be useful, when set in a social context, in discussing innovations related to production for local consumption. Leaves of some varieties of *opuntia* could be eaten directly from the plant. But the singeing of the cladodes for fodder, and especially the preparation of fruit and leaves in home manufactures, was time-consuming. *Opuntia* became a multi-purpose plant in Malagasy and African societies that had little access to manufactured commodities. The properties of such plants themselves were of great significance, representing, in a sense, a new technology that expanded the boundaries of cultivation and settlement.

A key question around plant transfer concerns the relationship between innovation and local knowledge systems. Isakandar and Ellen show how sacred law among the upland Baduy of West Java constrained the process of innovation, by prohibiting most new crops or cultivars. However, Baduy were also committed to the practice of swidden cultivation in an area of depleted forest.[84] After initial resistance they successfully adopted the leguminous tree *Paraserianthes falcataria*, which reduced fallow length and afforded some protection against further depletion of surrounding mature forests. The authors argue that successful, ecologically sound innovation in Baduy was grounded in pre-existing understandings of other nitrogen-fixing plants.

The idea that plant introductions are made with an eye to soil and forest conservation is probably not generalisable, even where people have a long established familiarity with the land. While the 'environmentalism of the poor' is a valuable concept, it is always necessary to specify the conditions under which it is possible.[85] The African adoption of maize and plough agriculture, for example, had widespread ecological impacts. We can also question whether crop innovators are able to predict the long term ecological implications of introductions. *Paraserianthes falcataria* is listed by some authorities as an invasive species, and the widespread promotion of it and other fast-growing leguminous trees in tropical agroforestry has been criticised.[86] Prickly pear undoubtedly competed with, and sometimes displaced, indigenous species, and its spikes, untreated, could harm livestock. A boon for some was a curse for others.

Crop innovation often required unpredictable adaptations of technology and knowledge. Many plant transfers take place in 'frontier' contexts, for example when people migrate into unfamiliar lands. Although these hybrid phenomena pose interesting questions about the interface between cultural templates and plant experimentation, they have been generally less well researched by anthropologists and ethnobotanists, who tend to be more interested in indigenous peoples and their knowledge of native flora.

Taste can also be a factor in plant transfers. One aspect of such cultural decision-making involves food preference and addiction.[87] An understanding of changing western taste is an essential element in some of the most significant plant transfers and African cash crop frontiers – sugar, cocoa, tea, coffee and cannabis. Tobacco and sugar were likewise important in changing African consumption, and a taste preference for maize, in one of its many cooked forms, is often expressed anecdotally. Prickly pear may seem a less obvious candidate for cultural appreciation, yet Africans and Malagasy speak with some appreciation about sweet-fruited *opuntia* varieties, and their place in the landscape.

African people were certainly open to plant introductions and many agrarian systems on the continent are now based on exotics. The extent to which prickly pear became a mainstay for southern Madagascar pastoralists is a case in point. In this context, Africa has probably been no less porous to plant transfers than other parts of the world, despite the relatively successful resistance to settler colonialism, and the lack of major demographic setbacks. It could be argued that plants transferred to Africa facilitated resistance, and demographic increase, by helping to underpin food security. In this case also, the relatively late commoditisation of agrarian systems did not inhibit the absorption of new species.

The history of African agrarian systems further undermines the model of asymmetrical transfers from the 'old' to the 'new' world. It is more difficult to mount an argument about the overall patterns of vegetation change in a vast continent. Clearly there are huge differences between, for example, North Africa and the Western Cape on the one hand, and the Congo forest and Kalahari on the other. European settlers sometimes sought to reproduce familiar landscapes in distant places by introducing European plants.[88] Western Cape settlers evolved a vernacular of kinds, drawing also on local species and producing something akin to a Mediterranean botanical bricolage. (The latter also incorporated Cape plants.) In botany as in culture, colonial societies often created new 'hybrid' forms.[89]

Yet there may be an argument that parts of Africa have escaped radical botanical transformation. Aridity, dense forests, sparse populations, resistance to new crops and high proportions of pastureland may be of significance here. Whether this would make Africa exceptional is less clear. One of the weaknesses of Crosby's overview is his failure to consider North America as a whole. The bulk of the continent's surface area is the tundra, the Canadian shield, the great plains, and the Rockies, none of which have been particularly porous, botanically speaking. His model of ecological imperialism – with respect to plants at least – is most relevant to the eastern seaboard and California. Much of the interior of Australia was also partly protected by its aridity. It may be more useful, analytically speaking, to disaggregate the large geographical blocs of old world and new world, or of continents.

This paper has explored some routes into the history of plant transfers, weaving together perspectives from contrasting disciplines. It does not pretend

to present a history, which is a much more complex task. However, we hope that it offers a range of researchable questions. We have deliberately tried to include cultivated crops, garden plants, weeds and plant invaders within the same frame of analysis because many plants – and *opuntia* species in particular – fit uneasily into any one of these categories.

The paper raises questions about the value of the concept of ecological imperialism, in relation to the power of European plant species themselves, and about the longer term asymmetry of plant transfers. We argue that human agency is certainly vital in understanding plant transfers and that the focus should be on informal as much as scientific and institutional agency. But a global history – as well as more particular histories – equally requires some understanding of the properties of plants and hence a more systematic incorporation of scientific literature. It is only through such interconnected research strategies that an understanding of the history of plants such as prickly pear, a widespread exotic with a chequered career, can be achieved.

NOTES

[1] Jared Diamond, *Guns, Germs and Steel: A Short History of Everybody for the Last 13,000 Years* (London: Vintage, 1998).

[2] Alfred W. Crosby, *Ecological Imperialism: The Biological Expansion of Europe 900–1900* (Cambridge: Cambridge University Press, 1986. Revised edn Canto, 1993).

[3] Michael A. Osborne, *Nature, the Exotic, and the Science of French Colonialism* (Bloomington, Indianapolis: Indiana University Press, 1994), 166.

[4] Lucile Brockway, *Science and Colonial Expansion: The Role of the British Royal Botanic Gardens* (New York, London: Academic Press, 1979); Mauro Ambrosoli, *The Wild and the Sown: Botany and Agriculture in Western Europe, 1350–1850* (Cambridge: Cambridge University Press, 1997); Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860* (Cambridge: Cambridge University Press, 1995); Richard Drayton, *Nature's Government: Science, Imperial Britain, and the 'Improvement' of the World* (New Haven: Yale University Press, 2000).

[5] See note 4; other recent examples include N. Jardine, J.A. Secord and E.C. Spary (eds), *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996); Stephen J. Pyne, *Vestal Fire: An Environmental History, Told through Fire, of Europe and Europe's Encounter with the World* (Seattle: University of Washington Press, 1997); Tom Griffiths and Libby Robin (eds), *Ecology and Empire: Environmental History of Settler Societies* (Edinburgh: Keele University Press, 1997); Paul Slack (ed.), *Environments and Historical Change: the Linacre Lectures* (Oxford: Oxford University Press, 1999); John McNeill, *Something New Under the Sun: An Environmental History of the Twentieth Century* (London: Allen Lane, 2000).

[6] Edward O. Wilson, *Consilience: The Unity of Knowledge* (London: Abacus, 1999).

[7] Crosby, *Ecological Imperialism*, 164.

[8] Crosby, *Ecological Imperialism*, 165.

[9] Edgar Anderson noted this in respect of Mediterranean plants in California, in his *Plants, Man and Life* (London: Andrew Melrose, 1954), 19.

[10] Quentin C.B. Cronk and Janice L. Fuller, *Plant Invaders: The Threat to Natural Ecosystems* (Royal Botanic Gardens, Kew and London: Chapman and Hall, 1995).

[11] Tim Flannery, *The Future Eaters* (London: Secker and Warburg, 1996) and 'The Fate of Empire in Low- and High-Energy Ecosystems', in Griffiths and Robin (eds), *Ecology and Empire*.

[12] The idea of a denser indigenous vegetation consequent on Native American depopulation is suggested in Timothy Silver, *A New Face on the Countryside: Indians, Colonists and Slaves in South Atlantic Forests, 1500–1800* (Cambridge: Cambridge University Press, 1990).

[13] Crosby, *Ecological Imperialism*, second edition, xiv.

[14] A.W. Crosby, 'The demographic effect of American crops in Europe', in A.W. Crosby (ed.) *Germs, Seeds, and Animals: Studies in Ecological History* (New York: Armonk, 1994), 148–66.

[15] Radcliffe Salaman, *The History and Social Influence of the Potato* (Cambridge: Cambridge University Press, 1949, revised edn 1985).

[16] Sidney W. Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York: Penguin, 1986).

[17] B. R. Tomlinson, 'Empire of the Dandelion: Ecological Imperialism and Economic Expansion, 1860–1914', *Journal of Imperial and Commonwealth History*, 26, 2 (1998), 89.

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[19] Anna Pavord, *The Tulip* (London: Bloomsbury, 1999).

[20] For 'open' and 'closed' habitats, see Anderson, *Plants, Life and* Man, 127. See also Charles Elton, *The Ecology of Invasions by Animals and Plants* (London: Methuen, 1958, republished 1977).

[21] Mark Williamson, *Biological Invasions* (London: Chapman and Hall, 1996).

[22] Williamson, *Biological Invasions*, 54.

[23] Williamson, *Biological Invasions*, 70.

[24] Elton, *The Ecology of Invasions*.

[25] I.A.W. MacDonald, F.J. Kruger and A.A. Ferrar (eds), *The Ecology and Management of Biological Invasions in Southern Africa* (Cape Town: Oxford University Press, 1986).

[26] Williamson, *Biological Invasions*, 77.

[27] Williamson, *Biological Invasions*, 30; see also F. di Castri, 'History of Biological Invasions with Special Emphasis on the Old World', in J. A. Drake, H. A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmánek and M. Williamson (eds), *Biological Invasions: A Global Perspective* (Chichester, UK: John Wiley & Sons, 1989), 1–30.

[28] Williamson, *Biological Invasions*, 30

[29] Radcliffe Salaman, *Influence of the Potato*; Mintz, *Sweetness and Power*; Marvin P. Miracle, *Maize in Tropical Africa* (Madison: University of Wisconsin Press, 1966).

[30] Pavord, *The Tulip*; Mark Pendergrast, *Uncommon Grounds: The History of Coffee and How it Transformed our World* (New York: Basic Books, 1999). Mark Kurlansky, *Cod: A Biography of the Fish that Changed the World* (London: Jonathan Cape, 1998) has been one of the most successful of this genre.

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[34] Grove, *Green Imperialism*, 93.

[35] Drayton, *Nature's Government*, 122.

[36] Ambrosoli, *The Wild and the Sown*.

[37] Ambrosoli, *The Wild and the Sown*, 109.

[38] Drayton, *Nature's Government*, 160.

[39] Richard Grove, Vinita Damodoran and Satpal Sangwan (eds), *Nature and the Orient: The Environmental History of South and Southeast Asia* (Delhi: Oxford University Press, 1998).

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[45] W. Beinart, *The Rise of Conservation in South Africa: Settlers, Livestock and the Environment, 1770–1950* (Oxford: Oxford University Press, 2003), chapter 8.

[46] M. Miracle, *Agriculture in the Congo Basin: Tradition and Change in African Rural Economy* (Madison: University of Wisconsin Press, 1966); Jan Vansina, *Paths in the Rainforest* (Madison: University of Wisconsin Press, 1990).

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[50] Brockway, *Science and Colonial Expansion*, 36.

[51] Toussaint-Samat, *A History of Food*, 130.

[52] Mintz, *Sweetness and Power*.

[53] Emmanuel Kreike, 'Hidden Fruits: A Social Ecology of Fruit Trees in Namibia and Angola, 1880s–1990s', in Beinart and McGregor (eds), *Social History and African Environments*.

[54] Miracle, *Maize in Tropical Africa*, 60; Ambrosoli, *The Wild and the Sown*.

[55] Anderson, *Plants, Man and Life*, 99–104.

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