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THE INVENTION OF SUSTAINABILITY

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This essay attempts something a little peculiar: a study of the genesis of a concept within discourses which did not, in fact, use the word. This is at least true of "sustainability" in English. The emergence of the German equivalent, *Nachhaltigkeit*, which might also be expressed by the idea of "lasting-ness", is, however, usually dated to the use of the word *nachhalthende* by Hanns Carl von Carlowitz in his *Sylvicultura oeconomica* of 1713, the first great forestry manual of the eighteenth century. In fact, the term can be found in the 1650s.[1]

The most familiar modern definition of the "sustainable" comes from the Brundtland Commission's report of 1987, where the term "sustainable development" was defined thus: "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs".[2] Formulations of sustainability are frequently rather vague, but they generally address the sense that humankind must ensure its *material* reproduction in a way that does not diminish the fortunes of future generations. This issue is, of course, a very current preoccupation for us, but preindustrial societies that laboured under the exigencies of the "organic economy" have frequently been assumed by historians to be effective ecological "optimizers", and to have developed institutional structures and economic practices to ensure their sustainability. In contrast, I will suggest that the modern notion of sustainability largely draws on ideas developed in the late eighteenth and early nineteenth centuries when new understandings of soil science and agricultural practice combined to develop the idea of a *circulation* of essential nutrients within ecologies, and hence allow the perception that disruption to circulatory processes could lead to permanent degradation. Whether agricultural practice was in most cases sustainable or not is, of course, a separate issue.

[1] H. C. von Carlowitz, *Sylvicultura oeconimica* (Leipzig, 1713); P.-M. Steinsiek, *Nachhaltigkeit auf Zeit. Waldschutz im Westharz vor 1800* (Münster, 1999), 78.

[2] World Commission on Environment and Development, *Our Common Future* (Oxford, 1987). See http://www.un-documents.net/ocf-02.htm.

THE *HAUSVÄTERLITERATUR*

From the sixteenth century, handbooks of advice and estate management were published in northern Europe, mostly in imitation of classical predecessors such as Virgil and Xenophon, of which the first English translations emerged in the 1530s.[3] When Conrad von Heresbach came to write his *Foure bookes of husbandry* (originally published in German in 1570), he cited some fifty-seven ancient authors, but only eighteen of his near contemporaries.[4] Early, and enduringly popular, forms of the genre were calendars advising on what agricultural tasks to perform throughout the year. While authors of what was known in Germany as the *Hausväterliteratur* (writings for the "father of the house", or the "patriarch") drew liberally on the classics, they nevertheless also felt compelled to assert their own experience in farming, and they by no means absorbed other thinking uncritically.[5] The *Hausväterliteratur* also provided a slow diffusion of ideas from south to north, sometimes, of course, bringing specific recommendations to inappropriate climes, and provided a kind of guidebook for the management of a country estate.

The bottom line in these handbooks was the maintenance of household income. Thus in Gervase Markham's 1616 English edition of Claude Estienne's *La maison rustique*, a work that originally appeared in 1554, he proclaims,

> it is my purpose . . . to lay out unto you the waies, so to dwell upon, order, and maintaine a Farme, Meese or Inheritance in the Fields (name it as you please), as that it may keepe and maintaine with the profit and increase thereof, a painefull and skilfull Husbandman, and all his Familie.[6]

There was little, if any, attention given to either the capital stock, or the land itself as a source of revenue that could be alienated or used to secure debt. The focus was squarely on year-to-year production (and to a large extent autoconsumption) on an estate that was expected to endure into an unforeclosed

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3 See discussions in J. Sieglerschmidt, "Die virtuelle Landwirtschaft der Hausväterliteratur", in R. P. Sieferle and H. Brueninger, eds., *Natur-Bilder. Wahrnehmungen von Natur und Umwelt in der Geschichte* (Frankfurt a.M, 1999), 223–54; A. McRae, *God Speed the Plough. The Representation of Agrarian England, 1500–1660* (Cambridge, 1996); G. E. Fussell, *The Old English Farming Books from Fitzherbert to Tull 1523–1730* (London, 1949); M. Ambrosoli, *The Wild and the Sown: Botany and Agriculture in Western Europe, 1350–1850* (Cambridge, 1997).

4 C. von Heresbach, *Foure bookes of husbandry*, trans. B. Googe (London, 1577), iv–v.

5 See Sieglerschmidt, "Die virtuelle Landwirtschaft".

6 C. Estienne, *Maison rustique, or The countrey farme*, trans R. Surflet, revised G. Markham (London, 1616), 1–2.

future. The moral centre of this idealized household was the virtue of thrift, as Thomas Tusser put it, or to "Eate within thy tedure", as John Fitzherbert put it in his *Boke of Husbandry* of 1523. By "eating within thy tedure . . . thou nedest to bege nor borowe of no man, so longe shalte thou ecncrease and growe in richesse"; if needs to beg or borrow, "that wylle not long endure, but thou shallt fall in to poverty".[7] Behind these encomia to making shift by thrift was the assumption that it was not overworking of the land that could prove one's undoing, but the overexpenditure of its products. These "how-to" books provided commentary on best practice for particular tasks, often organized according to the layout of the estate. This made them practical and easy to navigate, but also presented a conceptual obstacle that they could not convey a sense of how the various elements of farming were interconnected. The possibility of certain agricultural practice compounding difficulties or advantages in other areas of farming would be enduringly difficult to formulate effectively.

A THEORY OF THE SOIL

Any sensible explanation of how agriculture could endure had to address the soil and the weather. The able husbandman had to be able to read both, a capacity that might require "long and assured experience" to nurture.[8] It was not long before the international range of the *Hausväterliteratur* confronted readers with regional differences in soil, clime and practice; some of the latter having no obvious explanation except for customary practice.[9] Such problems came to the fore in agronomic literature with an outpouring of works in the 1610s and 1620s from Gervase Markham, who exemplified a great agronomic tradition of publishing numerous versions of the same book under a slightly different title with minor emendations. Markham made soil type the organizing principle of his treatises, and this would exercise a profound influence thereafter: local environmental variations became the foremost theme for agronomy.[10]

What was the soil? According to Estienne, soils are either simple or compound, and loose or binding.[11] In an English context, "loose" or "binding" was understood as a sandy or a clayey soil. These represented the two simple kinds

7 J. Fitzherbert, *The boke of husbandry* (1533), 71; T. Tusser, *Fiue hundred pointes of good husbandrie* (London, 1573), 7v.–12v.

8 Estienne, *Maison rustique,* 24.

9 T. Tusser, *Fiue hundred pointes of good husbandrie* (London, 1580), 41v, 43.

10 G. Markham, *Markhams farwell to husbandry* (London, 1620).

11 Estienne, *Maison rustique,* 528.

of earth, and all compounds were a mix of these. In turn, all soils displayed qualities derived from the four humors: clays were cold and moist, sands hot and dry, and most soils some blend of this palette. The farmer had to start, stated Markham, from a "true knowledge of the Nature and Condition of your Ground" that was to be combined with "the Clyme and Continent wherein they lye" and inferred by their "outward faces and charracters". Colour, texture and taste were the indicators on which the husbandman could develop such knowledge, largely derived from long observation: "every man in his owne workes knows the alteration of climates".[12]

Farmers knew very well that soil could become exhausted, fields worn out, or the land out of "heart". But as this focus on the "heart" of the particular field was preoccupied with balance, or at least an appropriate matching up of soil, husbandry, crop and climate, as yet it precluded a broader sense of the possibility of permanent degradation. Land was "out of heart" simply because the soil embodied an imbalance of the humors, or was being put to an inappropriate use. There was no essential element that could be, or come to be, deficient: all imbalances could be meliorated by the requisite lashings of some substance which provided the appropriate quality, or as Sir Hugh Plat wrote, "contraries are remedied by their contraries".[13] The prevailing theory of the soil thus helps explain the surprising optimism of early modern improvers, and equally their complete lack of sense that there could be a long-term trend in soil quality. Durability, or as we might say sustainability, was conceived as a question of *balance*, not, as would later be the case, of *flows*.

Agronomists would hold true to humoral thinking about the soil long into the eighteenth century. But the sixteenth century also provides us with an inkling of what was to come, from the pen of Sir Hugh Plat. His theory of "vegetative salts" as the source of generation was the first trial of a theory of soil nutrients that offered the possibility of circulation-based thinking about agriculture and ecology. His 1594 work on salts drew very heavily on translating the work of Bernard Palissy, another Renaissance polymath who wrote on fossils, hydrology and chemistry and practised ceramics, painting and surveying. It was a kind of salt (and for Plat there were many, including copper, nitre and sugar),

> that maketh all seedes to flourish, and growe, and although the number of those men is verie small, which can giue anie true reason whie dungue shoulde doe anie good in arable groundes, but are ledde thereto more by custome than anie Philosophicall reason, neuerthlesse it is apparaunt, that no dungue, which is layde vppon barraine groundes, coulde anie way enrich the same, if it were not for the salt which the straw and hay left

[12] Markham, *Markhams farwell*, 1620, 7–8; *idem*, *The English husbandman* (London, 1635), 95.

[13] Sir H. Plat, *The iewell house of art and nature* (London, 1594), 3.

behinde . . . it is not the dung itselfe which causeth fruitfulnes: but the salt which the seed hath sucked out of the ground.[14]

Plat prefigured later writers in seeking to identify more exactly the *active agent* that brought herbaceous growth.

Whatever that agent might be, everyone agreed that the soil could be subjected to amelioration to improve its fertility. In 1523 Fitzherbert had dwelt on the matter fairly briefly, drawing on Virgil: the dung of doves was best, that of all animals that chew the cud good, and the horse worst.[15] As fields also seemed to recover heart of themselves, in part because of inundations from the atmosphere, but also because fallowing permitted the removal of weeds, it was important to give many grounds their "rest" or "recreation". A field had to be kept in balance in a manner not unlike a person: "as a field starveth, if it not be dunged at all, so it burneth if it be over-dunged."[16]

PROVIDENCE AND PARTICULARITY

By the middle of the seventeenth century, however, the English focus had shifted from the maintenance to the *increase* of profit. Writing was still a mix of reportage on best local practice (with considerable respect for the Dutch and Flemish), sometimes sceptical reference to the ancients, and an increasing zeal for Baconian experimentation. Two phases of more coordinated networks of correspondents emerged: one associated with the Commonwealth and the circle around the Baltic immigrant and reformer Samuel Hartlib, the second connected with the Royal Society.[17] This era was in some ways the culmination of an accelerating transfer of information into and around England, but also reflected the special circumstances of displacement by war and the development of wide networks of letter writers who were confronted, like Sir Richard Weston in Flanders in the 1640s, with agricultural and botanical knowledge that appeared developed far beyond that of Britain. Weston's observations facilitated a shift from a preoccupation with the maintenance to the *increase* of profit: "But I advize you to make Trial your selv's of all these several *Husbandries*, and then to follow that which you finde cheapest and best."[18] Markham had rather tentatively and apologetically made some estimates of the costs of several inputs into agricultural production; Weston, developing the emerging art of the estate

[14] Plat, *The iewell house*, 14–5.

[15] Fitzherbert, *Boke of husbandry*, 23; Ambrosoli, *The Wild and the Sown*, 231.

[16] Estienne, *Maison rustique*, 536.

[17] C. Webster, *The Great Instauration: Science, Medicine and Reform, 1626–1660* (London, 1975).

[18] Sir R. Weston, *A Discours of Husbandrie Used in Brabant and Flanders* (London, 1650), 15.

and farm account, provided a balance sheet of the benefits of new techniques calculated over several years.[19] Authors remained, however, very particular in their observations, stressing the different practices to be employed for the melioration of particular soils and aspects of the land. Nevertheless, their confidence in their transformatory power was high; witness Walter Blith's assertion of 1649:

> All sorts of lands, of what nature or quality soever they be, under what Climate soever, of what constitution of condition soever, of what face or character soever they be (unless it be such as Naturally participates of so much fatnesse, which Artificially it may be raised unto) will admit of a very large Improvement.[20]

Thus the literature of improvement was not at all concerned with potential failings in production, but with the level of yields and profit attained. However, this was not a discourse of "mastery" over nature. The mid- and late seventeenth-century authors still operated with a strong sense of providentialism. The great synthesis of agronomic works provided by John Worlidge in 1669 consistently gave space to the "uncertain Dispositions of an Over-ruling Providence".[21] Some thirty years later, Timothy Nourse would agree: the farmer, "after he has cast his Business to the best Method his Reason can propose, must still depend upon Providence, as to the event, here being so many Accidents which may traverse his Designs, and such as can be never provided against, nor foreseen."[22] Indeed, part of the explanation for this general confidence in the responsiveness of the soil to human endeavour may have arisen from the increasingly widespread view that God rewarded industry and that godly virtues were most manifest in the industrious and sober husbandman. It was a highly disturbing and bewildering aspect of enclosure for its opponent Henry Hallhead that it could lead to higher yields apparently being achieved by less labour.[23] There was no space for the idea that misplaced labour could actually diminish the fertility of God's earth. Neglect could allow "barreness both by little and little [to] increase", but "nature is no niggard, but giveth riches to all that are industrious".[24] And in the end, fertility was in God's gift: in the collections of letters and discourses edited by Samuel Hartlib in the 1650s, "It is the Lord that maketh barren places fruitfull", so a husbandman must "walk as becommeth a Christian, in all Sobriety, Righteousnesse and

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19 Weston, *Discours of husbandrie*,16–9.

20 W. Blith, *The English improver improved* (London, 1652), 17.

21 J. Worlidge, *Systema agriculturae* (London, 1669), 179.

22 T. Nourse, *Campania Foelix* (London, 1706), 37.

23 J. O. Appleby, *Economic Thought and Ideology in Seventeenth-Century England* (Princeton, 1978), 69–70.

24 G. Plattes cited in Webster, *The Great Instauration*, 356–7.

Godlinesse: not to trust his confidence in his own labours, and good Husbandry; but on the Lord that hath made all things."[25]

Agronomy engaged with a broader debate about nature in the seventeenth century that nevertheless only tangentially touched upon agriculture: was Nature subject to a long-term process of degeneration over time, requiring the active and continuing intervention of God in the workings of the world? Or did Nature operate according to a set of constant laws—the more mechanistic view—that the virtuous could come to understand and use to restore the fertility of the past? Either way, whether farming practices were unsustainable or not was not a matter for concern, and those writers who on a more epochal scale suggested that tillage over the centuries could cause soil erosion simply saw this as a displacement elsewhere—partly an explanation of why soils were thin on mountains.[26] Success or failure in agriculture was determined by localized virtuosity subject to the long- or short-term course of providence.

FORESTRY AND SUSTAINABILITY

Forestry, however, presented a rather different case to farming. Here we find from an early date the linkage of concerns for the durability of local wood supplies with the fortunes of the state itself. In part this rested simply upon the biological properties of wood: any concern with it operates on a different time horizon to crops and animals.

Nevertheless, early writing about wood still related it to the household economy: did woodland management ensure that you obtained an affordable supply? Regulations and advice sought to demarcate space dedicated to wood production, protecting the wood from grazing and hunting, rather than mastery of the processes that brought good wood yields. Hence much earlier writing was about jurisdiction and access. This was the key preoccupation of the first two books devoted to forest matters published in Europe in 1560 and 1576 by the German jurist and bureaucrat Noé Meurer.[27] Coppicing, the systematic cutting back of trees to the rootstock and reharvesting after a set period of years, had been widely practiced in Europe for very many centuries. During the sixteenth and

[25] S. Hartlib, *The compleat husband-man* (London, 1659), 80–81.

[26] M. H. Nicolson, *Mountain Gloom and Mountain Glory. The Development of the Aesthetics of the Infinite* (Ithaca, 1959), 233–70; S. Schaffer, "The Earth's Fertility as a Social Fact in Early Modern Britain", in M. Teich, R. Porter and B. Gustafsson, eds., *Nature and Society in Historical Context* (Cambridge, 1997), 131–4; C. Glacken, *Traces on the Rhodian Shore* (Berkeley, 1967), 408–11.

[27] N. Meurer, *Vom forstlicher Oberherrligkeit und Gerechtigkeit* (Pforzheim, 1560); N. Meurer, *Jag und Forstrecht* (Frankfurt a.M, 1576).

seventeenth centuries, governments began to try and set the periods by which this cyclical harvest should occur, although this often related to a desire to calculate revenue. In the case of Colbert's famous Forest Ordinance of 1669, for example, the rather arbitrary ten-year cycle seems to have been set to make it easier to draw up leases of Crown estates.[28]

From the late fifteenth century, governments began to pass state-wide legislation relating to the supply of wood and the condition of the forests, pioneered in Italy and particularly in Germany. This legislation was largely concerned with demarcating forest space, preventing waste, and subjecting felling to the approval of a new forestry administration: a power that was largely negative and juridical. Everywhere—whether true or not—the word was of impending shortages and scarcity. In Bavaria the looming wood shortage would imminently lead to men leaving "their goods, homes and sustenance including even their wives and children and go from the same because of its lack." The fate of stands of trees was clearly linked to the general welfare.[29]

An English act of 1544, much like German contemporaries, spoke of "the great decaye of Tymber and Woodes" meaning " a great and manifest likelihood of scarcity". By 1577 William Harrison was also concerned about the possibility of general shortage: "it is to be feared that brome, turfe, . . . heth, firze, brakes, whinnes, ling, . . . straw, sedge, reede, rush, & seacole will be good marchadze even in the citie of London". And by 1611, after a period when woodland had become a prominent concern of commissions examining Crown land revenues in the first Jacobean years, Arthur Standish produced his *Commons Complaint*: his first grievance was "the generall destruction and waste of woods in this kingdome", there being "too many destroyers, but few or none at all doth plant or preserve". The consequences could be dramatic: "so it may be conceived, no wood, no kingdome".[30]

Standish presents something of a watershed in that he sets out his work as a systematic attempt, along with plenty of rough calculations, to lay out a plan for a secure national wood supply. What increasingly marked writing about wood was its concern for, as we might say, intergenerational justice: a new conception of struggles over allocation. As Noé Meurer put it in 1576 (echoing in fact language to

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[28] See, for example, P. Warde, "Fear of Wood Shortage and the Reality of the Woodland in Europe, c.1450–1850", *History Workshop Journal* 62 (2006), 28–57; A. Corvol, "La décadence des forêts. Leitmotiv", in A. Corvol, *La forêt malade. Debats anciens et phénomènes nouveaux XVIIe—XXe siècles* (Paris, 1994), 3–17.

[29] Warde, "Fear of Wood Shortage", 42.

[30] 35 Henry VIII c.17; W. Harrison, *An historical description of the Island of Britain* (London, 1577), 91; A. Standish, *The commons complaint* (London, 1611), 1. See also *idem*, *New directions of experience* (London, 1614).

be found in court cases from the 1550s), forestry officials were to prevent anyone overcutting wood, so that "not they alone, but also their descendants, heirs and children, will always have from their woods what they need [*die notdurft*] for building and burning".[31] Standish condemned men who overexploited woods, "desiring to become heyres of their owne time, without respect had to such heyres as shall succeed them". He thought that recent history contained a salutary lesson: "forty years ago ... the poorer sort scorned to eate a piece of meate roasted with sea-coles, which now the best Magistrates are constrained to do".[32] The most famous of seventeenth-century works on timber is John Evelyn's *Sylva*, a compendium of discussions among various members of the Royal Society in the early 1660s with a particular concern for the shortage of timber for shipbuilding (in fact, a rather exaggerated fear). As Evelyn put it, each generation was not born for itself, but for "posterity". The same word justifying action, *posterité*, was employed in Colbert's great forest ordinance of 1669. Defending "posterity" had long been a theme asserted by those defending customary rights, such as to commons. But to assert that that the resources themselves, rather than the right to utilize them, should belong to posterity represented a new sensibility that arose in the context of wood.[33]

The proposals in Evelyn's *Sylva*, which went through many subsequent expanded editions and became the standard text on arboriculture, were in fact rather more modest than those of Samuel Hartlib, who had wanted a Crown Officer of the Woods on the Continental model. Evelyn provided what could be an extended chapter in the *Hausväterliteratur* tradition: short essays on how best to propagate particular trees, rather than—as Standish did—a project of national regeneration. The estate owner's handling of his plantations was linked to the fate of the nation, most explicitly in having a national store of shipbuilding timber, but there was no advance on the notion propagated by Standish that a proper and systematic balance in wood management could be developed to ensure supplies in perpetuity.[34] In the end, the English Crown's interest in wood supplies was weak; unlike most parts of Europe, they no longer controlled many woodland assets, having leased Crown woodlands out as part of the desperate efforts to

[31] Meurer, *Jag und Forstrecht*, 5; P. Warde, *Ecology, Economy and State Formation in Early Modern Germany* (Cambridge, 2006), 325.

[32] Standish, *New directions*, 2.

[33] J. Evelyn, *Sylva, or, A discourse of forest-trees* (London, 1664), 111. For a German example see K. Mantel, *Forstgeschichte des 16. Jahrhunderts unter dem Einfluß der Forstordnungen und Noe Meurers* (Hambrurg, 1980), 70.

[34] Evelyn, *Sylva*; Worlidge, *Systema*, f.4v.

shore up state finances under James I and Charles I. In the same period, coal had rapidly overtaken firewood as the primary source of heat.[35]

Further steps were taken in Germany. It was there that the particular preoccupation with the durability of wood supplies came together with a tradition of state-wide resource regulation and a new science of government in the shape of "cameralism". Since the mid-seventeenth century, German political theory had displayed a preoccupation derived from the *Hausväterliteratur* with fostering good agricultural practice, including the notion that "each region can properly maintain only so many people from its own resources as can get their means of support from its yield".[36] Potential problems, as with the farm or estate, were conceived as arising for the hungry populace, not in the environment. Of course, the idea that if you continually extract more wood from a given area than grows back in the same time period then your wood will disappear was well known. Only gradually, however, was the notion implanted that this process could be controlled artificially, with conifers as well as deciduous trees, in such a way that the yield itself could be predicted even after long periods between harvests. This was the particular contribution of German forestry, especially in areas of high industrial demand—such as the Saxon mining districts overseen by von Carlowitz, who used the term *nachhaltende* in 1713.[37]

The eighteenth century saw the development of "sustained-yield" theory, the cornerstone of modern forestry. This came to rely on a limited number of reliable conifer species (in fact the systematic cultivation of conifers could be found around Nuremberg as early as 1368), the surveying and maintenance of fixed areas of growth divided into "age classes" that could be calculated from the moment of planting, or measuring the basal circumference of the tree.[38] This in turn required an expansion of the supply of professional foresters trained in surveying and geometry. One step forward was taken by Carl Christoph Oettel in the 1760s with the recognition that tree trunks should be treated as cones,

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35 On the leasing of the Crown estates see R. Hoyle, ed., *The Estates of the English Crown, 1558–1640* (Cambridge,1992); on coal use see P. Warde, *Energy Consumption in England and Wales, 1560–2000* (Naples, 2007).

36 From Seckendorff's *Der Christen Staat* of 1685, cited in A. W. Small, *The Cameralists: The Pioneers of German Social Policy* (New York, 1909), 48; see also K. Tribe, *Governing Economy: The Reformation of German Economic Discourse 1750–1840* (Cambridge, 1989).

37 See note 1.

38 There is a voluminous literature on these matters. See for example W. Schenk, *Waldnuztung, Waldzustand und regionale Entwicklung in vorindustrieller Zeit im mittleren Deutschland* (Stuttgart, 1996); U. E. Schmidt, *Der Wald in Deutschland im 18. und 19. Jahrhundert* (Saarbrücken, 2002); L. Sporhan and W. Stromer, "Die Nadelholzsaat in den Nürnberger Reichswäldern zwischen 1469 und 1600", *Zeitschrift für Agrargeschichte und Agrarsoziologie* 17 (1969), 79.

not cylinders. Oettel and his successors realized that by accurate calculation of growth volumes one could accurately calculate area yields by the multiplication of individual trees of a specified age. The logical consequence of this was that forests were most economically managed where standard trees could be grown on points where their growth rates could be predicted. Surveying the forest became a search for districts of homogeneity whose yields could be planned long into the future. The concept of the "normal tree", the *Normalbaum*, was born; the forest became the aggregate of the individual tree; and the best forest was that where what the famed "classic" forester Gottlieb Hartig called the "arbitrary" deviations of nature could be eliminated. The role of quantification shifted from being descriptive to being prescriptive.[39]

Not just studies by foresters, but general cameralist works on the fiscal state also could contain large sections on forest management, notably in the work of Johann Heinrich Gottlieb von Justi in the 1750s and 1760s. The purpose of the management was straightforwardly to work out how much "wood can be annually felled sustainably, economically and without ruin to the woodlands". Von Justi noted that the forester must adapt his methods to the what "was possible given the nature of the matter and the qualities of the ground"; wood was an important source of revenue but more important was an "indispensable necessity for the maintenance of the Inhabitants".[40] Government should also seek to record demand and keep that, too, in balance. All these were tasks that proved beyond the capacity of eighteenth-century administrations, but they set out a clear framework for the ambitions of scientific forestry.

MANAGEMENT AND IMPROVEMENT IN THE EIGHTEENTH CENTURY

In the early eighteenth century, the number of publications on agricultural improvement grew rapidly. Renowned authors could become consultants to estate managers, whether directly on the ground, as with the Hertfordshire farmer William Ellis, or via networks of correspondents, as with Richard Bradley, who probably conned his way to the chair of botany in Cambridge in 1720. In the case of lawyer and landowner Jethro Tull fame came by word of mouth, but he

[39] H. E. Lowood, "The Calculating Forester: Quantification, Cameral Science, and the Emergence of Scientific Forestry Management in Germany", in T. Frangsmäyer, J. L. Heilbron and R. R. Rider, eds., *The Quantifying Spirit in the Eighteenth Century* (Oxford, 1990), 315–42.

[40] J. H. G. von Justi, *Politische und Finanzschriften über wichtige Gegenstände der Stattskunst, der Kriegswissenschaften und des Cameral- und Finanzwesens* (Kopenhagen und Leipzig, 1761), 440–44.

was eventually persuaded into publication and eager antagonism from 1732.[41] As the number of publications expanded, so disputes became sharper, and authors became more insistent that their recommendations were based on observation, practice and success.

Most eighteenth-century works began with a detailed discussion of the properties of soil, and the wide range of substances that might be used to manure them: other soils, marl, lime, dung, rags, soot, ashes, animal remains. Agriculture remained a localized and particular enterprise; as Ellis wrote,

> every Farmer ought to make it his primary Study to inform himself of the several Sorts of Ground that often belong to his Farm, and that besides his own Judgment to consult his Neighbours, who as Natives on the Place may be able to let him know more than the Dictates of his own Reason, that formerly were more remote from the same.

The development of careful comparative analyses of soil types and local climates also gave a clearer sense of the limits of fertility, as Ellis again observed: "Manures to the Earth are in some degree as Food to Animals ... as they exhaust, the other feeds and supplies, or else the tone of the Ground's strength will soon be debilitated."[42] This perception may have arisen as a result of the clearly increasing application of all kinds of manure, the most prominent of which were marl, lime and animal dung, that had effects of varying duration.

Yet this remained a question of balance, and one that could be remedied by not persistently sowing the same crop, although the reason why different crops seemed to extract different things from the soil was not clear; or mixing soils with dressings and manures from elsewhere. Thus for Bradley, "the earth can never be rendered unprolific, unless she is constantly constrained to feed one kind of herb or plant". The mix was key, because in line with humoral theory (and in this regard Aristotle was still held in high regard), excess of any one element was the source of problems: "As the barrenness of most soils depends on the abundance of some one ingredient, there is scarce any one kind that may not serve as manure for some other."[43] All who wrote on the subject could agree that plant nutrition came from some kind of salt, as Hugh Plat had averred, and generally the consensus viewed that salt as being derived from the atmosphere in combination with sunshine and rain, a viewpoint that in part went back to experiments by Van Helmont indicating that plant growth did not diminish the

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41 Fussell, *The Old English Farming Books*, 82–111; *idem*, *More Old English Farming Books from Tull to the Board of Agriculture, 1731 to 1793* (London, 1950), 1–12; D. E. Allen, *The Naturalist in Britain: A Social History* (London, 1976), 16. See Bradley's *Dictionary of National Biography* entry at http://www.oxforddnb.com/view/article/3189.

42 W. Ellis, *Chiltern and vale farming explained* (London, 1733), 48, 372.

43 R. Bradley, *A General Treatise of Agriculture* (London, 1757), 97; T. Hale, *A compleat body of husbandry* (London, 1758), 107.

mass of the soil. The significant properties of different soils were in the manner they absorbed salts from the atmosphere.

The focus on atmospheric salt infusions meant that little of nutritional value for plants was thought to reside in the soil itself, although writers were inconsistent on this point. Many authors recognized that the quality of the tilth was an important determinant for plant growth, above all its degree of fragmentation. The finer the tilth, the greater the surface area of soil exposed and greater its ability to absorb "air salts" and promote the growth of plants. The explanation for the action of animal dung was thus that, like yeast in dough, its fermentation produced air pockets that helped break down the soil. Jethro Tull could, controversially, go as far as arguing that dung was unnecessary if the soil was properly worked in his "horse-hoeing husbandry", an idea that was partly justified by the theory that matter was infinitely divisible.[44] But the tide of competitive experimentation made it clear, as well as necessary to argue, that, as Hale put it, "A soil may be render'd worse by bad management; as certainly as improved by good." A providential view had been supplanted by one that insisted that a full understanding of nature's secrets, rather than simple labour, was the key to raising yield.[45]

THE "NEW HUSBANDRY"

It was only later in the eighteenth century that the discourse of agronomy shifted towards the pattern already established in forestry, to become a generalized theory of the management of agrarian resources. Major steps in this direction were taken in England, but systematic refinement was done in Germany. None of these later agronomists waxed larger in their self-importance, or international influence, than the prolific Arthur Young.

Young claimed in his *Rural oeconomy* of 1770 that not a single previous author had written one page of use to practical men armed with his new system of "general management".[46] Young's German equivalent and follower was Albrecht Thaer, a Hanoverian doctor turned farmer who founded the Prussian agricultural academy. According to him, "the science of agriculture rests on experience", as opposed to "simple tradition", although this was hackneyed language in both Britain and Germany. Yet it was important to Thaer's reputation to insist that

44 J. Tull, *Horse-hoeing husbandry* (London,1732)

45 Hale, *A compleat body of husbandry*, 84; see Schaffer, "Earth's Fertility", 133.

46 A. D. Young, *Rural oeconomy* (London, 1770), 2–4. Young was an extraordinarily prolific author and by no means trod the same narrow line in all of his works. See G. E. Mingay, *Arthur Young and His Times* (London, 1975); J. G. Gazeley, *The Life of Arthur Young 1741–1820* (Philadelphia, 1973).

the combination of "accident and necessity" in his own *experimental* conduct had brought him success in discovering efficacious new crop rotations, and not reading English authors such as Young, of whom he was in fact a conscious imitator. In fact the virtues of experimentation had long been exhorted, but the new vogue made them central to a process of theoretical refinement. Both the prestige of experiment and confidence in the rewards of agronomic investigation went hand in hand with the rapid advances in chemistry.[47]

"Experimental" agriculture was built on a new theory of the soil, where the farmer had the power to set the quality of the soil rather than having to merely adapt to local edaphic conditions. This relied on maintaining a balance between the extent of meadow and pasture, and the extent of arable. Each harvest of cereal crops reduced soil fertility as the crop removed nutrients. Continued high yields thus rested on replacing these nutrients. Some manure could come from feeding livestock the straw of the previous harvest, but obviously this still involved net loss of "succulent juices" in the recycling process. The answer was to pasture livestock on meadows, transferring biomass onto the arable fields, and logically to optimize output one needed the correct ratio of meadow to arable. Establishing this ratio, and all the "proportions" derived from this, was the stated aim of Young at the very beginning of his *Rural oeconomy* of 1770, and "if any of the proportions ... are broken, the whole chain is affected ... so much does one part of a well managed farm depend on the other".[48] Getting it wrong would eventually cause soil exhaustion. There was nothing new in the idea of balancing livestock numbers and tillage to produce an optimum supply of manure, but Young was right to insist on the novelty of understanding cultivation as a closed system where manure was *the* critical vehicle for recycling nutrients.

Thus what really marked Young and his successors out from predecessors was neither their practicality nor their experimentation, but a *theory of the soil* that viewed fertility as inhering in a substance that was transmitted through feed and animal dung. Other dressings of the soil, such as marl or lime, simply sought to optimize conditions for the uptake of this substance. This was a systematic *model* that, through experiment and calculation, could guarantee success. As much as experiment, farming was to become a matter of accounting, a training in which Young had probably acquired in a short and unhappy apprenticeship to a merchant in King's Lynn: a farmer should be "very ready at figures", and have

[47] Albrecht Thaer, *The Principles of Agriculture*, trans. W. Shaw (London, 1844), 3, 232–3. For an account of the interaction of chemistry and agriculture, see A. Clow and N. L. Clow, *The Chemical Revolution: A Contribution to Social Technology* (New York, 1952), 458–502.

[48] Young, *Rural oeconomy*, 12.

some knowledge of mechanics, geometry and "the application of mathematical studies".[49]

Albrecht Thaer drew extensively on Young in the conduct of his "experiments", and his hugely influential classic *The Principles of Agriculture* (1809–12). Thaer argued that "the produce generally depends more on the quantity of the manure than on the nature of the soil", and poor land was commensurately a product not of poor soil but of "want of manure". Naturally this required a correct proportioning of tillage and livestock, or, more precisely, tillage and fodder. Working from the principle that it was manure that recycled the necessary "nutritive juices" into the soil for crop growth, Thaer developed a form of accounting for this process based on "degrees" of fertility and advanced a model of the ideal proportions to be established between fodder input, animal numbers and agricultural output.[50] Young and Thaer, the two most influential writers of their age (among very many) on agriculture in Britain and Germany thus established early in their careers a relatively "closed" system-like model of nutrient flows within the farm, mediated via animal dung. While they remained keen observers of wider farming practice and the importance of producing a good tilth and combating weeds, they argued that only in this way could yields be improved. Sustainability consisted of effective management of this cycle.

THE END OF THE ISOLATED STATE: VON THÜNEN AND VON LIEBIG

It had long been argued that the state of tillage in a country was important for welfare, especially in the short run in preventing dearth and disorder. Yet unlike the case with trees, where from an early date wood supplies were perceived to be dwindling and where the resource suffered from an appreciable finitude, shortfalls in agricultural production were not linked to a deficient resource base. Only very gradually did "improvers" perceive that yield improvement could be seen as akin to expanding the national territory, while energy supplies or timber had long been linked to the fate of the state, and coal seams could be viewed as the equivalent of colonies ("England's Peru", or a "subterranean forest".)[51] Attempts to relate agricultural production to national capacity emerged most prominently in France with the Physiocrats, but it was in Germany that the "closed system" of farming as conceived from the 1760s was allied in a systematic way with the wider

[49] Mingay, *Arthur Young*, 13.

[50] Thaer, *Principles of Agriculture*, 24, 130–33, 138–9, 141.

[51] R.-P. Sieferle, *The Subterranean Forest: Energy Systems and the Industrial Revolution* (Cambridge, 2001).

world in which farms were embedded. This development took two very different courses, one a theory of the market, the other a theory of national ecology.

Johann Gottlieb von Thünen managed a large estate in eastern Germany, and his classic work of the 1820s, "The Isolated State", was above all an exercise in accounting and determining what kind of farming would turn a profit. He followed Thaer in developing crop and manure accounting, and absorbed critically the work of some of the new soil chemists, although this still formalized biological relationships into equations with rather vague elements such as the "Richness", and "Quality" of the land. His major contribution was to analyse how agriculture in a market economy had to adapt to what the market could bear. Imagining a land that was an "isolated state" with invariant environmental conditions and one urban major centre, von Thünen laid the foundations of economic geography. What could be profitably produced at any given point in space was a function of price, transport costs and costs of production (wages, capital and rents), producing an idealized landscape of a set of concentric circles displaying different land uses laid outwards from the urban centre.[52]

The system of the farm remained ecologically closed and thus dependent on management of the nutrient cycle, but the balance of products that cycle was to generate was determined by the market. This model of sustainability closely reflected the arguments aired in the brief florescence of liberal forestry in Germany in the early nineteenth century, when figures such as Pfeil argued that the cutting cycle of stands of trees should be determined by a comparison between their growth rates, the value of the stock of trees and rental of the land, and prevailing interest rates.[53] In practice, forestry practice could not be adjusted to the high variance in market indicators and the principles of sustainability in forestry remained vested in wood production, not revenue. For von Thünen, maintenance of household income was achieved by balancing local ecological with wider market considerations.

Young and Thaer provided models of material flows based on the farm that could provide a template for both success and stability, but the flip side was that mismanagement could lead into a spiral of degradation. This abstracted formal model would be both dramatically expanded in scope by Justus von Liebig, chemist and admirer and follower of Alexander von Humboldt, the naturalist who himself had been influenced as a young man by the prevalent cameralism

[52] J. G. von Thünen, *Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonmie* (Rostock, 1842), 243, 49–56, 83–7, 123, 56, 71–80. J. von Liebig, *Die Chemie in ihrer Anwendung auf Agricultur und Physiologie* (Braunschweig, 1862), 135.

[53] H. Rubner, *Forstgeschichte im Zeitalter der industriellen Revolution* (Berlin, 1967), 126, 142.

and forest science.[54] Liebig gave ecological substance and historical traction to the emerging model of sustainability, bringing a novel understanding of soil dynamics derived from agricultural studies together with the concern for the polity as a whole that had defined the wood-shortage debates.

Early nineteenth-century chemists had developed an "organicist" theory of plant growth, arguing that it was living matter in the humus of the topsoil that was in turn absorbed by and fed growing plants, a kind of recycling of vitalism, a life force inhering in organic matter. Manure, of course, was the agent of transmission in this recycling.[55] It was this that gave real substance to the ideas of Young. Liebig published the first edition of his *Chemistry* in 1840, responding to a request to write up an address to the British Association for the Advancement of Science in Liverpool in 1837.[56] In this and subsequent editions Liebig criticized the notion that the results from one farm could be universalized, as did critics of the "new husbandry", a controversy that continued over the real value of "experimental farms". Liebig argued in opposition to the "organicist" perspective that the fundamental roots of plant physiology were not some vitalist force inhering in organic matter, but the complex interactions of inorganic trace elements contained in the soil and atmosphere. This understanding of the chemical underpinnings of agricultural production also led Liebig to the conclusion that simple recycling of organic matter was insufficient to maintain soil fertility because each stage of processing involved irretrievable loss of elements, and thus led to long-term decline in yields.[57]

Liebig did not dismiss the recycling of manure, indeed he insisted on making it as efficient as possible. But he argued that the particular contribution this could make would vary greatly according to soil type; that inevitable wastage meant that additional supplies of elements had to be obtained from the atmosphere and processes of weathering of the land; and that in the face of a rising European population, alternative sources of nutrients had to be found if food supplies were to be kept in step with demand. In other words, he placed concerns of sustainability in a *dynamic* setting. In conditions of rapid urbanization this huge proportion of necessary elements was not being recycled within the system, but due to the construction of the water-closet and sewers, was instead discharged uselessly into the sea. Young had already lamented the loss of London's "night

54 W. H. Brock, *Justus von Liebig: The Chemical Gatekeeper* (Cambridge, 2002); also see dedication in Liebig, *Die Chemie in ihrer Anwendung*.

55 Thaer, *Principles of Agriculture*, 336; Liebig, *Die Chemie in ihrer Anwendung*, 13–14, 137.

56 Liebig, *Die Chemie in ihrer Anwendung*, vii–viii.

57 Ibid., 1–7, 13–5.

soil" in 1799.[58] Liebig saw this as no less than a process of "self-annihilation" (*Selbstvernichtung*), where the future of civilization rested upon the resolution of this "sewer question" (*Kloakenfrage*) and the return of urbanites' ordure to the farmers' fields.[59]

Partly due to some wildly inaccurate population estimates, Liebig interpreted the path of civilizations ever since the Greeks as being a story of slow, relentless overexploitation of the earth and consequent decadence and decline. "A people arises and develops in proportion to the fertility of the land, and with its exhaustion they disappear." Only China and Japan represented an exception of steady growth because of their extreme success in recycling, through the removal of livestock husbandry and directly applying human faecal matter to the land. Europe, and especially England, were only able to sustain population expansion through a vampiric dependency on imports, especially of finite stocks of guano, but including the gruesome excavation of bones from battlefields and ossories.[60]

Thus in Liebig we find something like the modern conception of sustainability: that a society's development is beholden to fundamental biological and chemical processes, but also that this was a complex dynamic system with feedback effects. He had turned the argument of an earlier English treatise on agricultural chemistry, that "Nature has fix'd bounds to fertility beyond which we cannot proceed, however prompted by avarice", into a general developmental model. Indeed, that 1760 treatise was also prescient in its argument "chemistry may contribute more to our knowledge of soils, and their productions, by its several operations, than all the attempts hitherto made by practice and observation".[61] Taken up by Liebig, a new ethic emerged that knowledge of those fundamental biological and chemical processes, courtesy of the newly minted scientist, would dictate the ability of *societies* to endure.

[58] D. Woodward, "'Gooding the Earth': Manuring Practices in Britain 1500–1800", in S. Foster and T. C. Smout, *The History of Soils and Field Systems* (Aberdeen, 1994), 106.

[59] Liebig, *Die Chemie in ihrer Anwendung*, 128–9, 153.

[60] Ibid., 96–7, 108, 110–11, 120–29.

[61] Farmer, *An essay on the theory of agriculture* (London, 1760), 5, 47.