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A Member of the Food Chain?: Quantifying Primary Productivity from Nazi Germany to the International Biological Program, 1933-74

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A Member of the Food Chain?:

Quantifying Primary Productivity

from Nazi Germany to the International Biological Program, 1933-1974

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy in History

by

Adam Christopher Lawrence

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ABSTRACT OF THE DISSERTATION

A Member of the Food Chain?:

Quantifying Primary Productivity

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University of California, Los Angeles, 2015

Professor Soraya de Chadarevian, Chair

A Member of the Food Chain?: Quantifying Primary Productivity from Nazi Germany to the International Biological Program, 1929-1989, tells the story of primary productivity, one of the fundamental measurements of the ecological and earth sciences today. Primary productivity is used in biology to refer to the aggregate photosynthetic production of the plant life of a particular region. Thanks to the rule of thermodynamics, most scientists have regarded the ability of plants to produce carbohydrates using carbon dioxide, water, and solar energy as foundational to all life throughout the twentieth century. Yet the history of the theory and methods used to quantify primary productivity is more complex than the straightforward and seemingly apolitical nature of the idea might initially suggest. This dissertation charts the genesis of this quantified measure from laboratory plant physiology, through agricultural science in National Socialist Germany, to postwar Global Ecology in the US.

The dissertation of Adam Christopher Lawrence is approved.

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Chapter 1

Introduction: The Vicissitudes of Productivity

I suspect...that we are indeed trapped in these things and they will work themselves out with a relentless logic.
-Robert Whittaker, 1969[1]

Introduction

We inhabit a world where the scientific disciplines dedicated to studying the functioning of this planet are increasingly given over to cynicism, nihilism, and despair. Eschatology in some form or another has existed for a long time across a multitude of human societies. The explicit codification of eschatology within a range of natural scientific professions is a recent event. It has occurred against a political and social backdrop of unprecedented wealth accumulation, population growth, energy use, economic expansion,

[1]Robert Whittaker. "Evolution of Diversity in Plant Communities". In: *Brookhaven Symposia in Biology* (1969), pp.196

environmental destruction, and mechanized slaughter. There are many places in the history of the twentieth century's phylogenetic tree of scientific disciplines and their fundamental concepts and methods one could look for evidence of this change. There are many different points where the relationship between this change in the natural scientific view of the human future and the vast social, economic, and technological changes of the twentieth century might be detected. Rather than choosing a particular discipline to inspect, this study charts the genesis of a particular concept, cutting across a range of disciplines. That concept is "primary production." This is an idea that runs like a red thread through twentieth century ecology, agronomy, economics, geography, oceanography, and demography.

Although many scientific disciplines factor into the story of primary production, and are dealt with in this dissertation, the highly heterogeneous, and relatively young, science of ecology is central. Generally, the complex behavioral and chemical interactions of individual organisms with each other and their environment is the discipline-specific focus of ecology. Reproductive interactions are generally treated as part of evolutionary biology and, most specifically, population genetics, especially in the pre-war era of primary concern to the present study. Drawing boundaries around the discipline of ecology is about as easy as demarcating where one ecosystem ends and another begins, which is to say, nearly impossible, and demanding of some rather arbitrary cuts. However, the type of ecology that invented the ecosystem, then turned its attention to quantifying it, is central to primary production's story. Two national scientific communities are fundamental to the genesis of this concept. They are those of Germany and America. Given the fundamental role these two would-be global empires played both scientifically and geopolitically in the last hundred years, it is not surprising to find primary production's history within theirs. Thus, the genesis of the scientific concept of primary productivity, and the methods for measuring it, not only tells us something about the rise of rational eschatology in the modern age. It tells us something about the intersection between science and the economic, political, and military violence which enabled the expansion and contraction of both these empires. To this end, the present study makes four interrelated arguments about science and society in Germany and America over the past 100 years. The example of primary production, the evolution of the concept and its measurement, serves both as a source of evidence for these arguments, and a focusing device for the overall narrative. This is a version of twentieth-century history where the emergent scientific understanding of man's role in the planetary system as an essentially antagonistic, destructive, and exploitative one takes central stage. The author's own opinions on mankind's place in nature and the probable near-future of our world and our global society are irrelevant here, of course.

The Science(s)

The ecosystem was usually defined as the biotic community plus the physical and chemical variables with which it interacts. The community was usually defined as the interacting array of plant, animal, and microbial populations in a given system. Populations are monospecific groups where the possibility of interbreeding is not limited by any geographical or behavioral factor. Central to all of the widely varying approaches to ecology was this hierarchical nesting of population, community, and ecosystem, from the most narrowly to the most broadly defined. From the standpoint of physiology, the functioning of an individual organism's metabolism and vascular system was the focus. From the standpoint of evolution, the population was the primary unit of focus, with the community and ecosystem being simply aspects of the changing environment which shaped the conditions of selection. From the standpoint of ecology, however, it was the system as a whole, and how it changes on timescales shorter than those traditionally of interest to evolution, but longer than those of interest to physiology, that was the primary focus.

What constitutes a system, and how movement within that system is defined and characterized was a central question of the nascent sciences of ecology and macroeconomics in the twentieth century. That the former discipline came to understand "production" as both limited by insurmountable upper barriers, and fundamentally limiting of both biological and economic growth, while the latter came to understand "production" as but one component of a larger, and hypothetically infinite, category called "growth," is neither a scientific, political, nor petrochemical coincidence.[2] Nor is it a coincidence that the movement of energy came to define the systemic functioning of ecosystems just as the modern global petroleum economy was being born from the combustion-engine powered slaughter of WWII and the ensuing reconstruction of Europe and Japan. Writing in 1942, US ecologist Raymond Lindeman defined "the basic process in trophic dynamics [as] the transfer of energy from one part of the ecosystem to another. All function," he continued, "and indeed all life, within an ecosystem depends upon the utilization of an external source of energy, solar radiation. A portion of this incident energy is transformed by the process of photosynthesis into the structure of living organisms."[3]

In ecology, primary productivity came to mean the total photosynthetic productivity of the planet. In economics, it referred to the mining, forestry,

[2] Timothy Mitchell. *Carbon Democracy: Political Power in the Age of Oil.* Verso, 2011 argues that the changing conception of economic growth as a hypothetically infinite process defined not by actual material production, but by an increasing rate of monetized transactions, was undergirded by the vast influx of virtually "free" energy that flowed into the world economy with the rise of the modern petroleum industry. This is an argument that is a central inspiration to all that follows.

[3] "The Trophic-Dynamic Aspect of Ecology". In: (), p.400

and agricultural sectors of the economy. Before and during World War II, in Germany, it dealt less with the trophic cascade and more with practical agronomic issues of plant yield. In the economic context of calculating potential agricultural outputs, weight was all that mattered. The demographic quantification of a particular crop's output was unimportant. Later, in the postwar context of American ecology, the trophic hierarchy became central to the definition of the concept. However, in all its iterations, the central idea of biomass, as opposed to a demographic statistic, as the most useful way of measuring biological productivity remained. From a Darwinian standpoint, and from the standpoint of population genetics, only the number of individuals within a population mattered. For German agronomists and the American ecologists who followed in their footsteps, on the other hand, practical economic and methodological considerations made biomass the central statistic. For plant ecologists, Darwinian demographic questions could quickly become ambiguous when dealing with organisms that self-polinate, clone themselves, change sex, and can produce an entire forest stand with a single genome. Thinking instead in terms of biomass and nutrient flows was one way to quantify plant systems without delving into murky population questions that were so much simpler when dealing with animals.

Yet there were theoretical reasons why quantitative ecologists of the postwar era would take up "primary productivity," and its simple calculus of potential future mass production, as one of their core statistics. The notion of trophic hiearchy is central here. The division between "autotrophs" and "heterotrophs" stretches back into the late nineteenth century. It is a physiological distinction that quickly became important to holistic thinking in the embryonic ecological sciences. As early as the 1890s, the distinction was employed in community biology by the influential Swiss botanist Carl

Schröter. An autotroph is an organism that can produce its own food through the synthesis of hydrogen and carbon in its surrounding environment. A heterotroph is a symbiote that depends on the carbohydrate production abilities of autotrophs.

Autotrophs can be either photosynthetic or chemosynthetic, but for the purpose of modern primary production measures, photosynthesizers are central. Photosynthesis research has its own history, which, like the history of primary production research, cuts across a range of disciplines: physiology, physics, and biology. Although plant physiology is central to the agronomic and ecological development of primary productivity, the story of photosynthesis is peripheral to the present narrative. The roll of carbon dioxide and water in photosynthesis was understood by botanists by the middle of the nineteenth century. However, the precise physical and chemical mechanisms by which photosynthesis occurred would only be elaborated in the 1920s and 1930s.[4]

More important than the details of photosynthesis for the developing concept of productive relations in nature, however, was the notion of trophic economics, or the food chain. Writing in 1942, American ecologist Raymond Lindeman credited German zoologist August Thienemann with developing this idea through his "community economics."[5] In the English-language literature, Charles Elton's 1927 *Animal Ecology*, virtually contemporaneous with Thienemann's *Die Nahrungskreislauf im Wasser*, introduced similar concepts. The crucial point here is that organisms were not defined by morphology or

[4]Kärin Nickelsen. "The Construction of a Scientific Model: Otto Warburg and the Building Block Strategy". In: *Studies in the History and Philosophy of Biological and Biomedical Sciences* (2009) details the roll physicists played in this development, and Doris Zallen. "Redrawing the Boundries of Molecular Biology: The Case of Photosynthesis". In: *Journal of the History of Biology* 26 (1993) documents biochemical photosynthesis research and argues for its place in the history of molecular biology.

[5]"The Trophic-Dynamic Aspect of Ecology", August Thienemann. "Lebensgemeinschaft und Lebensraum". In: *Naturw. Wochenschrift* (1918), August Thienemann. "Der Nahrungskreislauf im Wasser". In: *Verh. deutsch. Zool. Ges.* (1926)

descent, but rather by their function in a complete ecosystem, or community. These roles were essentially economic in nature: photosynthetic producers, who use solar energy to provide carbohydrates for the entire system, autotrophic consumers, who eat either photosyntheticly produced carbohydrates or organisms that eat those carbohydrates, and fungal reducers, that break down dead or dying tissue. This was a novel way to think about biological relationships. Indeed, this scheme was a novel way to think about nature itself. It was neither a static taxonomic hierarchy nor a branching tree of ancestor/descendant relationships. It was a dynamic network of consumer/producer interactions, where an organism's function in moving energy and nutrients through the system took precedence over evolutionary and classificatory understandings of a particular individual's place in nature. Thus, an economic mode of thinking about biotic communities and ecosystems was embedded in ecological theory from its earliest days. My method, going forward, is not to treat the movement between economic and biological thinking as a case of metaphors. If theoretical thinking about macrocosmic biological problems (as opposed to physiological ones) came of age with Darwin, than the economic worldview was embedded in ecology from the beginning. Few thinkers were as significant a resource for Darwin as Thomas Malthus.

The notion of symbiosis goes back to scientific work on lichens, which were hypothesized to be associations of fungi and moss in 1868 by the Swiss botanist Simon Schwendener.[6]y the 1870s, as Darwinism was being absorbed by the membrane of the continental European scientific consciousness, symbiosis-centric plant physiology labs were established by Schwendener in Berlin and Anton de Bary in Strassberg. Jan Sapp. *Evolution by Association: A History of Symbiosis.* Oxford University Press, 1994, p.4-5 documents the

[6]B

origins of symbiotic theory, and makes a compelling argument for its role in the genesis of evolutionary thought. The information on Schwendener and de Bary comes from him. Symbiotes were classified as mutual (both organisms benefit), commensal (one benefits, and the other is unaffected), and parasitic (one benefits, the other suffers). Many relationships between heterotrophs and autotrophs have parasitic qualities. Others, like those that involve telechory (seed dispersal), are mutual. Truely commensal relationships are hard to find. Predation overlaps with parasitism, but is characterized by a more distant relationship between the organisms, and by a more certain and rapid death of the disadvantaged dyad member. The cultural shift in the scientific understanding of mankind's place in nature can be defined in part as a realization that human civilization is a hetrotrophic parasite upon the entire global ecological base.

The Arguments

A crude distinction can be made between that half of my four arguments which primarily concern "intellectual" changes, and that half which deal with political economic shifts. The first two intellectual arguments deal with the changing conception of technology's role in aiding or inhibiting natural productivity, and the shifting scientific and political meaning of Malthusian theory. The second two political economic arguments deal with the movement from local to global concerns and calculations, and the shifting geopolitical order among the world's richest countries regarding autarky and international competition.

I will start by outlining the intellectual arguments. First is the shift alluded to at the beginning of this essay, from a fundamentally hopeful scientific view of the potential of human technology to enhance the earth's "natural" productivity, to a fundamentally pessimistic one, that saw human action as an inhibitor of productivity rather than an enabler of it.

Reinhold Tüxen was an important scientific and political player in Nazi-era German plant ecology (or, as he called it, plant sociology, a distinction which had significance for scientists at the time, but need not concern us at the moment). Tüxen administered one of the main state ecological institutions in Germany under the Third Reich. His concept of "potential natural vegetation" described cartographically the plant communities that would hypothetically exist in an area in the absence of human action. It hinted at the idea that the expansion of civilization may come at a cost to non-human communities. However, it did not directly suggest that productivity would be greater under non-anthropogenic conditions. The recognition of aesthetic deterioration of local environments was not new even then. It is the concept of nature as a quantifiable, integrated productive system that is unique to the twentieth century. And from this concept, the notion that anthropogenic "improvement" and "cultivation" are not necessarily long-term enhancers of overall production efficiency, when efficiency is measured in terms of either mass or energy.

Tüxen's *Pflanzensoziologie* was oriented towards mapping large vegetational zones, and classifying different types of plant "communities." This "syntaxonomy" has since been largely forgotten by modern ecological science. It is tangential to the central thrust of this study, relevant mainly because of the importance of Tüxen to German ecology and wartime ecological mapping, and the significance of both those practices to the genesis of primary production. Thinking of nature in terms of productivity would fall not to the *Pflanzensoziologen*, but rather to the physiologically informed quantitative ecologists and agronomists. Here, the work of the agronomist Eilhard Alfred Mitscherlich and the ecologist Heinrich Walter is paramount. However,

Mitscherlich understood natural productivity in terms that postwar ecologists would hardly recognize. He dreamt not of a future where the soil would be freed from man's corrupting influence, but rather one where even more synthetic and mined fertilizers would be pumped into the earth, and agricultural yields would stretch skyward into a bright future. Not coincidentally, Germany dominated the global market for potash (mined potassium salts) and many synthetic fertilizers (in part the legacy of the Haber-Bosch Process, which begin producing industrial quantities of synthetic ammonia in 1910) well before 1933. With the ascent of Hitler's government, both an optimistic belief in the limitless capacity of German scientific ingenuity to overcome material limits and an obsession with increasing agricultural productivity enabled Mitscherlich's quantitative agronomy to move from the pages of the journals of *Bodenkunde* to a national level agricultural experiment funded through the Nazi four-year plan for rearmament and economic autarky. While the Nazis paid lip service to the economic interests of the peasantry and countryside landlords who played a crucial role in voting the party into power, they simultaneously embraced the promise of labor saving technologies and scientific disciplines like quantitative agronomy which could dramatically change the way of life of the 32% of the German population that lived in rural communities of less than 2,000, and the 29% who made their living in agriculture in 1933.[7][p.167]tooze2007
This kind of synthesis of technological and agrarian optimism was characteristic of the particular vision of national modernity which the Nazis presented to the world. As elaborated upon in Chapter 1 of the present study, Mitscherlich's *Produktionskurve*, which quantified the ratio between a given fertilizer input and the expected agricultural output, embodied both the optimistic side of Nazi ideology, and the practical drive to attain German

[7] **“par** ff

economic self-sufficiency in advance of a second war for the domination of western Eurasia which would see tens of millions of humans slaughtered, and tens of millions more enslaved, maimed, and traumatized. It not only embodied this optimism in microcosm, but became embedded in Nazi economic planning, and funded by the German state, the potash cartel, and IG Farben. This funding pattern showed the synthesis of statist economic planning and private cartel capitalism which typified much of both the German and American development paths in the twentieth century.

Mitscherlich's equation was transported into ecology by Heinrich Walter, a pioneer in adapting laboratory physiology for a discipline often characterized by obsessive classification and extensive description with little attempt at quantitative measurement, experimental analysis, or causal explanation. Walter was part of the generation of German and British ecologists who began to think in the productive terms typical of agronomy with regards to natural ecosystems. While not sharing Mitscherlich's cheerful faith in technology, Walter's research in Africa was funded by the German colonial office, and geared towards ascertaining the productive potential of former German colonies that would, of course, be returned to German hands under the global Nazi empire. Like Mitscherlich, his understanding of the human relationship to natural productivity was essentially one of technological improvement. The nihilistic, misanthropic view would come into its own with the American ecologists of the Vietnam era, and embodies one of the fundamental intellectual shifts within the ecological, environmental, and earth sciences which this dissertation is concerned with.

The second intellectual argument involves the shift from the an ecological worldview that was symbiotic with the eugenic Malthusianism of the Nazis to one that was buttressed by a far more ecumenical and generally misanthropic kind of "Neo-Malthusianism." It is important to note that while Nazi ideology developed a particularly racist and annihilationist version of eugenic Malthusianism, some form of this kind of thinking was widespread throughout European and American life in general before 1945, and in the biological community in general. Although Darwin carefully steered clear of the human social issues that preoccupied his cousin, the influential statistician and coiner of the word "eugenics" Francis Galton, Malthusian theory was one of the most important resources upon which he drew. By the dawn of the twentieth century, it was becoming increasingly difficult to find a biologist who didn't partake of eugenic thought in some form or another. However, as with their pursuit of empire, and the symbiosis of the nation-state and cartel capitalism which underwrote it, Nazi eugenics represented a hyperatrophied version of a homology shared with America and the other major European powers. Whereas traditional eugenics sought to "improve" the human population by encouraging the reproduction of racially or economically "superior" individuals and discouraging the reproduction of "inferiors," the Nazi version, sought the annihilation of vast swathes of the human population, first through medicalized murder in the "moderate" pre-war era, and then through starvation, pogroms, and industrialized genocide following the invasion of Russia. A racialized Malthusian logic underwrote both the Nazi imperial drive and the genocide program that followed in its wake. Germany was the most populous country in Europe outside Russia, and was unable to feed all of its own people domestically even in peacetime. When engaged in total war against Britain from 1914 to 1918, a country that had the ability to shut off all maritime imports at will, extreme hunger ensued. Concerns of food supply were both practical, and emotionally resonant with all Germans in 1933.[8]

[8] "One way or another, virtually everyone alive in Germany in the 1930s had an acute personal experience of prolonged and insatiable hunger." Adam Tooze. *The Wages of Destruction: The Making and Breaking of the Nazi Economy.* Viking, 2007, p.168 The analysis

Production biology, in both its ecological and "agrobiological" forms, served the larger practical agenda of German self-sufficiency in food supply. However, it was in the African production ecology of Heinrich Walter that we can start to glimpse the intersection of this practical agenda and the virulently racist and militarist version of Malthusian doctrine which fired the Nazi drive to a global empire. Although Walter's work is resolutely practical, a concern with these regions on the part of the state interests that financed his research only made sense in the context of a Nazi vision of an overseas empire beyond even their immediate imperial goals of Europe and Russia. While Mitscherlich's work could, in theory, represent nothing more than a well meaning effort to scientifically solve Germany's very real problem of food security, Walter's implicitly embraced a vision of bright imperial future for the Third Reich, and a dark one for their once and future colonies.

Southwest Africa, where he did much of his research, had been the site of Germany's first experiment with imperial genocide during their brutal suppression of the Herero uprising of 1904-07, during which up to 100,000 humans were driven into the desert to die of thirst. Walter's main use of production ecology was, therefore, still one which fit with the basic view of human agency as an increaser of productivity. Nazi Malthusianism was "optimistic" in way that postwar eco-Malthusianism was not. The Nazi state acted on a (not wholly inaccurate) perception of physical limits to growth. Like the eco-Malthusians that would come later, they saw an eventual decimation of human population as inevitable, and thought that exerting some control over that process would be preferable to simply allowing it to happen. Where they differed was in their disregard for the non-human living world for its own sake (rather than as a means to human ends), and in their desire to

of the practical economic roots of Nazi Malthusianism comes from Tooze's masterwork, as does the treatment of the Nazi elite's patronizing and cynical relationship to the German agricultural population in my first argument, above.

violently shrink the population of outgroup humans to the benefit of a racially defined ingroup. In the hands of the postwar American eco-Malthusians (as well as Heinrich Walter's German student, Helmut Lieth), primary productivity was a tool for assessing how far the destructive "appropriation" of nature's productivity towards human ends had progressed, and hopefully finding a way to ameliorate the damage thus far done. Restricting population growth through mechanisms such as birth control was a crucial part of this project. The Nazis, however, used biological productivity measurements as a way of calculating how many "Untermenschen" they would have to murder, and how many they could afford to leave alive as slaves, so that the "Volk" could expand and thrive. Their Malthusianism was ultimately deeply natalist when it came to "true" Germans, Malthus's infamous "positive checks" would be applied disproportionately to "non-Germans," most importantly Jews and Slavs, with as much help from the Nazi state as they could provide. On the face it might appear ironic that Germans of the depression were the "optimists" when it came to their view of the future, whereas it fell to American ecologists of the affluent 1960s to express skepticism about the benefits of human action on the environment. Yet this was in line with the militant utopianism of the Nazi period, as well as the increasing distrust of the status quo which characterized much of American intellectual life in the Vietnam era.

I move now to my two political arguments, which complement my two arguments about the intellectual shift in production ecology from optimism to pessimism about human technology and the Malthusian balance. Here, I am arguing broadly that the scientific shift in the way natural productivity was conceptualized and measured paralleled two larger shifts in the global political economy. The first of these transformations was the transformation of a

geopolitical order based on the pursuit of national autarky for transnational empires to one based on a pool of globally priced commodities shared by the US, the wealthy former old empires (Britain and France) and the wealthy failed new ones (Germany and Japan). Geopolitical rivalry still existed, obviously, both within the western bloc and between the US and its rival for global domination, the USSR, but was fundamentally different in several ways. First, the number of ”superpowers” in the planetary geopolitical game was reduced from the five of the war era (six had France used its full military might and risked a longer rematch with Germany) to two. Second, open violent confrontation between the most powerful countries on earth was replaced with proxy wars where at most one side fielded soldiers of their own military in conflict with local forces sponsored by the other power (the Soviet and Chinese-backed North Vietnamese Army and VietCong in Southeast Asia, the US-backed Mujahadeen in Afghanistan). Finally, the ninteenth century transnational empires characterized by Britian's direct political and economic control over South Africa and South Asia and France's over Northern Africa and Southeast Asia, and which Germany and Japan sought to emulate in Russia and China, were replaced with a far more subtle system. Here, the two great powers established blocs of satellite states that, while not exactly colonial holdings, were home to large concentrations of military power.
While the pursuit of national autarky remained a guiding principle of international and domestic politics for the US and the USSR, the subservient former European powers (and Japan), along with the consistently dominated Eastern European states, became increasingly dependent on their semi-imperial ”benefactors.” At the same time, the increasingly global markets for ”primary products” (an economic parallel to the biological term, meaning unprocessed products of the agricultural, fisheries, and mining sectors)

engineered by the US after 1945 meant that the US often had a stake in commodities not produced by a region under their direct political control. Because an increase or decrease in supply or demand for these commodities effected the global price of the commodity regardless of where a consumer state's primary products were sourced, the US-ruled capitalist world order required economic and military interventions on the part of the superpowers to move prices in the desired direction. The most central commodity here as the American age progressed was petroleum, understood as stored "primary production" by most scientists as quantitative ecology established its core concept as a foundational paradigm of a wide range of earth and biological sciences. Not only could productivity changes (or consumption changes) in autonomous nations change the global economy in ways that were or were not desirable to the new global hegemons, for the capitalist countries they could effect the interests of national corporations with international holdings. This system had a precedent not only in the British and French empires, but also in the control of Middle Eastern oil fields by *Deutsche Bank* going back to before World War I.[9] However, as the age of empires waned, it came to occupy an increasingly important role in the maintenance of a global economy based around relatively poor and "undeveloped" primary producer nations and wealthy, powerful primary and secondary consumer powers.

This differed from the period leading up to WWII, where the old global powers (Britain and France, most importantly) focused on extracting primary products through direct political and military control of "primary producer" nations. The would-be German and Japanese empires pursued a hybrid strategy. Like the old European empires, they sought to control human, agricultural, and mineral resources through the direct military control of

[9] Mitchell, *Carbon Democracy: Political Power in the Age of Oil* details the early history of western investment in Middle Eastern oil.

agrarian regions, and the exploitation of the existing population. However, the Third Reich and the Empire of the Sun also prioritized the creation of a large contiguous growing and extraction hinterland in the hope of emulating the ascendant USSR or the ”neo-European” nations: Australia, South Africa, Argentina, and, most importantly, of course, the US. The seminal work by Alfred Crosby on *Ecological Imperialism* argues that the biogeographical simularity of these regions to Europe made them well suited to large scale settler colonialism of the type that expanded from New England and Ontario across western North America in the nineteenth century.[10] The Nazis explicitly modeled their genocidal colonial expansion into eastern Europe on the conquest of the American West. As Adam Tooze powerfully and persuasively argues in his masterful *The Wages of Destruction* they looked more to a future of a German-dominated western Eurasia populated by German settlers and an enslaved, racialised laboring class to parallel the slaveholding American south and the decimated American west than they did to a past of a German overseas empire to rival those of Britain and France. However, as the work of Heinrich Walter in Southwest Africa, the actual invasion of North Africa, and the involvement of Walter's future boss in eastern European mapmaking, biologist and SS officer Otto Schulz-Kampfhenkel, in an SS sponsored Brazilian expedition, all demonstrate, such dreams did occur to them. The Japanese empire, on the other hand, moved into many formerly European dominated areas in French Indochina, British Malaysia, Burma, and Northeast India, and the Dutch East Indies, and, along with their complete nautical mastery of the region, bore a bit more resemblance to the nineteenth-century overseas empires.

[10] Alfred W. Crosby. *Ecological Imperialism: The Biological Expansion of Europe, 900-1900.* Cambridge University Press, 1986 is a major influence not only on the present study, but on more widely read mainstream books such as Jared Diamond. “Guns, Germs, & Steel: The Fates of Human Societies”. In: (1986)

The new global order that dawned after 1945, therefore, prioritized at least the illusion of ”shared” resources within given ”blocs” over the scramble for autarky and direct imperial control that defined the nineteenth century era of inter-European squabbling, with the rest of the planet as the chessboard. The mechanisms by which hegemony was asserted were now more subtle, and they called for a more subtle scientific conception of resource production. The genesis of primary productivity from a concept associated mainly with national productivity and the productivity of potential colonies to one associated with the global productivity of resources held ”in common” mapped this vast geopolitical shift. Given that the first production ecologists and agronomists in Nazi Germany were funded by the Four Year Plan and the German Colonial Office, while the American production ecology of the 1960s and 1970s was funded by a cooperative of various national funding agencies, working through the channels of the International Biological Program, this is hardly surprising. Crucial to the shift from autarkic, metropole-based empires to power blocs ”sharing” in globally priced commodities was the major energy transformation that the US led from 1945 on. While the age of hydrocarbons had been dawning since the British industrial revolution, the creation of a global petroleum economy by the US and its oil companies was an unprecedented environmental, economic, and financial change for the planet. This system helped entrench ecology’s view of photosynthetic carbon production as the primary budget for all life in a range of sciences outside of its biological birthplace, including geology and even some areas of the social sciences. It also underwrote the US-dominated economic system in several important ways, as historian Timothy Mitchell has argued in his masterful *Carbon Democracy*. First, the dollar was able to remain strong regardless of what happened to the domestic US economy, due to the fact that oil was priced in dollars no matter what the nationality of the company that sold it was. Therefore, every country on earth needed to buy copious amounts of dollars to hold in reserve for oil purchases. Secondly, the redefinition of the economy as not a system of material flows, but rather of financial ones allowed the policy of infinite growth to be pursued by the US not only domestically, but also as the main goal of international development. Development was one of the main non-military weapons in the US war with the USSR over the nonaligned "third world." Mitchell argues, correctly in my opinion, that the pursuit of infinite growth in a finite world was rendered the appearance of not being insane, indeed, was even treated as the cutting edge of academic economic thought, in part by the willful ignorance of the actual cost of hydrocarbon extraction and consumption.

While primary productivity's move from a science of practical agricultural production in the context of global world war to one of global ecological assessment paralleled the demise of the old European imperial order and the rise of the American and Soviet one, it also came to push back significantly against these trends. Most importantly, as ecologists broke with their agronomic past and begin to criticize the productivist view of nature which their discipline had been handmaidens to in the first half of the century, they provided solid scientific evidence to challenge the economic view that infinite growth was a rational, reasonable goal. They sought to use an array of scientific and rhetorical tools, of with the changing concept of primary production was one, to suggest that all human economic activity, like all living processes, was ultimately grounded in the material productivity of the earth and the accompanying system of energy transfers. This complex relationship between the biological sciences and capitalism, at once enablers of the economic form of primary production (as opposed to the photosynthetic one) and vociferous opponents of the gospel of growth, was facilitated by the intellectual changes in the view of human technology's roll in aiding or inhibiting productivity, and in the changing political connotations of Malthusian thinking.

Accompanying this global political shift was an increasing inclination to treat local problems, whether political, economic, or environmental, not as isolated episodes, but as specific manifestations of larger global issues. If the shift towards petroleum was the energy transformation at the heart of the shift from autarkic global order to a planetary "free market," the emergence of nuclear technology was the energy transformation that played the greatest roll in the globalization of catastrophe (along with the afforementioned petrol, of course). The cold war, and the threat of nuclear annihilation that came with it, heralded a shift in thinking about catastrophe as a global process, rather than a local one. This came along with the creation of an increasingly interconnected global society, where failure in one node of the network could lead to cascade effects elsewhere. The global commodity markets for essential primary products were part of this system. So were the international transfers of hydrocarbon energy. Thinking of nature as a system of transfers, where a change in one variable could lead to changes in many others, came naturally to ecologists. This scientific view not only suited the "complex system" that was the postwar global civilization, but also a growing understanding of environmental problems, whether they be climate change, drought, an exhausted mineral resource, or pollution, to name a few, not as isolated local issues, but as problems of a global nature, and in need of global solutions. The measurement of world primary productivity, such an essential part of the International Biological Program, reflected this change.

All of this may sound a bit grand, and perhaps detached from the detailed study of the genesis of particular scientific concepts and methods which unfolds in the following pages. My specific research deals with the quantification of biological productivity, and the role that played both in explicit state planning, and the more subtle relations between different forms of quantification and the political shifts sketched above. In the German case, the quantification of potential agricultural yields as a ratio of fertilizer inputs by Eilhard Alfred Mitscherlich was an essential component of rearmament and the overall preparation for a war which, the German leadership realized, would inevitably result in decreased food imports in the short term. However, in the US, where a perception of nearly limitless pan-continental resources mitigated the autarkic imperial drive (or at least led it to manifest itself in more subtle forms), agrobiologist and popular writer O.W. Willcox used Mitscherlich's equation to argue for an end to war. In the postwar era, as the world drifted towards a new political economic configuration, the quantification of primary productivity became an issue of global resources, rather than national ones. And, as the oil shocks of the 1970s set in, a language of "resource constraints" came to replace the language of abundance. The ways in which biological productivity was quantified, and the uses to which these different quantifications were put, reflected changing systems of imperial control over raw materials. As the "classical" European colonial era gave way to the brief and bloody flourishing of the German and Japanese Eurasian empires, and in the dawning capitalist American age that followed 1945, scientific quantifications of productivity shifted both in service to these aims, and, increasingly from the 1960s on, in opposition to them.

Literature Review

This dissertation draws upon a wide array of fields, and the range of secondary sources that have influenced it is quite diverse. While it exists most obviously at the intersection of the history of scientific methods and practices and the social and material history of the environment, much of the larger context for these scientific changes comes from political economic history. In its treatment of the history of science, the work of Soraya de Chadarevian, Ted Porter, Norton Wise, and Tiago Saraiva is especially important. De Chadarevian's work on the diverse strands of biochemical research that fed into the creation of an ostensibly new discipline (according to those who had the most invested in creating it) of "molecular biology," while dealing with a rather different set of biological practices than the ones dealt with herein, demonstrates how one can utilize different key players in a scientific story without ascribing transformative importance to any one of them.[11] In my work, the central concern is the changing scientific and social meaning of "primary productivity," and how it reflects changing political, economic, and environmental conditions. Individual scientists emerge as more or less important at different stages in this process, and the prosopographic connections between them serve to render tangible the movement of so vast and amorphous a concept as biological productivity between radically different contexts. However, they are not the agents of the history which envelops them, but rather products of it, just one among a wide array of more or less important variables. More concretely, as the first chapter of this study deals heavily with plant physiology, as I argue that it was an fecund factory of concepts and methods for ecology and agronomy as they struggled to become "properly" quantitative and experimental sciences, de Chadarevian's early

[11] Soraya de Chadarevian. *Designs for Life: Molecular Biology After World War II.* Cambridge University Press, 2002

work on the experimental methodology of plant physiology, and the problem of codifying and standardizing "country house" science, was most informative.[12] The intersection of the social and natural sciences is central to this dissertation's concerns. Here, Ted Porter has demonstrated that many of the tools of the natural sciences originated not only in the context of social concerns, but in the sciences whose goal it was to quantify human society for purposes of statist management (demographers) and capitalist profit maximization (actuaries).[13] In a similar vein, Sharon Kingsland's work on the rise of population ecology in the US stresses the role of Raymond Pearl's logarithmic curve in moving human demographic tools to the ecological sphere.[14] The relationship between demography and ecology is a complex one, which is explored at various points in my dissertation, most fully in the last chapter. Two recent books, by Thomas Robertson and Derek Hoff, have attacked this relationship in the context of US history from both the economic (Hoff's text) and the environmental (Robertson's work).[15] Not only did ecology draw upon human demographic tools to both quantify natural populations and establish the "laws" governing their growth and decline, biologists also became increasingly concerned with the impact of human population fluctuations on the global ecology. While demographic concerns

[12]Soraya de Chadarevian. "Graphical Method and Discipline: Self-Recording Instruments in Nineteenth-Century Physiology". In: *Studies in the History and Philosophy of Science* 24.2 (1993) and Soraya de Chadarevian. "Laboratory Science versus Country-House Experiments: The Controversy between Julius Sachs and Charles Darwin". In: *The British Journal for the History of Science* (1996)

[13]Theodore Porter. *The Rise of Statistical Thinking, 1820-1900.* Princeton University Press, 1986, Theodore Porter. "Rigor and Practicality: Rival Ideals of Quantification in Nineteenth-Century Economics". In: *Natural Images in Economic Thought: "Markets Read in Tooth and Claw".* University of Notre Dame Press, 1994, Theodore Porter. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life.* Princeton University Press, 1995, and Theodore Porter. *Karl Pearson: The Scientific Life in a Statistical Age.* Princeton University Press, 2004

[14]Sharon Kingsland. *Modeling Nature: Episodes in the History of Population Ecology.* University of Chicago Press, 1985

[15]Tom Robertson. *The Malthusian Moment:Global Population Growth and the Birth of American Environmentalism.* Rutgers University Press, 2012 and Derek Hoff. *The State and the Stork: The Population Debate and Policy Making in US History.* University of Chicago Press, 2012

became increasingly peripheral to modern economic science, as Derek Hoff documents, they nonetheless would emerge at different key moments in US history as focal points of American policymaking. This increasing disinterest in demography on the part of academic economists paralleled an increasing interest on the part of ecologists, a process documented in Thomas Robertson's excellent history of the re-emergence of Malthusianism in US biology after World War II.

This study concerns less the movement of tools from the social sciences to the natural ones, and more the shift in using science to maximize biological productivity in order to satisfy economic ends, in the context of German agronomy and imperialism, to utilizing those same tools to identify the negative impact human technological change and economic "growth" was having on natural production. There is an intriguing parallel history of "primary productivity" within economics, but it is largely outside the ambit of the current dissertation. Hopefully I will have an opportunity to explore it in later work. As for Malthusianism, its variety of meanings in different political contexts is a central concern of this work, as discussed in the "Arguments" section above.

Finally, on the relationship between fascism and science, a central concern of the first three quarters of this dissertation, the 2010 issue of *Historical Studies in the Natural Sciences*, edited by Norton Wise and Tiago Saraiva, is quite relevant. Wise and Saraiva identify the pursuit of autarchy as one of the primary goals of those mid-century European regimes that can be considered at least partially "fascist." Like pure capitalism or pure communism, as Wise and Saraiva allude, a "purely fascist" regime has never existed. Even the most ideologically dogmatic and structurally coordinated "classical" fascisms, Nazi Germany and Fascist Italy, existed in a symbiotic state with pre-fascist institutions: the Catholic Church, the Italian monarchy, the German military, and, of course, the cartels that drove Germany's export-based economy. In this context, the fascist component of societies with more "traditional" elements can be understood as essentially "developmentalist." These developmental programs could serve the interests of the entrenched elites, as in the case of the Nazi Four Year Plan's use of productivist "agrobiology" to justify a demand for more of the synthetic and mineral fertilizers produced by IG Farben and the German Potash Syndicate, as discussed in the first chapter of this study. This was, of course, the case with Soviet Communism as well, the other major alternative to conventional forms of social organization to emerge out of the First World War. The developmental impulses of the Nazi state, and the surprisingly underdeveloped nature of the pre-1933 German economy, are a central part of the argument of Adam Tooze's *The Wages of Destruction*, perhaps the most important piece of secondary scholarship for this current work. In Saraiva and Wise's analysis, the pursuit of autarky (economic independence) was the goal of fascist developmentalism, while "autarchy" (authoritarian government) was the means by which this goal was pursued. This work by these two exemplary historians of science and technology is both highly informative to my own research, and supported by the function of production biology in its pre-American phase. As discussed above, one of my main arguments is that primary productivity transitioned from being a scientific concept useful primarily to the pursuit of autarky in a multipower geopolitical environment, to one focused on assessing the total "shared" resource base for a two superpower world. This argument, made on the basis of my discovery of the movement of primary productivity from German agricultural science to American global ecological research, provides further evidence for the arguments Wise and Saraiva make regarding fascist autarkic goals.

This brings me to *The Wages of Destruction*, a masterwork that is indispensable to my understanding of twentieth century history, and Germany and America's rolls in it. Therein, Adam Tooze argues that despite the large size of its economy, pre-World War II Germany was in many ways a country that lagged behind the "norm" established by the UK and the US. The US was, prior to the onset of the Great Depression, the world's largest national economy, while the British Empire, taken as a single economic unit, was the largest economy on earth by far. In terms of per-capita income, automobile ownership, percentage of the labor force involved in agriculture, and many other markers of modernity, significant room for growth remained for Germany in 1933. The Nazis' militaristic, and increasingly genocidal drive to conquer eastern Europe was motivated by a desire to carve out an agrarian hinterland comparable to what the British had in South Asia and South Africa, the French in North Africa and Southeast Asia, and the Dutch in the East Indies (the last one of the first oil-exporting colonial "primary producer" nations). However, more importantly, it was a way to build a contiguous pan-continental empire with the economic self-sufficiency to compete with both the British Empire and the rapidly ascending US. In Tooze's analysis, it was German economic weakness, and a realistic perception of this weakness, not the strength that has so often been ascribed to the pre-1933 German economy, which motivated the drive to the east. The Nazis realized that they had a narrow window of opportunity with which to build this empire. As Tooze points out, it is ludicrous to suggest that everything they did was "practical" and economically motivated. The genocidal programs that consumed increasingly large quantities of precious human and material resources that could have been used to fight the Allies make sense only in the context of a toxic, and overpowering racial ideology. The Nazis' message of German superiority also alienated many potentially fascist and sympathetic movements across Europe, as historian Mark Mazower, among others, have pointed out.[16] Most importantly, in Tooze's estimation, the perception of impending economic dominance by the US, while essentially accurate (and, in the end, what happened), only became an existential crisis when coupled with the Nazis' view of history as a struggle between different racial groups, and their own dominance by Anglo-American capitalism in the west, and Russian Bolshevism in the east, as a submission to enslavement by the Jews who, in their view, controlled both through finance and communism.

This work informs my own in many ways, most importantly in the suggestion that the Nazis pursued a rational economic policy focused on attaining autarky. My research suggests that a preoccupation with agricultural productivity was one of the main motivators behind the development of one of the central concepts of modern environmental science. It suggests that fundamentally modern scientific methods grew out of rural preoccupations, that quantitative ecology began in part as a handmaiden to agronomy, and that a synthesis of industrial-scale production and fertilizer chemistry with the age-old question of how to feed a population gave birth to "primary productivity." When one understands Germany as a "developing" country, with a sizable rural population, and a history of extreme resource stress and hunger during the First World War and the Depression, as Tooze's work makes clear, this preoccupation with agricultural productivity makes perfect sense. So do Germany's efforts to expand into Africa and South America, outposts of a global empire which would have added even more raw resources inputs to the Reich's metropolitan industrial maw. As documented in chapters 3 and 4, these efforts were presaged by ecological reconnaissance efforts which employed

[16] Mark Mazower. *Dark Continent: Europe's Twentieth Century.* Alfred Knopf, 1999

the language of primary productivity, and technologies (such as aerial bio-cartography) that would one day be used to assess it. I add to Tooze's political economic account a narrative of scientific change. My work shows not only how scientists were mobilized by the Nazi pursuit of empire and autarky, but how the Nazi ideology of infinite growth (an ideology that would be reimagined in the postwar capitalist order as the bedrock of modern macroeconomic management, as discussed below), of a boundless future of bountiful resources, as well as the imperial dreams of infinite geographical expansion that fired the Nazi imagination, penetrated into the minutiae of agricultural and ecological research.

In addition to Tooze's work, Timothy Mitchell's *Carbon Democracy* stands out as essential to the political economic narrative of twentieth century history in which this humble story of the history of science is embedded. Mitchell argues that the fundamental problem of the oil industry for the first half of the twentieth century was abundance, not scarcity. Having acquired oil fields cheaply throughout the middle east, European and American oil companies in the 1920s and 1930s were left with the problem of potential overproduction to deal with. This was solved in part by engineering a post-WWII world where petroleum became the lifeblood of the global economy. Along with this material transformation, an intellectual one took place whereby academic economics reimagined the economy not as a system of material production, but rather an accelerating exchange of monetary transactions. This meant, in Mitchell's argument, that "infinite growth" became the goal of US economic policy (and by extension, all the countries where US development aid played an engineering roll, starting with the Marshall Plan nations), rather than increasing productivity within the confines of a world of finite resources. However, as it became necessary to restrict imports to protect the American market in the 1970s, a rhetoric of scarcity developed in the environmental sciences which paralleled the new focus on restricting production. Through all this, the macroeconomics of "infinite growth" were, for Mitchell, underwritten by discounting both the finite nature of hydrocarbons, and the external costs to society and the environment of continued hydrocarbon extraction and consumption. Like Mitchell, I view the environmental sciences as both allies and enemies of "economic growth." While Mitchell refers broadly to the environmental movement and the famous Club of Rome meeting of quantitative social and environmental scientists on the *Limits of Growth* in 1972, he does not deal in depth with the quantitative ecologists who are my focus. From what I have discovered in my archival research on the American ecologists, their concern for the limits of growth had many sources, not just the economic agenda of the US energy companies which they may have been unwittingly serving. For Robert Harding Whittaker, one of the central scientists to the propagation of productivity ecology in the US during the postwar era, a deep antipathy towards urbanization seemed to be at least as important to his use of ecological science to argue for a limit to economic growth as any larger political and economic agenda. Of course, the degree to which personal motivations and individual biographies are but mere proxies for political, economic, and social shifts is another question for another day. Finally, I would be remiss if I did not discuss two of the most important works on the history of ecology. First, Peder Anker's *Imperial Ecology* argues for a symbiotic relationship between early British ecosystem ecology and the British imperial goals. Arthur Tansley, the Freudian turned botanist who gave rise to ecosystem ecology in the anglophone scientific sphere, used British imperial funding to conduct research in Africa and the North Atlantic. In my story, Heinrich Walter, one of the founders of production ecology, used German colonial office funding to conduct research on the African Savannah, wrote on the applicability of this research to the Russian Steppes, and ended up working on reconnaissance in eastern Europe for the German military. The key difference between the German and the British case is that while the former could only dream of an overseas empire, the latter already had theirs, while the Germans' was an empire of the imagination. Finally, on the subject of the development of German ecology, Lynn Nyhart's *Modern Nature* is indispensable. Although earlier than my period, and not dealing directly with the self-identified discipline of ecology, Nyhart's work documents important strands in the genesis of the ecological (what she calls "the biological") view. For Nyhart, taxidermists, zookeepers, and museum workers were essential to moving biology away from a static focus on hiearchy and towards an emphasis on dynamic interactions in nature. This was an important pre-requisite for the development of modern ecology, but Nyhart goes farther and suggests that the modern concept of "biology" was in part born out of this activity going on beyond academic science departments. While my story focuses on academic science far more than Nyhart's, it also demonstrates that the impetus for a particular view of nature- as a dynamic system of interactions in Nyhart's telling, as a productive system of energy and mass transfers in my own- my research has demonstrated that the impetus for this transformation came from a wide range of different fields, from laboratory plant physiology, to practical forestry and quantitative agrobiology. Biology and ecology remain highly heterogeneous disciplines, and the inputs for paradigm shifts have come from many directions.

The Chapters

Chapter 2, *The Threshold of Malthusianism: Fertilizer Science and National Destinies in Depressing Times* zeros in on the work of the German agricultural scientist Eilhard Alfred Mitscherlich, whose work, starting in 1909 and gaining increasing importance through to the outbreak of World War II, marks the birthdate of primary production science. I compare the militarist use of the yield law (Ertragsgesetz) in Nazi Germany to the contemporaneous adoption of the law by University of Iowa agrobiologist O.W. Willcox for pacific purposes. Primary production research would come to focus on ostensibly natural systems, and the limits on biological productivity placed by the workings of civilization, yet it was born in agronomy and efforts to increase cultivated yields through the massive application of fertilizers. Similarly, a science that became central to cosmopolitan global ecology in the 1960s had its roots in the racist pursuit of national autarky by Nazi Germany in the 1930s. In *Chapter 3, The Territory of Fables: Ecological Productivity in Nazi Germany's Imaginary Empire*, I chart the initial transition of primary productivity research from the cultured realm of Germany's domestic agriculture to the less cultivated systems more often associated with modern ecology. The equation initially gained traction in the context of 24,000 field experiments (Feldversuchen) into the proportional relationship between potash, nitrogen, and phosphate fertilizer inputs and final yields conducted on German farms from 1934-1936, with the support of IG Farben and the German Potash Syndicate. Its transition into Nazi imperial ecology was facilitated by Heinrich Walter, who applied it to his studies of the former German colony of Southwest Africa, as well as the Italian colony of Libya. His research focused, however, not on fertilizers but on water, something that had preoccupied him in his early days of training in the kind of laboratory plant physiology that I discuss in Chapter 2.

In *Chapter 4, The Cracks in the Earth: Bioeography and Military Geography in Eastern Europe in Nazi Germany's Final Years* I show how aridity continued to concern him as he turned his attention towards Nazi imperialism in eastern Europe as a member of the Forschungsstaffel zur besondere Verwendung des Oberkommando Wermachts, a civilian adjunct to the German army in the east tasked with developing new mapmaking techniques. In a grimly ironic parallel, Michael Zohary, a Czech-German educated Jewish ecologist at the University of Jerusalem, shared this preoccupation with the development of plant life in arid ecologies, publishing his dissertation on dispersal ecology in Palestinian desert plants in the Botansichen Centralblatt.

In conclusion, *Chapter 5, A Member of the Food Chain: Trophic Class and Population Control in the Cold War* examines the history of population control, both as an ecological term referring to the regulation of population sizes within multi-species communities and a political one referring to the external control of fertility by national and international structures. Here, a scientific debate about whether natural ecologies are characterized by chaos or stability paralleled public debates about the effect of the growing global human population on the environment. Primary productivity also became a central piece of the International Biological Program of 1964-74. The primary characters here are Robert Whittaker, in whose personal archives I have researched, and his colleague Helmut Lieth, who together edited the summation of their International Biological Program funded research on global primary productivity. Other important scientists in the population control debate are Garret Hardin, Lawrence Slobodkin, and Paul Ehrlich.

Part I

Germany and Global War, 1929-1945

Chapter 2

The Threshold of Malthusianism: Fertilizer Science and National Destinies in Depressing Times

> *Weltmacht oder Untergang! Such is the sinister option that confronts a hemmed-in population when it has been ushered across the threshold of Malthusianism by its too great multiplication on the one hand, and the bankruptcy of its agronomic science on the other hand.*
>
> -O.W. Willcox, 1935[1]

[1]O.W. Willcox. *Nations Can Live at Home.* George Allen & Unwin, 1935, p.207

The Nazis were optimistic about the future. That optimism, and the militant racism that accompanied it, were embodied in many artifacts of German society which rose to prominence during the thousand-year Reich's twelve-year ontogeny. One such artifact was Eilhard Alfred Mitscherlich's *Produktionskurve* (production curve).[2] The *Produktionskurve* came into being in 1909, yet it would not rise to prominence until after 1933.[3] It was then that the *Produktionskurve* was absorbed into the Five Year Plan for rearmament. Mitscherlich's method for predicting crop output in response to fertilizer input was tested with 27,069 field experiments (*Feldversuchen*) over four years.[4]

In the embrace of the *Produktionskurve* by the Five Year Planners, several features of Germany's war goals were embodied. First, the curve was practically useful in the drive to autarky and self-sufficiency on the part of the *volkisch* elect at the expense of all other human beings. This was epitomized by the curve's use to chart domestic food production. Keeping the perpetually hungry German population fed while cut off from the food imports they depended on was as essential to the war effort as keeping bullets in the *Wehrmacht*'s guns.[5]

Secondly, the curve dovetailed perfectly with the general faith in the capacity of German science and technology to create a brighter future for that elect. This future would justify the suffering and penury of the present with abundance and comfort to rival pre-1929 America.[6] In the case of the curve,

[2]Also referred to as the *Ertragskurve*, or yield-curve, due to the common use in German agronomy of *Ertrag* to refer to the totality of a harvest by weight.

[3]Eilhard Alfred Mitscherlich. "Das Gesetz des Minimums und das Gesetz des abnehmenden Bodenertrages". In: *Landwirtschaftliches Jahrbuch* (1909) marks its first appearence.

[4]Willcox, *Nations Can Live at Home* gives a good summary of these experiments. Eilhard Alfred Mitscherlich. "Das Ergebnis von über 27000 Feld-Düngungsversuchen". In: *Pflanzenernährung, Düngung, und Bodenkunde* (1947) and Eilhard Alfred Mitscherlich. *Die Ertragsgesetze.* Akademie-Verlag Berlin, 1948 give Mitscherlich's post-war account of his pre-war work.

[5]Avner Offer. *The First World War: An Agrarian Interpretation.* Oxford University Press, 1989 argues convincingly for the decisive impact Germany's over-dependence on food-imports had on the First World War.

[6]Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy* makes

the unlimited application of synthetic and natural fertilizers, seen as the product of German chemical and mining ingenuity, would produce unprecedented crop yields. This faith was often juxtaposed with the racist perception of Eastern European peoples as being too primitive to make efficient use of their land, as will be discussed in greater detail in Chapter 4. Thirdly, the curve was one of many tools employed by Germany's militarist state and its private cartels in their mutually beneficial experiment with military Keynesianism and slave labor. This symbiosis, essential to both the motives behind the war effort and its prosecution, was represented by the organizations that supported Mitscherlich's nearly thirty thousand field experiments. Mitscherlich's nationwide study in what one might call "Big Dung Science" was not only a part of the Five Year Plan.[7] It was also sponsored by two of Germany's biggest private cartels, which dominated their respective global export markets before 1939: IG Farben and the German Potash Sydicate (*Deutsches Kalisyndikat*). Finally, the curve found its way into Germany's extra-Eurasian imperial ambitions, as it was deployed in ecological reconnaissance in the former German colony of Namibia (*Sudwest Afrika*). That final relationship between the curve and the Nazi war effort will be dealt with in the next chapter. For now, the curve's role in domestic war preparations is my primary concern.

The Curve

Although Mitscherlich's production curve found a hospitable environment in the nexus of state and capital that governed the Nazi's pre-war pursuit of

the argument that much of German war-planning was predicated on the (accurately perceived) need to compete with America in the near future. That is but one of the compelling arguments made in this text, and supported by both quantitative and qualitative sources.

[7] *Pflanzenernänrung, Düngung und Bodenkunde* was the general field of study of which this kind of quantitative agronomy was a part.

autarchy, its origins lie elsewhere. Mitscherlich's work had roots in the German tradition of fertilizer science going back to the mid-nineteenth century work of Justus von Liebig.[8] However, a more immediate scientific source for the production curve was the quantitative plant physiology undergoing a European renaissance just as Mitscherlich first theorized his production curve in 1909. Here, I will give two examples of this research and the experimentally-based proportional laws which Mitscherlich's research drew upon. The first comes from the Utrecht lab of F.A.F.C. ("Frits") Went, and A.H. Blaauw's dissertation on *The Perception of Light* in plants, published the same year that Mitscherlich first suggested the production curve. The second, from the much later 1927-32 work on CO^2 uptake by Peter Boysen-Jensen, bridges the gap between Boysen-Jensen's Copenhagen lab and the larger laboratory of depression-era Europe's fields and forests. This work formed a common scientific millieu for both quantitative German agronomy, and its embrace by some American agronomists. That last point is addressed in the final section of this chapter. For now, it must only be noted that a distinctive feature of the quantitative plant physiology illustrated by the case studies below was echoed by Mitscherlich's work. This was the desire to quantify material inputs from the external ecology and their output as plant growth in terms of proportional laws. For Blaauw, the input was light. For Boysen-Jensen, it was CO^2. For Mitscherlich, it was the range of organic (such as the potassium salts controlled by the German Potash syndicate) and synthetic (such as the nitrogen compounds produced by I.G. Farben, the world's largest chemical concern) fertilizers. While Boysen-Jensen transferred his physiological theories on the relationship between CO^2 uptake and growth from the lab to Denmark's forests, Mitscherlich took such experimental macro-physiology to a

[8]William H. Brock. *Justus von Liebig: The Chemical Gatekeeper* is the definitive source on the life and work of Justus von Liebig.

new level. The backing of the Five-Year Plan, I.G. Farben, and the German Potash Syndicate allowed him to transform Germany's entire food production system into his laboratory. The "Great German Fertility Survey" (soil fertility, that is, although the relationship to the human variant will be discussed soon enough) was but one of the ingenious large-scale experiments conducted upon Europe's population by callous and inventive governments between the October Revolution and Berlin Airlift. However, it cannot be properly understood without first examining in detail the smaller scale experiments of Blaauw and Boysen-Jensen. Smaller they were, but no less innovative, and no less tied to vexed human concerns, albeit more subtly.

A.H. Blaauw's 1909 dissertation, the *Die Perzeption des Lichts*) attempted to establish a proportionality law for a plant's response to different wavelengths of light. Blaauw explicitly related this proportionality law to the mid-nineteenth-century Fechner-Weber law, which established a proportionality between additions of a unit stimulus (such as weight) and the moment when that stimulus was first perceived by a human subject. More deeply, Blaauw's experiments and their graphical presentation represented an effort to re-frame plant physiological units of measurement in purely physical terms, and therefore to ground plant physiology in objective quantification.[9] The paramount importance of physical measurement for Blaauw's work was

[9]Patricia Faasse. *Experiments in Growth*. Universiteit Amsterdam, 1994 made the convincing argument that Blaauw's phototropism experiments were intended by him to do away with subjective, physiological units of measurement, dependent upon a specific research object's reaction to a stimulus and the experimenter's measurement of the first appearance of that reaction. According to Faasse, Blaauw intended to replace such subjective, physiological units of measurement with objective, physical ones. These units were (hopefully) independent of whether the research objects were the Utrecht researchers' beloved *Avena sativa* coleoptiles, another plant, an animal, or even a piece of photochemical paper. Furthermore, Faasse demonstrated that Blaauw was largely successful in convincing subsequent Utrecht physiologists and the larger European physiological community that he had achieved what he set out to do, thus grounding plant physiology in the terrra firma of optical physics. The epic upheaval that the physics of light underwent in Europe contemporaneous with the phototropism experiments of Blaauw and others, provides a suggestive context for Blaauw's wavelength curves, but sadly one that cannot be further investigated here.

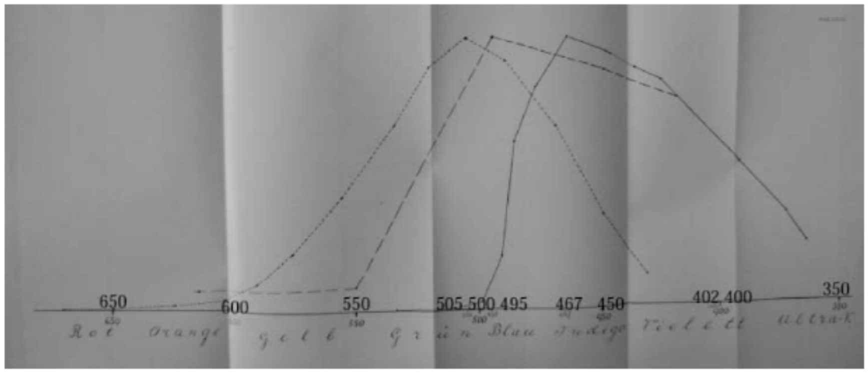


Figure 2.1: Phototropic Wave-Length Perception Curves, 1909 (from A.H. Blaauw. *Die Perzeption des Lichtes*. Nijmegen: F.E. MacDonald, 1909)

embodied by his phototropic wave-length perception curves, displaying the impact of different wavelengths of light on a plant's phototropic reactions.[10] Blaauw intended his phototropism experiments to usher in a new age of quantitative plant physiology. To a large extent, they were successful.

2.1

The phototropic wave-length perception curves were the only fold-out graph in his 1909 dissertation. This graph laid bare the connection to both the physical wave theory of light, and the psychophysical study of human light sensation. In Blaauw's words:

> For two very different organisms from the plant kingdom [*sativa*, or oats and *Phycomyces nitens*, the latter since reborn as member of the fungus kingdom] it is now proven, that the quantity of energy necessary to produce a constant phototropic effect, such as a macroscopic yet just visible curvature, is constant for a given plant species. For this constant effect a constant quantity of energy is necessary and it is for the plant all the same, how this energy is

[10] A.H. Blaauw. *Die Perzeption des Lichtes*. Nijmegen: F.E. MacDonald, 1909, p.68 gives the data Blaauw used for these curves, the preceding pages describe his experiments.

divided between time and intensity. *The plant experiences only the quantity of energy as a stimulus*; the time and the intensity are nothing more than factors of the energy measure. Only this quantity of energy works as a stimulus, for the plant itself neither the intensity nor the time exist as specific measures. The idea of presentation time existed only for for the plant physiologists, not for the plants.[11]

The historian of plant physiology Patricia Faasse has delved into far more detail on Blaauw's light experiments and Went's Utrecht lab more generally. Her clear and compelling argument for the impact of Blaauw's work on the larger paradigm of plant physiology is summed up thusly:

> *Instead* of determining the influence of a certain light intensity on the reaction of a plant, Blaauw tried to establish (and varied) the amount of energy related to a *constant effect* [a curvature, in cm]. He sought to *isolate*, in other words, the factors responsible for a *constant effect*, rather than to wait for any variable effect to occur...He did so by applying methods that were more or less standard in *the physics laboratory.* Technically, this was difficult enough: there was no method to differentiate

[11] "Für zwei sehr verschiedene Organismen aus dem Pflanzenreich ist jetzt also bewiesen, dass die Quantität Energie, die erfordert wird, um einene konstanten phototropischen Effekt, n.l. eine makroskopisch noch gerade sichtbare Krümmung zu erzielen, für eine Pflanzenart konstant ist. Für diesen konstanten Effekt ist eine konstante Quantität Energie nötig und es ist also für die Pflanze gleichgültig, wie diese Energie, über Zeit und Intensität verteilt, zugeführt wird. *Die Pflanze empfindet nur die Quantität Energie als Reiz*; die Zeit und die Intensität sind nichts mehr als Faktoren von der Energiemasse. Nur diese Quantität Energie wirkt als Reiz, für die Pflanze selbst besteht weder die Intensität, noch die Zeit als eine absonderlich Grösse. Der Begriff Präsentationszeit hat darum nur für den Pflanzenphysiologen existiert, nicht für die Pflanzen." Blaauw, *Die Perzeption des Lichtes*, p.29-30. The emphasis on "The plant experiences only the quantity of energy [time $\times$ intensity] as stimulus;" is Blaauw's emphasis.

> the intensity of light over various colors, too long waves might be disturbed, sunlight was only accidentally available, and repeating attempts with exposure times of more than 18 hours were simply too expensive. The major difference, however, and one which went to the heart of perception, was that, in contrast with other investigations, *the stimulus was dissected into physically measurable units.* Physical research on light defined the amount of energy (the stimulus) by its intensity and exposure time. In Blaauw's investigations, crudely put, time became a function of the amount of energy (the light waves), rather than a property of the reaction of the plant, as it had been with Pfeffer [the dean of German plant physiology during the turn of the century]

[12]

A decade after Blaauw's first study, but before he took off to California, H.L. van de Sande-Bakhuyzen summed up his Utrecht forbearer's contribution thusly:

> Before 1909, people thought that phototropic reactions of plants depended only on the strength of the light [*lichtsterkte*] to which the plant was unilaterally exposed... In 1909 Blaauw and Fröschel found that the *lichtenergie*, rather than the *lichtsterkte*, was the product of intensity and exposure time... Therefore, the intensity-threshold [*intensification*] was abandoned, and an energy-threshold was taken up, for coleoptiles of *Avena sativa* [oats] this energy-threshold is over 20 Meter Candle Seconds.[13]

[12] Faasse, *Experiments in Growth*, pp.51-52

[13] "Voor 1909 dacht men, dat de fototropische reactive van de plant allen afhankelijk was

The important point here was that the energy ($i \times t$, where i= luminous intensity, and t= time) alone was "perceived" by the plant. Working from this principle, Blaauw set about on a series of experiments in which he tested his proportionality law, dubbed the *Reizmengengesetz* by 1915. These experiments culminated in the phototropic wavelength perception curves. The x ordinates were the different wavelengths of visible light, from the longest, lowest energy, red waves ($650\mu\mu$) to the shortest, highest energy, blue waves ($350\mu\mu$). On the y axis lay a hypothetical scale of sensitivities, scaled so that all three lines peaked at the same point on the sensitivity axis, but for different wavelengths. Because only energy, the product of light intensity and time, existed in the plant's phenomenological world, Blaauw was able to vary either i or t when producing a given curvature in a plant.[14] He could then produce the same curvature in another plant of the same species with a different wavelength, isolated through refraction. Blaauw thus determined the sensitivity of the plants to the artificially refracted wavelengths when exposed to those wavelengths in the *Normalspektrum*. The *Normalspektrum* was the aggregate of all wavelengths in the visible spectrum, a proxy for the average light exposure experienced by the average plant on the average day. Blaauw's experiments had prismatically isolated the different wavelengths from the visible spectrum, he then adjusted the sensitivity ordinates for the curvature as if it had been a sub-curvature of a larger curvature. This larger curvature was the response of the plant to the multitude of wavelengths making up the normal spectrum. The three curves represented the Utrecht lab's two cherished model organisms, *Avena sativa* and *Phycomyces nitens*, and a third

van de lichtsterkte, waarmee men deze eenzijdig belichtte...Nu hebben in 1909 Blaauw en Fröschel gevonden, dat niet de lichtsterkte, doch de lichtenergie, het product van intensiteit en belichtingstijd, den doorslag gaf...Zoo kwam men er toe, den intensiteitsdrempel te verwerpen, en een energiedrempel aan te nemen; deze ligt bij coleoptielen van Avena bij ongeveer 20 M.K.S."H.L. van de Sande-Bakhuyzen. *Analyse der fototropische Stemmingsverschijnselen.* M. de Waal, 1920, p.1 lux×second = $\frac{1\text{lumen}}{m^2}$ ×1second = 1candela×1steradian×m^{-2}×1second

[14] light intensity = $\left(\frac{lumen}{steradian}, \text{or} \frac{lumen}{plane}\right)$

$$\gamma = K\frac{d\beta}{\beta}$$

The Weber-Fechner Law...

$$\gamma = K\left(\log\left(\frac{\beta}{b}\right)\right)$$

...& Its Integrated Logarithmic Form, 1860

species they did not experiment with in their dark rooms, *Homo sapiens*. *Sativa* is represented by the solid line, *nitens* is represented by the broken line, and *sapiens* is represented by the dotted line.

Blaauw compared his proportionality law for phototropism and Gustav Fechner's 1860 mathematical treatment of Ernst Heinrich Weber's 1846 psychophysics experiments. Where γ is a human sensation (of weight, light, or any other sensory stimulus), β is the stimulus, d is an incremental increase in γ or β, and K is a constant, dependent on the units of measurement used for γ and β.[15] Fechner added another term, b for his integrated logarithmic expression of this proportional relationship between $d\gamma$ (incremental change in sensation) and $d\beta$ (incremental change in stimulus). The term b expresses the threshold value of β, that is the point at which the stimulus is felt as its value (in kilograms, or lumens, or...) goes up, and the point at which it disappears as its value goes down. Blaauw's debt to nineteenth-century psychophysics is clear in his third curve on figure 1.1, the dotted line representing human visual perception (*menschliche Gesichtsempfindung*). This curve came from a photometric textbook, published three years before Blaauw's dissertation. This text presented a series of human light-perception curves derived from physiological experiments on humans and photochemical experiments on light-sensitive papers, taken as analogues for human perception. Not least among these curves was one which the text's author, Herdis Krarup, took from

[15] Michael Heidelberger. *Nature From Within: Gustav Fechner and his Psychophysical Worldview*. University of Pittsburgh Press, 2004 provides a thorough account of Fechner's life and work.

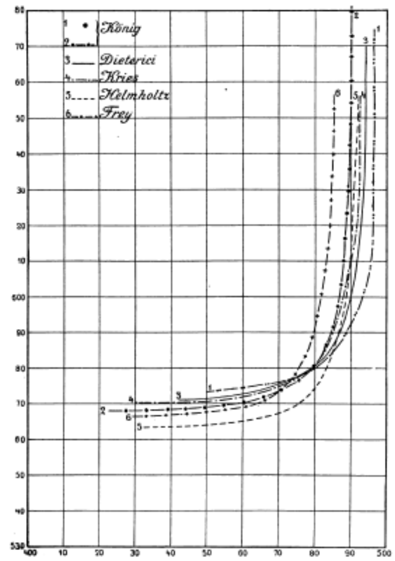


Fig. VIII.

Human Light-Perception Curves, 1906 (from Herdis Krarup. *Physische-opthalmologische Grenzprobleme: Ein Beitrag zur Farbenlehre.* Georg Thieme, 1906)

the legendary Hermann von Helmholtz.[16]

Over half a century earlier, Robert Bunsen and Henry Roscoe contributed their own quantitative proportionality law to photochemistry and this provided the closest analogue to the proportionality law which drove Blaauw's research and much subsequent plant physiology. Reflecting on animal and human visual perceptions (*tierische und menschliche Gesichtsempfindungen*), Blaauw wrote:

> From these researches came the final result, *that, for the threshold of the visual perception, the product of time and intensity is constant only within very limited boundaries...* In photochemistry...Bunsen and Roscoe (1862) found from their researches: *that within very wide limits the same products of intensity and isolation duration the same darkening on*

[16]Herdis Krarup. *Physische-opthalmologische Grenzprobleme: Ein Beitrag zur Farbenlehre.* Georg Thieme, 1906, p.87

> *chlorargyrite paper correlates with the same sensibility.* ...Nernst said...*the photochemical effect is dependent only on the product of intensity and duration of illuminance.* And Ostwald formulated the same law in the following way: *"that the photochemical effect is like the product of time and intensity"*[17]

Blauuw's debt to human psychophysics and photochemistry was also visible in his use of the visible spectrum only. There is no inherent reason why one would have expected a plant's phototropic growth curvature to be oriented only towards light that is peceptable by human eyes. Blaauw made much of placing plant physiology on the firm quantitative foundation of physics. Yet while his deployment of wavelengths connected his work to the electromagnetic wave theory of light, he remained grounded in the human concerns embodied by photometric units of measurement. Blaauw's basic unit was MKS (meter candle seconds). The meter candle was similar to the SI photometric unit lux, a lumen (candela × steradian) over a unit m^2. $\frac{\text{lumen}}{m^2} = lux$, and when any photometric unit was multiplied by a term for time (one second, hence meter candle second), it went from being a measure of luminous flux (lumen) or luminous flux per unit are (lux) to being a measure of energy. However, since he confined his wavelength experiments to the spectrum of light visible to humans, and even generated his curves by mathematically placing his refracted wavelengths in the normal spectrum, Blaauw remained deeply

[17] "Aus diesen Untersuchungen geht als Endresultat hervor, *dass für die Schwelle der Gesichtsempfindung das Produkt aus Zeit und Intensität nur innerhalb ziemlich enger Grenzen constant ist...* In der Photochemie...Bunsen und Roscoe (1862) finden als Ergebnis ihrer Untersuchungen: *dass innerhalb sehr weiter Grenzen gleichen Produkten aus Intensität und Isolationsdauer gleiche Schwärzungen auf Chlorsilberpapier von gleicher Sensibilität entsprechen...*.Nernst sagt...*'die photochemische Wirkung nur von dem Produkte aus Intensität und Belichtungsdauer abhänig ist.'* Und Ostwald formuliert dasselbe Gesetz in der folgenden Weise: *'dass die photochemische Effekt gleich dem Produkt aus Zeit und Intensität ist."'* Blaauw, *Die Perzeption des Lichtes*, pp.45-48. The emphasis is in Blaauw's original text. For a late-nineteenth-century collection of Bunsen and Roscoe's mid-nineteenth-century photochemical experiments, see:Robert Bunsen and Henry Roscoe. *Photochemisch Untersuchungen (1855-1859).* Wilhelm Engelmann, 1896

connected to the human sciences. Blaauw's stated goal was to remove the purely physiological measure of light strength, in which both the specific curvature and the time (in seconds) were subordinate to the measure of light strength or intensity (*Lichtstarke* or the Dutch *lichtsterkte*, measured in meter candles). Plant physiologists trained in the tradition of the late-nineteenth-century Germans, headed by Pfeffer's Leipzig lab, subjectively assessed the first appearance of any phototropic curvature in the organism as the light strength increased, and then marked the strength at that point. The specific quantified curvature was irrelevant. Summing up this work in 1909, Blaauw appropriated the term stimulus threshold (*Reizschwelle*) to refer to both the time and intensity thresholds *Zeit-* and *Intensitätsschwelle* at which the experimenter first detected phototropic curvature. For Blaauw, the threshold for the exposure time and for the light strength were dependent only on the physiologist's subjective judgement, and had meaning only within plant physiology. Finding the energy (intensity in meter candles × time in seconds) necessary to produce a specific, quantified curvature, rather than the intensity or time necessary to stimulate the first appearence of curvature which happened to stimulate the experimenter, brought physiology closer to the quantitative experimental sciences, as far as Blaauw was concerned.

Another branch of quantitative physiological research into plant growth, closely related to the phototropic (and later, hormonal) research of the Utrecht lab was the effort to identify the role of the different factors of production (*Produktionsfaktoren*). In a very different sense, the quantification of the impact of production factors on growth rates was an abiding interest of German macroeconomists. For physiologists, production factors were those that modified growth, cast in physical-chemical terms as the rate at which CO_2 was assimilated and incorporated into a plant's structure. CO_2

assimilation and dry-matter production was called *Stoffproduktion*. Here, Peter Boysen-Jensen's Copenhagen lab was the leader by the end of the 1920s. *Stoffproduktion* would chart a course through German ecological reconnaissance of the 1940s to ecological production research in the 1960s and 1970s. But in 1932, when Boysen-Jensen summed up the state of *Stoffproduktion* research, that destiny was concealed by time.

Boysen-Jensen first identified a range of production factors which modulated the rate of CO_2 assimilation, apart from the CO_2 content of the air itself. These included light, temperature, and water. For reasons that are already obvious, light is one of the most important production factors for this story. For reasons that will be obvious soon enough, water and the nutrient content of the soil are equally important. Although grounded in the same rigorously controlled laboratory experimentation as the Utrecht physiologists, Boysen-Jensen was no stranger to economic issues of (living) resource production. While studying at the University of Copenhagen in the first decade of the twentieth century, Boysen-Jensen conducted quantitative research on the food production of the Danish coast under the fisheries biologist Carl Geog Johannes Peterson.[18] In addition, he was most likely exposed to the Copenhagen botanist Eugen Warming's huge 1895 descriptive text on plant associations (*Plantesamfund*) and their geographic distributions, one of the earliest explicitly ecological scientific works.[19] Warming's own turn from purely taxonomic botany to descriptive geographical ecology had itself been the result of both his collecting trip to Brazil and his concern "with the acute economic problems involved in agricultural development in Jutland, a

[18]Peter Boysen-Jensen and Carl Georg Johannes Peterson. *Valuation of the Sea: Animal Life of the Sea Bottom, its Food and Quantity.* Centraltrykkeriet, 1911

[19]Eugen Warming. *Plantesamfund: Grundtroek af den økologiske Plantegeografie.* Philipsen, 1895, the German translation in which most non-Danish scientists would have encountered Warming's foundational ecology textbook is Eugen Warming. *Lehrbuch der öcologischen Pflanzengeographie.* Borntraeger, 1933.

solution of which involved the use of plants in controlling sand and the conversion of heath into tillable land."[20] Warming's son, Jens Warming, became an agricultural economist who wrote, among other things, an influential 1911 article on the common-property problem in relation to fisheries.[21] Warming's most important student, Christen Raunkiaer, continued his ecological and agronomic work, and his path most likely crossed with Boysen-Jensen's during their shared time at Copenhagen. Both Warming and Raunkiear grounded their ecology in qualitative physiology, and focused on the relationship between a plant's functional needs for water, food, and light and its geographical distribution. This focus on the connection between physiological need and geographic distribution became one of the enduring unifying features of the different forms of descriptive and quantitative ecology throughout the next 100 years. Before Boysen-Jensen turned to the factors of

[20]William Coleman. "Evolution into Ecology? The Strategy of Warming's Ecological Plant Geography". In: *Journal of the History of Biology* 19.2 (1986), p.186. This essay by the great historian of biology contained both an analysis of early descriptive geographical ecology's debt to Darwinian biogeography, and the role Warming's text played in the divorce of much of ecology from explicitly Darwinian concerns, a divorce which lasted until the 1960s for many field biologists. George Williams. *Evolution and Natural Selection: A Critique of Some Current Evolutionary Thought*. Princeton University Press, 1966 marks one of the most decisive attacks on (what individual-centered Darwinists) regarded as anti-evolutionary forms of population ecology, embodied (for the icthyologist Williams) by the group selection theories of the ornithologist Vero Wynne Cooper-Edwards.

[21]Jens Warming. "Om Grundrente af Fiskegrunde". In: *Nationaløkonomisk Tidsskrift* 49 (1911) is the original Danish article, Jens Warming. "On Rent of Fishing Grounds". In: *History of Political Economy* 49 (1983) provides an English translation and a helpful historical introduction by Peder Andersen. Andersen treats the younger Warming's article as a precursor to H. Scott Gordon. "The Economic Theory of a Common Property Resource: The Fishery". In: *The Journal of Political Economy* 62 (1954), a foundational article in fisheries economics which itself cites Boysen-Jensen and Peterson, *Valuation of the Sea: Animal Life of the Sea Bottom, its Food and Quantity.*Einar Jensen. *Danish Agriculture: Its Economic Development*. J.H. Schultz, 1937 provides a depression-era history of the Danish agricultural economy, and draws heavily on Jens Warming's work. As recently as Kenneth Pomeranz. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton University Press, 2000, economic historians have treated Denmark's rise to wealth as an alternative path of economic development, in that while the food output to land and labor input ratio went sharply upwards during the second industrial revolution, this was not accompanied by a large shift of the economy towards manufactured output. Denmark, therefore, is often treated by economists and historians as the model for a primary producing, food exporting country that nonetheless bears all the marks of a rich country, save for a period of massive manufacturing production at some point on their evolution from a subsistence economy to a rich, service economy.

Stoffproduktion, his economic work with Peterson on "the valuation of the sea" was one of several efforts to quantify fisheries production which contributed methods to both resource economics and ecology in the decades before and after the War.[22]

Betraying his roots in this world of field biology and resource management, Boysen-Jensen's 1932 *Stoffproduktion* monograph moved from matters experimental to the factors of production governing competition and cooperation among plants outside the laboratory's walls. Nonetheless, Boysen-Jensen's text was clearly grounded in the plant physiology of Pfeffer's Leipzig lab, where he worked in 1911, and in the quantitative physiology developing contemporaneously in his Copenhagen lab, in Frits Went's lab in Utrecht, and in Hans Molisch's in Vienna. Yet, after considering the experimental data on the effect of a range of production factors on individual CO_2 assimilation and transpiration (the exhaling of O following CO_2 and H_2O uptake), Boysen-Jensen moved to a consideration of plant productivity in more social environments. His 40 page analysis of production in plant associations (*Stoffproduktion in Pflanzenassociationen*), together with his

[22]Lynn Nyhart. *Modern Nature: The Rise of the Biological Perspective in Germany.* University of Chicago Press, 2009 demonstrates the foundational role of Karl Möbius's work on oyster fisheries near Kiel, Germany for the late-nineteenth-century "biological perspective" in Germany. This holistic perspective, which viewed living things in complex interaction with each other rather than as the objects of static taxonomy, would take on the name *Ökologie* in Germanophone Europe by the 1920s, although the term had been available for use since Ernst Haeckel coined it in the 1860s. Nyhart's "biological perspective" bears comparison with Raunkiaer's taxonomic concept of the life-form, whereby the functional relationship of a plant to its conditions of subsistance, rather than common descent or anatomical simularity, formed the basis of classification. In the British Empire, the fisheries ecologist E. Barton Worthington applied his trade to the great east African lakes in the 1930s, as documented by Peder Anker. *Imperial Ecology: Environmental Order in the British Empire, 1895-1945*. Cambridge: Harvard University Press, 2001. Peterson and Boysen-Jensen's own methods had a part to play in the economics of renewable resources by the 1950s (for an example, see Gordon, "The Economic Theory of a Common Property Resource: The Fishery"), along with other contributions from the fishery sciences. Forestry was the other practical management science seen as an ancestor by both ecology and resource economics by the post-war era. Peterson and Boysen-Jensen's *The Valuation of the Sea* was accepted as an important ecological contribution by Anglophone science immediately after its 1911 publication in English C. Adams. "Review of 'The Valuation of the Sea'". In: *The American Naturalist* 47.558 (1913). Poul Larsen. "Peter Boysen-Jensen, 1883-1959". In: *Plant Physiology* (1959) gives biographical information on Boysen-Jensen.

consideration of water's role as a production factor in forests, occupied half of his text. These social conditions took many forms, not least that of "the struggle of the suppressed trees for the necessities of life...it is in this struggle for vital conditions, that the assimilation system, the condition for the *Stoffproduktion*, will function as long as possible."[23] For his discussion of how the struggle for light, food, and water, Boysen-Jensen drew upon both lab work and field experiments. The plant's social life could be the robust outdoor one experienced by the ash (trees of the genus *Fraxinus*) stand of the Lille Bøgoskov, which Boysen-Jensen and D. Müller conducted a time series growth study of from 1923 to 1925.[24] Or, its socialization could be limited to that experienced by a cluster of *Avena* or *Sinapsis* living and dying in Boysen-Jensen's gasometer. Of course, given the centuries of managed forestry virtually every tree in Denmark had been subjected to, perhaps there was not as wide a gulf between the gasometer society and the Bøgoskov *Fraxinus* stand.[25]

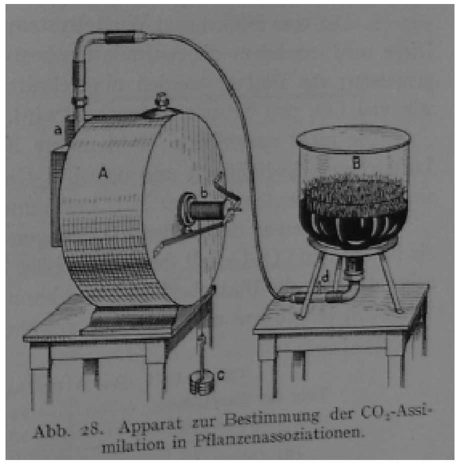
"Naturally," Boysen-Jensen "wished that experiments with natural plant associations could be carried out."[26]. In the absence of this possibility, Boysen-Jensen's social gasometer allowed the experimenter to quantify the CO_2 uptake by an *Avena* or *Sinapsis* association, confined to an open glass dish (B in figure 1.3). The experimenter did this by maintaining the suction on the vacuum chamber at a known rate, quantified in $\frac{\text{liters}}{\text{hour}}$. Given this rate and a calculation of the CO_2 content of the air $\left(\frac{mg}{\text{liter}}\right)$ before it was sucked past the glass-bound *Sinapsis* association, the experimenter found the rate of

[23] "der Kampf der unterdrückten Bäume um die Erhaltung des Lebens...es ist in diesem Kampf von vitaler Bedeutung, daß das Assimilationssystem, die Bedingung für die Stoffproduktion, solange wie irgend möglich intakt gehalten wird." P. Boysen-Jensen. *Die Stoffproduktion der Pflanzen.* Jena: Gustav Fischer, 1932, p.75

[24] Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, pp.69-71 discusses his and Müller's field experiments.

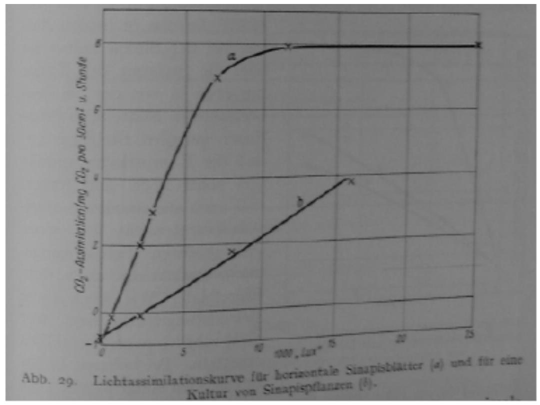
[25] In the arboreal context, the word *Bestand* usually denotes a managed forest stand.

[26] "Es wäre natürlich sehr erwünscht gewesen, diese Untersuchungen mit natürlichen Pflanzenassoziationen durchzuführen." Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, p.58



The Social Gasometer, 1932 (from P. Boysen-Jensen. *Die Stoffproduktion der Pflanzen.* Jena: Gustav Fischer, 1932)

CO_2 assimilation under (claustrophobic) social conditions. Boysen-Jensen and Müller thus calculated the rate of CO_2 assimilation from the difference between the CO_2 content of the air pulled into the vaccum chamber after a given amount of time and the CO_2 content of the air before entering the hose leading to the chamber. But first, the CO_2 absorbed by the soil in which the *Sinapsis* society was rooted had to be discounted as well. To do this, they found the difference between the CO_2 content of the soil before and after running the vaccum, and subtracted that difference from the difference in CO_2 content between the air before and after it entered the vaccum. Since the plant association stood between the outside air and the vacuum chamber, the assumption was that all the CO_2 not absorbed by the soil and not remaining by the time the air arrived in the vaccum had been assimilated by the plants. Moreover, the open top of the glass dish could be covered with tinted paper of varying degrees of transparency, thus allowing the experimenter to correlate different light intensities with different rates of CO_2 assimilation. They



Light Assimilation Curves, 1932 (from P. Boysen-Jensen. *Die Stoffproduktion der Pflanzen.* Jena: Gustav Fischer, 1932)

generated Light Assimilation Curves in this way.[27]

Like Blaauw, Boysen-Jensen and Müller used a physical measure of visible luminosity taken from physics and photometry, the lux. The lux was interchangable with Blaauw's favored measure of meter candles (MK), as both are equivalent to one lumen unit illuminating one m_2 unit. Had the experimenters multiplied the lux units that made up their x axis by a term for time, they would have transformed their measure of $\frac{\text{lumen}}{m^2}$ into a measure of energy. Instead, the curves generated by the social gasometer experiments left the time term to their rather intricate y axis, whose ordinates gave the mg of CO_2 assimilated by a 50 cm^2 leaf area per hour. Incidentally, the x ordinates for the Bøgoskov ash stand observations were purely temporal (months). Boysen-Jensen had lamented the impossiblity of conducting experiments on "natural plant associations," and as far as the larger plant association was concerned, the best he and Müller could manage were longitudinal dimensional measurements of the standing trees over two years, with these geometric

[27]Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, pp.59-64 explains the workings of the gasometer, and Boysen-Jensen and Müller's experiments correlating light intensity with CO_2 assimilation.

dimensions used to derive an estimate of monthly *Stoffproduktion*. "The form of the plant is conditioned through its mode of feeding," Boysen-Jensen wrote towards *Stoffproduktion's* end, "because the CO_2-Assimilation is dependent on the supply of light energy, the plant must offer the light a great surface area, its leaves, and thus must the further vegetative organs of the plant hold a higher water content."[28] After invoking Blaauw's beloved energy unit, (*Lichtenergie*), Boysen-Jensen moved to a discussion of the crucial role of water absorbtion in *Stoffproduktion*.[29] This predictive production curve did not escape Boysen-Jensen's notice either, as he closed his 1932 text with a discussion of the relationship between *Stoffproduktion* and edaphic (soil) factors, noting in an aside that

> Some have attempted to present mathematical formulas for production curves (namely the effect law of growth factors of Mitscherlich-Baule). It is well known that there is a comprehensive literature on these questions, that I will not explore here. As I have remarked above, such mathematical formulas are perhaps practically useful; yet they are not able to explain in what ways the plant production is influenced by the scarcity of a specific nutrient.[30]

[28] "Die Form der Pflanze ist durch ihren Ernährungsmodus bedingt. Weil die CO_2-Assimilation von der Zufuhr von Lichtenergie abhängig ist, muß die Pflanze dem Lichte eine große Oberfläche darbieten können, den Blättern, erreicht wird ferner müßen die Vegetationsorgane der Pflanzen einen hohen Wassergehalt haben."Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, p.94

[29] The photosynthetic equation was identified in the post-war era as $6CO_2 + 6H_2O + \text{light} = C_6H_12O_6 + 6O_2$, meaning that six molecules of CO_2 and six molecules of water combined into a single carbohydrate, and exhaled six simple dioxide molecules. However, the process of photosynthesis did not exist in anything like its modern form for physiologists of the pre-war period.

[30] "Man hat versucht, mathematische Annäherungsformeln für solche Ertragskurven darzustellen (vgl. namentlich das Wirkungsgesetz der Wachstumsfaktoren von Mitscherlich-Baule). Bekanntlich liegt über diese Fragen eine sehr umfassende Literatur vor, auf die ich nicht eingehen möchte. Wie oben bemerkt, können solche mathematischen Formeln vielleicht praktisch brauchbar sein; sie vermögen aber nicht zu erklären, in welcher Weise die Pflanzenproduktion durch Mangel an einem bestimmten Nährstoff beeinflußt wird."Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, p.105

$$\log A - y = \log A - c(x + b)$$

The *Ertragsgesetz*, 1933

Perhaps Boysen-Jensen was right. Perhaps Mitscherlich's production curve did not clarify how the limiting of a specific nutrient influenced plant production. However, that did not stop this seemingly humble equation from being used by the National Socialist four year plan, American agrobiology, I.G. Farben, and the German potash syndicate (*Kalisyndikat*. Or perhaps the Curve used them to propagate itself. After all, from the ashes of Germany's sordid *Götterdammerung* the Production Curve emerged unscathed to become a crucial component of global global production ecology.

In the *Ertragsgesetz*, y, c, x, and b can all be filled with emprical values. A, on the other hand, represented only a dream of a food-filled future. Y represented the actual yield of a given crop at a given time. C was a constant, determined by the type of nutrient but independent of the quantity of the nutrient. The logarithmic slope of the *Produktionskurve* was determined by the value of c in the *Ertragsgesetz*. X was the quantitity of the nutrient added in a given trial, where b was the quantity of the nutrient already present in the soil prior to the addition of x quantity of phosphorous, potassium, or nitrogen. Nowhere in the *Ertragsgesetz* was there a term for the plant species under study. While A and y might be greater for different species and individuals, the proportion of A and y on one side, and the quantitity of a given nutrient on the other, never changed. By establishing a proportionality between the final yield and the fertilizer quantity, agronomists could calculate the hypothetical upper limit that would come with the addition of more of a particular fertilizer. It was in this promise of future yields far greater than what was being realized that the economic power of the *Ertragsgesetz* lie.

If the origins of biology lay in the attempt to differentiate between the planet's manifold life-forms, then Mitscherlich's production curve, first formulated in 1909, was a kind of anti-biology.[31] It sought to eliminate the differences between individuals, populations, and species. It sought to replace biological difference with differences between nutrients and their quantities. Between 1934 and 1938, Mitscherlich and his colleagues conducted 27,000 field experiments with potassium (potash, or *Kalibum*), nitrogen, and phosphorus on a range of different crops, most importantly wheat, rye, oats, and barley.[32] Fitting these empirical results into the algebraic expression of the production curve, the yield law (*Ertragsgesetz*), Mitscherlich and his associates concluded that

> All our cultured plants regulate the utilization of food in the production of yield (*Ertragsbildung*) in the same way! There is no cultured plant, for example, that might assimilate the earth's phosphorus better than another! This viewpoint belongs to the realm of fables (*Bereich der Fabeln*)[33]

In other words, the quantity and the type of nutrient used, not the plant it was used on, determined the final yield. Moreover, the hypothetical final yields promised by A were vastly higher than those currently realized by German agriculture. The power of the *Ertragsgesetz* lie in the proportionality it established between an actual yield and the quantity of a given nutrient. Both sides of Mitscherlich's equation, the actual yield and the food's food, were expressed as the difference between those quantities and a hypothetical

[31] Mitscherlich, "Das Gesetz des Minimums und das Gesetz des abnehmenden Bodenertrages"

[32] O.W. Willcox. "Meaning of the Great German Soil Fertility Survey". In: *Soil Science* 79.2 (1955), pp. 123–132 reprints the tables listing the results of all the field experiments. Willcox was the loudest American voice supporting Mitscherlich's method from the 1930s into the postwar era. It is in this 1955 article that the 27,000 field experiments were coined the "Great German Soil Fertility Survey," as far as I can tell.

[33] Frans van der Paauw. "Critical Remarks Concerning the Validity of the Mitscherlich Effect Law". In: *Plant and Soil* 4.2 (1952) repeats the quotation from Mitscherlich, "Das Ergebnis von über 27000 Feld-Düngungsversuchen", which is itself the source for Willcox, "Meaning of the Great German Soil Fertility Survey"

upper yield, A. It was this hypothetical upper yield that embodied the hopes and dreams of 1930s Germany. This kind of proportionality law had the physiological laws of the Utrecht experimenters and the psychophysical laws of the mid-nineteenth century as its ancestors.
This predictive production curve did not escape Boysen-Jensen's notice either, as he closed his 1932 text with a discussion of the relationship between *Stoffproduktion* and edaphic (soil) factors, noting in an aside that

> Some have attempted to present mathematical formulas for production curves (namely the effect law of growth factors of Mitscherlich-Baule). It is well known that there is a comprehensive literature on these questions, that I will not explore here. As I have remarked above, such mathematical formulas are perhaps practically useful; yet they are not able to explain in what ways the plant production is influenced by the scarcity of a specific nutrient.[34]

Perhaps Boysen-Jensen was right. Perhaps Mitscherlich's production curve did not clarify how the limiting of a specific nutrient influenced plant production. However, that did not stop the National Socialist four year plan, American agrobiology, I.G. Farben, and the German potash syndicate (*Kalisyndikat* from using this humble equation for their own ends. Or perhaps it was the equation that used them. After all, from the ashes of Nazi Germany's sordid *Götterdammerung*, the production curve emerged unscathed to find its way into global production ecology.

[34]"Man hat versucht, mathematische Annäherungsformeln für solche Ertragskurven darzustellen (vgl. namentlich das Wirkungsgesetz der Wachstumsfaktoren von Mitscherlich-Baule). Bekanntlich liegt über diese Fragen eine sehr umfassende Literatur vor, auf die ich nicht eingehen möchte. Wie oben bemerkt, können solche mathematischen Formeln vielleicht praktisch brauchbar sein; sie vermögen aber nicht zu erklären, in welcher Weise die Pflanzenproduktion durch Mangel an einem bestimmten Nährstoff beeinflußt wird."Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, p.105

Technocracy and the Agrobiologist's Dream

North America and Germany were faced with a series of similar, and globally interconnected problems, between 1929 and 1939. Both societies were hit by the global financial crisis that originated in America. Both knew that war was looming, although Germany knew a little more than most other players. And both were faced with severe food shortages. In North America's case, the ecological catastrophe of the Dust Bowl synchronized perfectly with the economic catastrophe of the Great Depression. In Germany, on the other hand, the perennial problems that the most populous country in Europe (outside Russia) had in feeding its population were amplified by the Depression. In Europe, socialism and fascism had vied for dominance as novel political solutions to the unique problems faced by densely populated and heavily armed countries sharing the Eurasian peninsula while exerting direct imperial control over African and Asian colonies since the First World War. With the onset of the Depression and the rise to power of a fascist one-party state in Europe's largest economy, the potential solutions offered by these political experiments became increasingly radical. In North America, on the other hand, the possibility of either a socialist or fascist takeover was a distant one. This left open the question of what would fill the void when the existing conservative, laissez faire, and isolationist regime of the 1920s proved wholly inadequate to addressing the problems introduced by 1929. A Keynesian welfare state with a highly militant and interventionist foreign policy ultimately took shape, and survived in a gradually mutating form for the rest of the century (with the Keynesian component following the German path of state-sponsored armaments production in wartime, and never really demobilizing). However, there were other options, even if they remained untaken.

The obscure political movement known as Technocracy Incorporated never gained much traction in the halls of power. However, it illuminates several distinctive features of the North American political situation during the Depression that distinguished it from the German. These distinctive features include a cynicism about military action abroad and a strident disdain for both socialism and fascism (and other products of the "old world"). The American Technocrats shared the Nazis' faith in science and technology, as well as their nationalist belief in their nation's unique destiny. However, they did not indulge in their virulant racism or their romantic idealization of warfare. Rather, the Technocrats were relatively pacific and believed that in order for America to whether the crisis of the 1930s and emerge as the pinnicle of western civilization, they must refrain from unnecessary foreign entanglements. Although Oswin William Willcox, the production curve's primary American conduit, was not a member of Technocracy Inc., he shared many attitudes and ideas with them. Yet he also diverged in a number of crucial ways. Firstly, he was an isolationist and a pacifist, while the technocrats, as skeptical as they were about the specifics of America's interventionist foreign policy following the German invastion of Russia, supported a powerful American military. Secondy, the Technocrats believed that limitations on natural resources had little to do with poverty and hunger, at least in North America, which they saw as exceptional. Finally (although this difference points to their deeper similarities) the Technocrats thought that the American economy should be turned over to engineers. Willcox, on the other hand, seemed to thing that it was the role of quantitative agronomists to shepard North American (and global) society towards a more rational and equitable productive system. Yet like the technocratic authors, who included the young geologist M. King Hubbert, later orignator of the Peak Oil hypothesis, Willcox offered up scientific solutions to political and economic problems in the public arena. While Mitscherlich published primarily for an elite scientific audience, despite his considerable engagement with social questions, the technocrats and Willcox occupied the role of pragmatic public intellectuals. Therefore, to help illustrate the unique features of the scientific reaction to the Great Depression in America that laid the groundwork for the quite different career of the production curve their, a detailed examination of a few case studies from the odd political career of Technocracy Inc. is in order. Then we will see how the production curve adapted itself to the American environment through the vector of O.W. Willcox.

Given that Mitscherlich and Willcox's work in quantitative agronomy would quickly become relevant to quantitative ecology, and this movement is one of the many important lines in the twentieth-century history of that heterogeneous discipline, it is worth noting that the relevance of the "technocratic optimism" embodied by Scott and his followers for the postwar development of systems ecology has previously been studied. The historian Peter Taylor suggests that the spirit of Technocracy Inc. was emblematic of a deeper American "political fantasy," of which the founding Anglo-American systems ecologists of the 1940s and 1950s, G. Evelyn Hutchinson and Eugene Odum, would later partake:

> In Howard Scott's words, technocracy alone offered life. Technological development had made the Technocratic social order possible- vast increases in energy utilization allowed Technocracy to promise a short work week for all. At the same time, technological change had made a new order necessary: industrial production had become so complex and interdependent that the failure of any one component could disrupt the entire "machine."

> In fact, the Great Depression and idle productive capacity proved to the Technocrats and their supporters that the organization of industry had broken down. Only a cadre of engineers using scientific principles could solve the technical problem of restarting and running the industrial machine at maximum efficiency. ...H.T. Odum, like Howard Scott before him, had a vision that reduced the complexity of social and ecological relations to a single energy dial for the social engineers to adjust. In his high-quality, low-energy circuits Odum had found "in nature" a special role for systems engineers, working in the service of society.[35]

Odum's 1956 work on *Primary Production in Flowing Waters* would become a key node in the network of relationships that created quantitative production ecology, a network whose origins in economic crisis and war are being examined here.[36] For now that is all that need be said.

In 1938, one of their numerous anonymous pamphlets (some had attributed authors as well) declared that

> Even with the crude agricultural methods now in general operation, we are able to produce more food in the United States and Canada than we can distribute under the Price System. Only by giving away vast quantities to foreign continents, and by allowing still greater quantities to go to waste, have we been able to hold the surplus abundance down to the capacity of our storage facilities. If only a few of the new machines and processes now invented were put into general use, the political guardians of

[35]Peter Taylor. "Technocratic Optimism, H.T. Odum, and the Partial Transformation of Ecological Metaphor after World War II". in: *Journal of the History of Biology* 21 (1988). technocracy inc., pp.234,241

[36]H.T. Odum. "Primary Production in Flowing Ocean Waters". In: *Limnol. Oceanog.* 1 (1956)

> scarcity would really have something to worry about.[37]

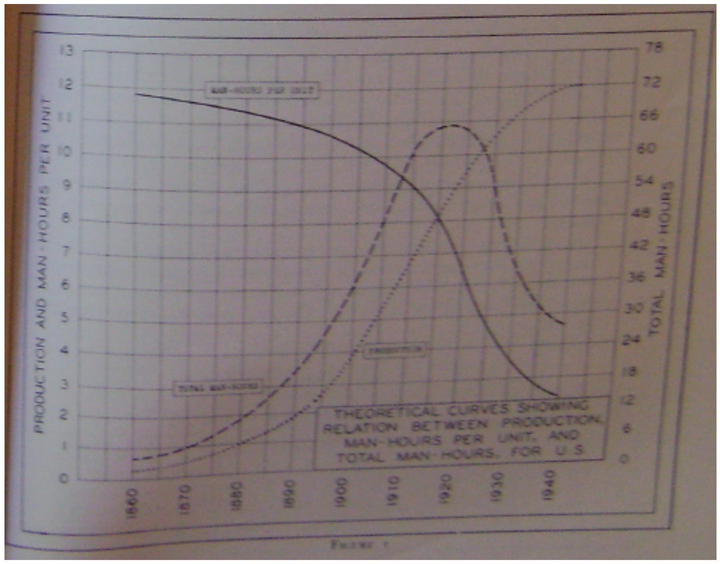
For the Technocrats, it was not that there was not enough food to go around (never mind the food availability constraints placed on America and Canada by the draught-driven collapse of Great Plains agriculture). Nor was it that agricultural and industrial production were destroyed and shipped over seas because North American citizens already had all the food and durable goods they needed. "Rather," they declared, "people do not have the means to purchase what they want."[38]

This viewpoint highlights a distinction between social scientists and natural ones, between those who quantify economic production and those who quantify ecological production. It is a distinction which will become increasingly important as the story of primary production's journey from the Great Depression through World War II to the postwar American-led neoliberal empire progresses. By looking to social causes, such as market price, rather than environmental constraints to explain production limits, Technocracy Inc.'s founder, Howard Scott, fit himself into a tradition stretching back through Karl Marx to Adam Smith and David Ricardo. More immediately, Scott took inspiration from the brilliant Norwegian-American institutional economist Thorsten Veblen. Howard Scott was an engineer of questionable repute whose Come to Jesus moment had arrived in the unlikely shape of Professor Veblen in 1918. Before that, he had worked for the Air Nitrates Corporation during World War I, producing one of Mitscherlich's muses, nitrogen fertilizers, using energy derived from the newly constructed Wilson Dam. Built by the American government's Muscle Sholes project over the Tennessee River in Alabama, the Sholes project was an important precursor to the massive construction projects of President Roosevelt's New Deal. Indeed,

[37]Technocracy. *America Must Show the Way!* Technocracy Inc.t, 1938, pp.7-8
[38]Technocracy, *America Must Show the Way!*, p.10

it would eventually be absorbed into the Tennessee Valley Authority in 1933, the year both Hitler and Roosevelt took power. Ironically, despite his zealous committment to engineering efficiency, "a federal government inspector alleged that the crew under Scott's direction had been responsible for gross waste, inefficiency, and shoddy workmanship."[39] Another engineer who had worked alongside Scott on nitrate production considered him to be "a strange character who insisted on packing a gun and who talked so strangely that the other workmen complained he was a German spy."[40] After World War I, Scott moved to New York where he encountered Veblen, then teaching at the New School for Social Research. There he successfully failed to sustain a business manufacturing floor wax.[41] Veblen and his work on *The Engineer and the Price System* pulled Scott from the ashes of a failed engineering and entrepreneurial career. He found his purpose in life: to enlighten the masses as to the uselessness of market pricing for rationally allocating goods, and pave the way for the general ascendence of engineers to control over the economy. Fresh out of graduate school at the University of Chicago, and beginning postdoctoral research at Columbia University, the geophysicist M. King Hubbert came to know Howard Scott as his roommate in the early 1930s. The geophysicist with an interest in economics and the engineer with an interest in physics made an interesting pair. By 1948, Hubbert would have moved beyond the Technocrats' view that it was the price system, and not real resource constraints, that led to inefficient distribution. At that point, his mispent youth as a technocratic revolutionary had been eclipsed by work as an analyst for the Board of Economic Warfare during the 1940s, and then a career as a prospecting geologist for Shell Oil.

[39] William Akin. *Technocracy and the American Dream.* University of California Press, 1977, p.28 Akin's monograph is the definitive source on the weird history of Technocracy Inc.
[40] Akin, *Technocracy and the American Dream*, p.28
[41] Akin, *Technocracy and the American Dream*, p.29



Man Hours & Distribution, 1940 (from M. King Hubbert. *Man Hours and Distribution.* Technocracy Inc., 1940, p.9)

However, in 1940, he was still a loyal follower of Scott's Technocratic agenda. A pamphlet on *Man Hours and Distribution* lays bear the relationship between the solution the Technocrats presented to the problems of the 1930s, those offered by Mitscherlich and the Nazis, and those put forth by Mitscherlich's American disciple Willcox. Before moving on to Willcox's pacifist application of the *Produktionskurve*, a discussion of Hubbert's work for the Technocrats is in order. 1940's pamphlet *Man Hours and Distribution* is a perfect example of this.

Hubbert started with an assumption not entirely alien to Mitscherlich or Willcox, and quite in line with Scott's thinking. Namely, that productivity was potentially much higher than what was being realized, and that inefficiency and a lack of scientific acumen on the part of political elites was to blame for the crisis of production experienced across every economic sector in Germany and North America during the 1930s. However, he differed from the agronomists in that it was not a direct application of technology (in their case, synthetic fertilizers) that was the solution to the production crisis. Rather, Hubbert suggested that the limits on agricultural and industrial productivity, were in fact the result of a defective social system- capitalism- and an essentially supersitious mechanism of distribution-the price system. Indeed, although the Technocrats had boundless faith in technology's potential to solve the crises of the 1930s, Hubbert suggested that within the confines of a fundamentally irrational labor regime, increasingly rational and efficient production techniques were actually a key part of the problem. This was due to the fact that in a capitalist society, where natural scientists and engineers like himself were relegated to middle management and advisory roles, "it is contrary to the will of God that man should receive something for nothing, for the unemployed to receive relief without working for it, it manifestly becomes necessary that work be provided for which wages can be paid."[42] For Hubbert, the crisis of the 1930s was the result of overproduction and underemployment. This was ultimately due to three main factors, two related to dynamic and potentially irreversible processes, and the third to the changing nature of ownership over the means of production. The first was increasing technological efficiency, which allowed more to be produced for a given unit of labor, here quantified as a man-hour. Hubbert drew most of his examples from the manufacturing industries, but his arguments extended to agriculture and (his long-term bread and butter) extraction. The second was increasing population, which increased demand but only further diminished the percentage of the total potential labor supply actually employed by capital. Finally, there was the increasing conglomeration of industry in the hands of fewer and fewer owners.

This final mechanism meant an increasingly large percentage of an increasingly

[42]M. King Hubbert. *Man Hours and Distribution.* Technocracy Inc., 1940, p.20

large human population was systematically pushed out of the ownership class and into the ranks of the would-be laborers. This concern with the effect of industrial conglomeration on the demand for labor was a reaction to changes in the organization of capital that had swept Europe and America since the Second Industrial Revolution. As we saw back in Germany, cartels were a key mechanism by which both the German chemical industry and the country's extraction industries (iron, coal, and potassium salts) maintained a leadership position in international export markets. Two of these cartels, IG Farben and the German Potash Syndicate, were major patrons of Mitscherlich's Great German Soil Fertility Survey. Once closed off from most world export markets by the onset of hostilities with England in 1939, Germany's cartels not only survived but prospered by Closer to home, Willcox had examined the potential for industrial self-government in the sugar industry, and the tendency of unregulated industries to cartelize.[43]

The first two mechanisms by which the man-hours per unit of production were systematically being reduced were not part of any kind of cyclical trend. This is important, both from the standpoint of Hubbert's approach to the worldwide depression's effect on North America, and Mitscherlich's attempt to deal with the similar economic problems faced by Germany. For Mitscherlich, his *Produktionskurve* trended sharply upwards, suggesting "that one could increase our plant yields in the agricultural economy [*Landwirtschaft*] by 50% to 100% solely through the sufficient application of fertilizer."[44] Through the application of agronomic science and the synthetic and mineral products of German industry, the German agricultural economy could escape the cycles of near-famine that had bedeviled it since unification in 1871. In the deceptively humble form of a steeply sloping upward curve, Mitscherlich held out the

[43] O.W. Willcox. *Can Industry Govern Itself?: An Account of Ten Directed Economies.* W.W. Norton, 1936

[44] Mitscherlich, "Das Ergebnis von über 27000 Feld-Düngungsversuchen", p.22

promise of dynamic growth in the agricultural sector. For Hubbert, it was this very technological dynamism across all sectors of production that had created the present crisis of unemployment. In Germany's case, the irrational logic of the price system, which allocated goods only through monetary exchange, while the same capitalist social order mandated increased productive efficiency at all costs, was not a problem. After all, Germany had embraced military Keynesianism before any other country in Europe or North America, subordinated private industry to the goals of the state, relegated the profit motive to a junior status in relation to the conquest of western Eurasia, and instituted a buildup to a full war economy that would create sufficient domestic demand for labor regardless of technological increases in efficiency. Indeed, come 1939, the labor supply of the youngest and strongest workers would be increasingly squeezed by the limitless demands of the *Wehrmacht* for more soldiers. Following the conquest of France, Germany's home population, large as it was, could not possibly satisfy the domestic labor demand created by its relentless war production (which extended far beyond the armanents industries, as pointed out above food and fertilizer production were at least as crucial to the war effort as guns and tanks). As a result, writes economic historian Adam Tooze,

> Since the Nuremberg tribunal introduced the term 'slave labour' into the discussion, [Nazi Foreign Labor Minister] Sauckel and his programme have been variously described as 'millennial' and 'Pharaonic.' Such terms certainly capture the increasingly brutal means to which Sauckel resorted in recruiting 'his' workers. But such anachronistic language also tends to obscure the fact that Germany's programme of foreign labour conformed to the most elementary principles of classical economics. Labour had been

> desperately scarce in Germany since 1939. Per capita productivity was far higher in Germany than anywhere else in continental Europe. It made sense, therefore, for a 'rational economic dictator' to redeploy the workers of Europe so as to concentrate them in the factories of the Reich. The fact that Sauckel, with his woolly National Socialist rhetoric, did not conform to the ideal type of the technocrat should not obscure the basic rationality that underpinned his efforts. ...In economic terms, given the desperate shortage of labour in Germany and the ever-increasing productivity gap between Germany and the collapsing economy of France, the case for concentrating as many wokers as possible within the Reich remained strong.[45]

So, while Germany's high productivity only created a greater demand for labor, this does not obviate Hubbert's 1940 analysis. Germany had, by 1939, ceased to resemble a traditional capitalist economy with market allocation through a price-system. The Technocrats reserved a venom for Fascism that even capitalism did not earn, however, they did not seek a cessation of the development of the technologies that had led to such increased productivity and decreased employment. Rather, they sought to allow the engineers who had developed the technologies to create a more rational social order in which those technologies could be implemented. Otherwise, there was no hope, because just as with Mitscherlich's dynamically optimistic *Produktionskurve* shooting towards a sky filled with endless food (and endless fertilizer), and just as with the German war economy's ever increasing labor demand, increasing productivity per man hour was an inevitably upwards trending curve:

> It cannot be emphasized too strongly that the trends we are

[45] Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy*, p.518

> describing [technological improvement and domestic population growth] are long-time trends and were thoroughly evident prior to 1929. These trends are in no way the result of the present depression, nor are they the result of the World War. On the contrary, the present depression is a collapse resulting from these long-term trends. It is further to be emphasized that there is nothing in any of these trends corresponding to the economists' concept of a 'business cycle.' The steady growth of population and the steady decline of man-hours per unit are both *non-cyclical phenomena*[my emphasis], and they do not repeat themselves. Neither has the mean growth of production exhibited any repetitions, nor has the curve of total man-hours, other than by minor zigzag oscillations. It rose steadily to a maximum and then steadily declined. We would like to emphasize that this ensemble of events has only occurred once in American history and, furthermore, it is absolutely certain that it will never occur again. Consequently all interpretations of the present situation as merely a recurrence of a situation that has been happening at intervals in the past, are basically fallacious and worthy of no serious consideration.[46]

This bore a striking resemblance to Hubbert's treatment of the history of human energy use eight years later, where he declared "our present position on the nearly vertical front slopes of these [energy production] curves is a precarious one, and that the events which we are witnessing and experiencing, far from being 'normal,' are among the most abnormal and anomalous in the history of the world."[47] For now, it is important to note first that "the

[46]Hubbert, *Man Hours and Distribution*, p.18
[47]**hubbert1948**

economists' concept of a 'business cycle"' came in part from the work of Ernst Wagemann, head of the *German Institut for Business Cycle Research* (*Deutsches Institut für Konjunkturforschung*). Wagemann was a German technocrat of the Weimar and Nazi eras, whose work was important for both the practical quantification of Germany's national productivity (one of several prototype Gross Domestic Product measurements developed in the 1930s, with Jan Tinbergen's work in the Netherlands and the Russian-American Simon Kuznets's work in America being others), and for laying the theoretical basis for such national accounts.[48] Wagemann enjoyed an administrative authority that Scott and Hubbert could only dream of, although Hubbert would draw closer to power soon enough through his relationship with the Office of Economic warfare, followed by his work for Shell Oil. Second, Hubbert's concept of dynamic and unrepeatable changes as characteristic features of economic transformation, and his disdain for economic theories of cyclical change paralleled nascent debates in the ecological sciences. As detailed further in the next chapter, Frederic Clements concept of ecological changes as a series of predictable successional changes dominated American ecology in the 1930s, and heavily influenced German Plant Sociology, the European varient of Clements's sucessional ecology. In the schemes propounded by Clements and Germany's chief plant sociologist, Reinhold Tüxen, every plant community eventually reached a climax state, at which point dynamic change stopped. This was the ecological version of the business cycle, only with the promise that one day the booms and busts of history would end in a steady equillibrium. Heinrich Walter, the ecologist who transported Mitscherlich's

[48] Adam Tooze. *Statistics and the German State, 1900-1945: The Making of Modern Economic Knowledge.* Cambridge University Press, 2001 chronicles this history, Ernst Wagemann. *Konjunkturlehre.* Hobbing, 1928, Ernst Wagemann. *Struktur und Rhythmus der Weltwirtschaft: Grundlagen einer Weltwirtschaftlichen Konjunkturlehre.* Hanseatische Verlagsanstalt, 1931, and the English version Ernst Wagemann. *Economic Rhythm: A Theory of Business Cycles.* McGraw-Hill, 1930 are the relevant primary texts.

equation to the former German colony of Southwest Africa, and who will figure heavily in the next chapter, was an early critic of Clements and Tüxen's theories, especially as they were applicable to "wild" ecologies free from the long historical influence of human agriculture (such as the German forests studied by Tüxen and the North American praries to which Clements devoted his life). In the postwar world, the increasing influence of mathematical demography and Neo-Darwinism on the disciplines that make up ecology would lead to a tension between visions of "equilibrium" and those of "chaos" in complex multi-species systems that would animate much of ecological debate through the 1950s and 1960s. These struggles over struggle are the subject of Chapter 5, while the distinction between European plant sociology and quantitative ecology are discussed in the next chapter.

So, if Fascism and military Keynesianism were out of the question, what solution did Hubbert offer to the crisis of unemployment? Here, Hubbert evoked Technocracy's standard solution to all social problems, the organization of a Technate wherein the price system was replaced by alottments of energy certificates. Yet it getting to that conclusion, Hubbert developed a set of simple proportions that would not have been foreign to Mitscherlich, Blaauw, Boysen-Jensen, or Willcox. Underlying all this was a particular concept of energy as the ultimate unit for quantifying all human activity. However, in 1940, Hubbert remained trapped in the reigning economic paradigm which treated fossil fuel energy sources as essentially, a paradigm he would do much to challenge eight years later. Historian of the middle-east and the petroleum industry Timothy Mitchell has argued powerfully that the creation of modern macroeconomics by Keynes and others during the Great Depression was faciliated by the promise of limitless hydrocarbon energy. In Mitchell's argument, mid-century macroeconomics re-imagined the economy as a peculiar entity which

> could expand without getting physically bigger. Older ways of thinking about wealth were based upon physical processes that suggested limits to growth: the expansion of cities and factories, the colonial enlargement of territory, the accumulation of gold reserves, the growth of population and absorbtion of migrants, the exploitation of new mineral reserves, increasing volumes of trade in commodities. All these were spatial and material processes that had physical limits. By the 1930s, many of those limits seemed to be approaching: population growth in the West was leveling off, the colonial expansion of the United States and the European imperial powers had ended and was threatened with reversal, coal-mines were being exhausted and agriculture and industry were facing gluts of overproduction. The economy, on the other hand, measured by the new calculative device of national income accounting, had no obvious limit. National income, later renamed the gross national product, was a measure not of the accumulation of wealth but of the speed and frequency with which paper money changed hands. It could grow without any problem of physical or territorial limits.[49]

Therefore, it remained only to quantify the energy inputs and outputs of a single human laborer. Potential restraints on energy supply, and thus on the fuel of economic growth, did not need to enter into Hubbert's equations in 1940. Unfortunately for humans, it turned out they were dreadfully energy inefficient relative to machines. One kilowatt hour, by Hubbert's calculations, cost one cent while outputting 13 times the energy of a man hour. Yet even at

[49] Mitchell, *Carbon Democracy: Political Power in the Age of Oil*, pp. 417-418

$$c = \frac{i}{p} = \frac{w}{e}$$

Consumption is Income is Man-Hours, 1940

25 times the cost of the kilowatt hour, the human laborer was being paid below the poverty line. Inexpensive energy would thus limit the demand for labor, and in doing so limit economic consumption. Hubbert showed this with one of several similar equations, where c is consumption, i is income, p is price per unit, w is wages, and e is total man-hours.

Thus, in Hubbert's scheme, the limits to the growth of a capitalist economy would always be set by the limits of labor demand, as declines in total income would equate to declines in consumption. However, the solution was a simple one: the price system could simply be recognized as the fundamental fiction that it was, and replaced with a system where everyone received equal allocations and did equal work, which, given technological increases in productive efficiency, shouldn't be much more than four hours a week. Again, the fictional nature of the price system could be exposed with a bit of energy accounting. The price system rested upon the lie that "somehow a man is able by his personal services to render to society the equivalent of what he receives, from which it follows that the distribution to each shall be in accordance with the services rendered and that those who do not work must not eat."[50] The truth was, "it costs the social system on the North American Continent the energy equivalent to nearly 10 tons of coal per year to maintain one man at the average present standard of living, and no contribution he can possibly make in terms of the energy conversion of his individual effort will ever repay the social system the cost of his social maintenance."[51] While some humans do very little work and receive more energy than others who work very hard, it is physically impossible for a human being to output as much energy as it

[50] Hubbert, *Man Hours and Distribution*, p.27
[51] Hubbert, *Man Hours and Distribution*, p.28

takes to sustain him. After all, "man is an engine operating under the limitations of the same physical laws as any other engine. The energy that it takes to operate him is several times as much as any amount of work he can possibly perform. If, in addition to his food, he receives also the products of modern industry, this is due to the fact that material and energy resources happen to be available and, as compared with any contribution he can make, constitute a free gift from heaven."[52] But of course, M. King Hubbert did not really believe in heaven, any more then the Nazis. When he referred to "a gift from heaven," what he really meant was that "since also the energy-cost of maintaining a human being exceeds by a large amount his ability to repay, we can abandon the fiction that what one is to receive is in payment for what one has done, and recognize that what we are really doing is utilizing *the bounty that nature has provided us* [my emphasis].[53]

For the Nazis, their heaven would arrive on earth in the form of a pan-Eurasian slave empire. For Hubbert and the Technocrats, the far more magnanimous vision of a Technate, run by engineers and scientists, was the promise held out by a successful solution to the crises of the 1930s. In this Technate, each would work only the minimum actually required for the continued functioning of the social organism. They would receive an energy certificate, redeemable for those goods necessary to live a comfortable life. Citizens of the Technate would work between 25 to 45, but would have a guaranteed income for the duration of their metabolic functioning. The certificates would be ascribed a value only at the point of purchase, and would be null and void at the end of the year, and therefore impossible to accumulate. The certificates would not be in exchange for their labor, but rather would be given in the same spirit as that labor, as a way of insuring

[52] Hubbert, *Man Hours and Distribution*, p.28
[53] Hubbert, *Man Hours and Distribution*, p.28

that "the entire social mechanism then becomes one unit organization with as many branches as there are industrial and social functions to perform."[54] That social mechanism would compromise "all members of the population. The area to be operated as a unit is the entire Continent of North America."[55] If the Technocrats shared little with the Nazis but a vaulting ambition to unify society under a new form of organization that would render it impervious to the tumult that had engulfed the world between 1914 and 1939, they had perhaps a bit more in common with O.W. Willcox's ambition to employ quantitative agronomy to create a more peaceful world. However, while Willcox would certainly agree that consumption was linked to "the bounty that nature has provided us," he disagreed about the size of that bounty and its role in constraining economic growth and determining geopolitics. Now that we have some idea of the nature of the scientific public sphere in Depression-era America, and the attempts by the public intellectuals who inhabited it to solve an unprecedented global crisis, albeit theoretically, we can turn to Willcox's role in reinterpreting Mitscherlich's research for a North American context.

Oswin William Willcox agreed with the Technocrats that a pure market organization of the North American economy was insufficient to the demands of the present crisis. However, he did not agree that such a market was in existance at all. For Willcox, his concern was with the solutions he perceived as being offered by industry itself. In a time and place soon to come, the Iowa agronomist might be called a neoliberal: one who believes in the capacity of private industry and the magical workings of the market to most efficiently allocate goods, but supports the creation of a society in which this market can function optimally through state intervention. Like the Technocrats, he felt

[54]Hubbert, *Man Hours and Distribution*, p.29
[55]Hubbert, *Man Hours and Distribution*, p.28

that overproduction was at the root of the Depression. Moreover, he agreed that technical advances were more than adequate to the task of satisfying the consumptive needs of the world's existing population. However, like Mitscherlich, he did not feel that a revolution in the current social organism was necessary to create the conditions needed to rationally allocate this overproduction. And, like Mitscherlich, whose work Willcox held up as a model for the future of agronomy, he did not see the political system of Nazi Germany as an impediment to rational allocation. For Willcox, private capital could govern itself through cartelized proration (by which he meant simply the management of production so as to avoid unneeded surplus) so long as the surrounding political unit respected private property. In the case of Soviet Russia, this was impossible despite its holding one of "the principle divisions of the Caucasian race" due to Bolshevism's partaking of an "Oriental" rather than an "Occidental" civilization. However, "even in Nazi German and Fascist Italy the farmer is left in ownership and operation of his far; the industrialist remains in possession of his factory and is still financially responsible for its sucessful operation. Both the farmer and the industrialist are entitled, by the basic laws of all these lands, to indemnification if the state exercises its paramount right of eminent domain."[56]

Making reference to the sugar industry, one Willcox had extensive experience with in his agronomical work, and using it as a model of how capital could control its own overproduction, Willcox summed up the Malthusian state of 1936 Germany:

> The German nation now occupies a territory of about 186,000 square miles, with a population of about 65 million. The extent of arable land is about 50 million acres, exclusive of grass land; this

[56] Willcox, *Can Industry Govern Itself?: An Account of Ten Directed Economies*, pp.17-18

figures less than one acre of cultivated land per inhabitant, which means that the German people cannot be maintained on a high level of comfort on their own agricultural produce; we have previously referred to the estimate of sociologists that the maintenance of a reasonable standard of living requires somewhat more than two acres per person. Extra food, especially products that would give a varied and balanced diet; must therefore be importated, but in recent years the Germans have found it increasingly difficult to procure foreign credits with which to finance imports, and in consequence the average German standard of living has sunk to an uncomfortable level.[57] This perception of Germany's food situation did not differ much from either that of the Nazi Agricultural Ministry, or that of modern economic history:

> ...Hitler's obsessive preoccupation with food was rooted in contemporary reality. Though famine had been banished from Western Europe in the second half of the nineteenth century, in large part due to Europe's ability to tap huge new sources of overseas supply, World War I had forced the question of food supply back onto the agenda of European politics. The British and French blockade, though it failed to produce outright famine, did succeed in producing an epidemic of chronic malnutrition in Germany and Austria that was widely blamed for killing at least 600,000 people. Depression and mass unemployment brought a return of serious deprivation. And even in good times, at the the bottom of the social

[57]Willcox, *Can Industry Govern Itself?: An Account of Ten Directed Economies*, pp.178-178

> scale chronic malnutrition was widespread in Germany as it was in every other European society in the early twentieth century. One way or another, *virtually everyone alive in Germany in the 1930s had an acute personal experience of prolonged and insatiable hunger.* Nor was mass starvation a distant threat confined to Africa and Asia. On Germany's eastern borders in the early 1920s, the turmoil of war, revolution and civil war in Russia, Poland and the Ukraine had precipitated an agricultural disaster, which by 1923 had claimed the lives of perhaps as many as 5 million people.[58]

Indeed, as Adam Tooze shows, the presentation of the Nazi obsession with living space as backwards and atavistic was self-serving from the standpoint of the victors of World War I. Britain and America divided the vast agricultural inland regions of North America between themselves, and the former had privileged access to Australia and India to boot. Even France, the least expansive of the three major western allies, controlled the second largest of the overseas European empires and a homeland with fewer people and more arable land than Germany. And despite the global prominence of its manufacturing industries, most importantly the chemical sector discussed above, much of Germany's population remained tied to the land. Close to 30% of the German workforce was absorbed in the agricultural sector in 1933, while over 50% of the population lived in country towns of 20,000 or fewer people. Moreover, half of that 50% lived in towns

[58] Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy*, p.168

of 2,000 or less.[59] Issues of food production could not be divorced from issues of land supply in 1930s Germany. However, Mitscherlich's *Produktionskurve* promised a way out of the land-hunger trap through the systematic application of synthetic and mineral fertilizers. Yet, once embedded in a social organization capable of implementing the nationwide agricultural experiment necessary to substantiate Mitscherlich's theory, this dream of autarky took on a life of its own. What could have been the promise of a peaceful world where conflict over *Lebensraum* had been obviated by chemically enhanced yields, instead became evidence that Germany could produce enough food at home to temporarily survive the inevitable blockades and deprivation that would accompany their second attempt in a generation to forcefully dominate western Eurasia.

Willcox agreed with the Nazi assessment of Germany's unfavorable land-to-population ratio. And he fully embraced the *Produktionskurve* as the future of agronomic science. Yet, just as Keynesianism failed to take hold in England, Mitscherlich's teachings were not being sufficiently applied in the land of their birth. The Nazi state had the power to institute a massive test of Mitscherlich's theory, but not, in Willcox's estimation, to actually reform the agricultural sector in accordance with his insights. Thus, just they had been in 1914, Germany was faced with

> World power or downfall! Such is the sinister option that confronts a hemmed-in population when it has been ushered across the threshold of Malthusianism by its too

[59]Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy*, pp.167-69

> great multiplication on the one hand, and the bankruptcy of its agronomic science on the other hand. It is an option that cannot fail to arise sooner or later, whenever, for the vitals of its existence, a nation ceases to depend mainly on the resources under its control, and comes to place its trust in means controlled by or exposed to the domination of others. A social-economic structure built on an unstable foundation of foreign trade is subject to collapse under the pressure of foreign entities that also have to exist, and are perhaps themselves in the same perilous situation. O.W. Willcox. *Nations Can Live at Home*. George Allen & Unwin, 1935, pp.207

Yet even with a scientific application of fertilizers sufficient to allow Germany pacific autarchy, there was another variable that would constrain their food production without a rational re-allocation of resources: "But there is one detail that will bear emphasis whenever the quantitative relation of population to arable land comes up for consideration," Willcox continued, "and that is the efficacy of water as a promoter of national self-sufficiency."[60] If this limiting factor was a concern, due to insufficient distribution and the increased hydration needs of the more productive agriculture that Willcox foresaw, in the rain soaked lands of central Europe, then it was an even greater concern in *Produktionskurve*'s next port of call: the deserts of Southwest Africa, once a German colony and now the target of Nazi ambitions, and Libya, a place which would, before the coming war was done, become the site of

[60]Willcox, *Nations Can Live at Home*, pp.219-20

Germany's last desperate attempt to win the war by cutting Britain off from its petroleum lifeblood.

Chapter 3

The Territory of Fables: Ecological Productivity in Nazi Germany's Imaginary Empire

All of our cultivated plants respond to nutritional assimilation and nutritional utilization in regards to producing yield in exactly the same ways! For example, there is no plant that uptakes the earth's phosphoric acid better than any other! This view belongs to the territory of fables.

-Eilhard Alfred Mitscherlich, 1947[1]

[1] Mitscherlich, "Das Ergebnis von über 27000 Feld-Düngungsversuchen", p.34

The ecologist Heinrich Walter arrived in Southwest Africa in 1941, at the outset of an age which would see the world's deserts metastasize in reaction to the increasing thirst and hydrological ingenuity of a growing human population. Aridity was an environmental dilemma wholly unlike any confronted at home in the German homeland. Germany suffered from many restrictions on its own productivity. It was unable to adequately feed its own population due to limited land. It was unable to fuel its own factories and military by 1941 due to limited coal, oil, and iron. Yet Germany did not want for water. In the absence of *Homo sapiens*' parasitism, all of central Europe should have been a giant temperate forest, as the Potential Natural Vegetation maps of Reinhold Tüxen's *Zentralstelle für Vegetationskarte* would show. Comparing Germany to the lands it coveted, its temperate ecology was not as wet as the tropical environs of the Brazilian Amazon, yet nowhere near as dry as the sands of the Sahara and its bordering grasslands to the south, or the rolling Russian Steppes to the east. At home, Mitscherlich's primary concern had been food restraints, and he sought to demonstrate how resources Germany had in abundance, synthetic chemicals and mined potassium salts, could be used to increase agricultural yields. Water never entered into the equation.

The *Produktionskurve*'s move from domestic German and American agronomy to arid ecology was facilitated by Nazi imperial interests. At home, the curve promised a bountiful future of adequate food supplies. For the American agronomist O.W. Willcox this meant a more peaceful future. For E.A. Mitscherlich's patrons in the state and in the chemical and mining industries, it meant synthetic and mineral fertilizer sales and a sustainable *Blitzkrieg* across Europe. Yet the Nazis' hopes and dreams did not stop in the fields of Europe. Once they made short work of the French, British, and Russians, they hoped to extend their imperial grasp to the colonies of their defeated enemies.

In the beginning, their Japanese allies would be more successful beneficiaries of this strategy than the Germans. As Holland and France fell quickly before the German onslaught of 1939, and Britain saw itself besieged by the *Luftwaffe* after being driven off the continent at Dunkirk, the Dutch East Indies, French Indochina, and British-controlled Burma and Malaysia were absorbed into the "Greater East Asian Co-Prosperity Sphere." But the Nazis were nothing if not enthusiastic about the long-term prospects for a German empire capable of dismantling the old British system, and standing toe-to-toe with the rising North American hegemon. From their standpoint, absorbing Austria and conquering eastern France was but the beginning of the irredentism necessary to amend the Versailles settlement. 1918 had also deprived Germany of its moderately vast and slightly world-straddling overseas empire. German Southwest Africa and German East Africa (today Namibia and Tanzania) had gone to the British, Cameroon to the French, and Togo was split between the two. These were convenient additions to the British and French African empires. In Asia, Japan assumed control over the German leasehold in China's Shandong peninsula.

Yet before the Nazis could take to reconstructing and expanding their pre-1918 colonial empire, a little reconnaissance was necessary. This reconnaissance would be practically useful when it came time for the German military to occupy South Africa. However, it was also useful to the narrative maintained by German society from the summits of political and military power, on down into the streets. Unable to deploy serious military manpower, food, and equipment to the far reaches of Germany's imaginary empire, the Nazis settled for sending their biologists and geographers. To Brazil, they sent the biologically trained SS officer Otto Schulz-Kampfhenkel. To Southwest Africa, the plant physiologist turned quantitative ecologist Heinrich Walter. Schulz-Kampfhenkel went at the behest of Heinrich Himmler. Walter went in service to science, particularly to seek a better understanding of the factors influencing primary productivity in a non-agricultural ecosystem.

The two would later find their interests converging in the Libyan desert. There, Walter continued a fascination with the restraining roll of water on plant growth that went back to his laboratory bench days. Schulz-Kampfhenkel, having concluded that the Nazi conquest of the Amazon might have to wait a few years, turned the aerial mapmaking skills he honed on the world's largest river in its largest forest to a considerably less wet and less green place. Yet what Libya lacked in water and soil resources it made up for in its strategic proximity to the Suez Canal, the key transport route for British oil. Moreover, it provided terrain wonderfully well suited to the movement of tanks and horses, two crucial components of the German martial organism.

The circuitous route of this variant form of what Peder Anker termed "imperial ecology" eventually returned to the most immediate target of Nazi colonial dreams, eastern Europe.[2] This is the subject of the next chapter. However, on the way there, the curve was fundamentally transformed. What originated in Germany and America as a tool for quantifying the proportional relationship between fertilizer inputs and domestic crop outputs had become a tool for testing the water needs of wildtype plants in biological communities far beyond the metropole. An agronomic theory became an ecological one, and the particular form of ecology under consideration was, like its British counterpart developing synchronously, resolutely global. This transformation of provincial agronomic science into global ecology was not due to any profound cosmopolitanism. Indeed, like the global system that would follow the denouement of Germany's imperial hopes, it was the product of extreme cultural chauvinism and a violent program for remaking the world in the image of a single national superpower. Yet it was paralleled by a similar transformation within holistic biology, which moved from "plant sociological" studies of discrete units of temperate vegetation within Europe, to far more ambitious quantitative and causal ecological studies of the multi-species biological systems beyond the long-cultivated European soil. As the agronomic *Produktionskurve* became one of the theoretical instruments of ecological reconnaissance in Southwest Africa, provincial plant sociology (*Pflanzensoziologie*) gave way to global quantitative ecology. Along the way, the path of this humble proportional curve toured the sites of European imperialism's initial death throes. This tour brought German

[2] Anker, *Imperial Ecology: Environmental Order in the British Empire, 1895-1945*

ecology from sub-Saharan Africa, through the Middle East, and finally back home to Russia.

The Sociology of Plants

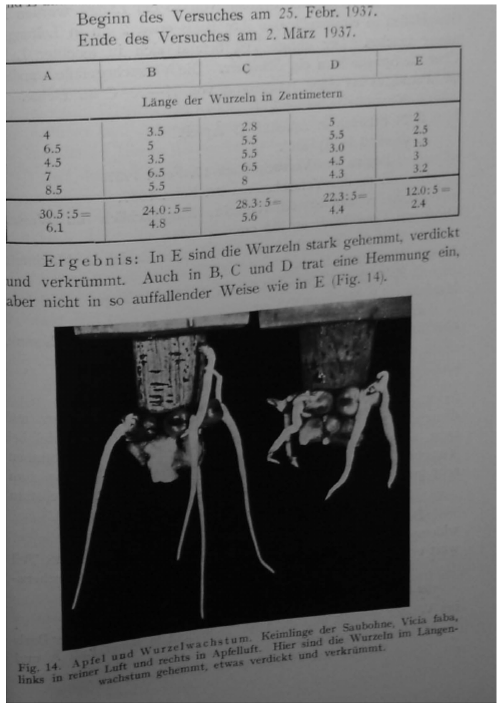
Like many other biologists in 1920s Germany, Heinrich Walter was trained in laboratory physiology. In this respect Walter was quite similar to Reinhold Tüxen, Germany's chief proponent of *Pflanzensoziologie*. Plant science faced a problem representative of the dilemma in front of the biological sciences as a whole in the first half of the twentieth century. Namely, how to free itself from the minimally predictive, minimally quantitative descriptionism and classification of natural history and taxonomy. The solution to this problem had existed in the realm of experimental physiology since the end of the nineteenth century. However, physiology introduced its own set of problems into the equation. Some of these problems had to be addressed within the laboratory itself. Especially in the study of plant life, so much of physiology remained shackled to subjective observations made by the experimenters. For scientists committed to a vision of experimental modernity which demanded the separation of the scientist's personality from their work through rigorous quantification, this was unacceptable.[3] H.L. Blaauw's phototropism work in 1909 and Peter Boysen-Jensen's *Stoffproduktion* work, contemporaneous with Walter's 1920s experiments, had represented an attempt to solve these problems from within the laboratory itself. One way to do

[3]Porter, *Karl Pearson: The Scientific Life in a Statistical Age* has defined modern scientific objectivity, as it emerged in the 1890s, in this way: as the complete removal of the scientist's personality from their work.

this was by adhering strictly to measurable units taken from the physical sciences.

While Walter worked within this tradition, problems remained for the adaptation of controlled laboratory experiments on single organisms to the study of complex interactions between many organisms in outdoor environments. In Boysen-Jensen's comprehensive 1932 study of CO^2 uptake and emissions discussed in the previous chapter, he had offered one possible solution. Boysen-Jensen integrated his laboratory experiments correlating CO^2 consumption with dry-matter (*Stoff*) production with longitudinal studies of the Lille Bøgoskov forest, as discussed in the last chapter. However, this only told the scientists how plants too large to fit in a petri dish assimilated a particular compound within a monoculture. Boysen-Jensen's ambitious long-term study of the Lille Bøgoskov forest was not that far off from Mitscherlich's shorter-term but wider spread study of the assimilation of different fertilizers by Germany's main crops, especially when one considers how thoroughly managed Denmark's forests had been for over 200 years.

Another option was to remain within the lab, and study interspecific relationships under its comfortably controlled conditions. In 1937, a year before the Nazi annexation of Austria, the influential University of Vienna physiologist Hans Molisch published a series of studies on what he termed "allelopathy." Here he attempted to examine the degree to which chemicals emitted into the soil and air by one plant could inhibit the growth of others nearby. Molisch believed, as did both Walter and Germany's



Beginn des Versuches am 25. Febr. 1937.
Ende des Versuches am 2. März 1937.

A	B	C	D	E
Länge der Wurzeln in Zentimetern				
4 6.5 4.5 7 8.5	3.5 5 3.5 6.5 5.5	2.8 5.5 5.5 6.5 8	5 5.5 3.0 4.5 4.3	2 2.5 1.3 3 3.2
30.5 :5 = 6.1	24.0 : 5 = 4.8	28.3 : 5 = 5.6	22.3 : 5 = 4.4	12.0 : 5 = 2.4

Ergebnis: In E sind die Wurzeln stark gehemmt, verdickt und verkrümmt. Auch in B, C und D trat eine Hemmung ein, aber nicht in so auffallender Weise wie in E (Fig. 14).

Fig. 14. Apfel und Wurzelwachstum. Keimlinge der Saubohne, Vicia faba, links in reiner Luft und rechts in Apfelluft. Hier sind die Wurzeln im Längenwachstum gehemmt, etwas verdickt und verkrümmt.

Plants Struggle Slowly, 1937 (from Hans Molisch. *Der Einfluss einer Pflanze auf die andere: Allelopathie*. Gustav Fischer, p.65)

political elite, that struggle was the organizing principle of every relationship, either within a species or against a common competitor:

> That there are in nature yet many other interdependencies between plants, such as the competition in the struggle for existence, for nutrition, for light, for air, and other factors, is generally known and in the books of Braun-Blanquet discussed in detail.[4]

Molisch was referring to the vision of community structure of the Swiss plant scientist Braun-Blanquet, Europe's most influential

[4]Hans Molisch. *Der Einfluss einer Pflanze auf die andere: Allelopathie.* Gustav Fischer, p.11

progenitor of plant sociology:

> A division into "accidental," without advantage to the individual organisms, and "essential," for the benefit of all the individuals or of some of them (Deegener), cannot be considered in the case of plants. The principles of usefulness, of division of labor, of conscious support, of marshaling all resources for the accomplishment of a common purpose do not exist in the plant world. The struggle for existence rules here undisturbed. It regulates directly or indirectly all the unconscious expressions of the social life of plants. Herein lies the deep and fundamental difference between the vital relations of plant and those of animal communities.[5]

Although the interaction between early ecology/plant sociology (functionally the same from a high enough vantage point, profoundly different from the magnification level of the practitioners of the time) and Darwinian theory was often somewhere between complicated and non-existent, Braun-Blanquet clearly saw "struggle" as an organizing principle of ecological relationships.

In the first half of the twentieth century, both physiological ecology and quantitative agronomy (or agrobiology) differentiated themselves from classical taxonomy and the newer discipline of *Pflanzensoziologie* (plant sociology) through their search for

[5] Josias Braun-Blanquet, George Fuller, and Henry Conard. *Plant Sociology: The Study of Plant Communities*. McGraw-Hill, 1932, p.5 is the contemporaneous English translation of the original German edition, Josias Braun-Blanquet. *Pflanzensoziologie: Grundzüge der Vegetationskunde*. Springer, 1928.

general principles. Physiological ecology sought to determine the global laws governing the relationship of plants and animals to their environments. This relationship was shaped by the incessant struggle for existence: for water, for food, for air, for offspring, and, especially important for photosynthetic primary producers, for light. The reader might recall Peter Boysen-Jensen's words from 1932 (Chapter 2): "the struggle of the suppressed trees for the necessities of life...it is in this struggle for vital conditions, that the [carbon dioxide] assimilation system, the condition for the *Stoffproduktion*, will function as long as possible."[6] Both militarist democracies and militarist autocracies could appreciate the role that endless competition played in shaping an organism's life, long or short. Just as importantly, physiological ecology held out the possibility of creating general principles that could guide the creation of global measurements of biological productivity. When thinking on the scale of continents, German leaders could not afford to be distracted by the details of individual and species-wide uniqueness. Nor could they worry very much about the local specificity of circumscribed regions, unless, of course, those regions were part of the unique and wonderful *Vaterland*. Therefore, *Pflanzensoziologie*'s vegetation mapping techniques, focused on small scales and community taxonomy, dominated at home. At the same time, physiological ecology's proportional relationships and large-scale maps of entire climatic zones dominated in the areas of eastern Europe and Africa that were soon to be integrated into the

[6] "der Kampf der unterdrückten Bäume um die Erhaltung des Lebens...es ist in diesem Kampf von vitaler Bedeutung, daß das Assimilationssystem, die Bedingung für die Stoffproduktion, solange wie irgend möglich intakt gehalten wird."Boysen-Jensen, *Die Stoffproduktion der Pflanzen*, p.75

Third Reich. Moreover, according to Walter, *Pflanzensoziologie* was perfectly adapted to the long-cultivated temperate zones of central and western Europe. It was less fit for the arid deserts and tropical rainforests of Africa, or the Russian Steppes. That was because *Pflanzensoziologie* sought to classify specific, clearly demarcated plant communities on the basis of their species composition. Similarly, classical taxonomy, a discipline originally founded in botany, had sought to classify specific, clearly demarcated species on the basis of the shared characteristics of their individual members. For Walter, the clearly demarcated communities that *Pflanzensoziologen* studied were a product of their own methods and the centuries-long process of cultivation and forest management that humans had imposed on the European land.

Walter and Tüxen would ultimately be bound together by their symbiotic relationship with the Nazi organism. However, as early as 1937, Walter was mounting a pointed critique of Tüxen's taxonomic plant sociology. This critique was based on his experience doing ecological reconaissance in Germany's imaginary empire, as well as on his abiding interest in the role of water limitations on plant growth. For Walter, while particular developmental tendencies could no doubt be observed in particular vegetational units, the "climax community" (*Klimaxgesellschaft*), upon which both European plant sociology and American ecology of the Frederic Clements school, depended, was a "purely theoretical construction."[7] This was because the climax depended upon a single stable state, at which point change ceases. In order

[7] **walter1937**

for a climax sequence to follow through, there must exist time periods for which a constant climate is certain, Walter pointed out. Yet, in the entire postglacial period, Walter continued, there has been no proof of a single successional series following through to a climax state. Like Hubbert in his mockery of the "business cycle" and the notion of cyclical recovery, or like Mitscherlich and Willcox in their belief in a steadily upward trending curve of food production, Walter saw in the world around him a process of ceaseless change. A notion of predictable successional stages heading towards a stable and unchanging climax state might be a useful model to hold up against actual ecological processes, but it as a description of reality it was sorely lacking.

More specifically, Walter took issue with Tüxen's view of the natural climax state of Germany. A crucial concept for Tüxen's school of plant sociology and vegetation mapping was that of "potential natural vegetation." The potential natural vegetation was the living ecology of an area that would be present in the absence of human action. It was, in some sense, the mirror of Willcox and Mitscherlich's vision of the potential productivity that the soil could bear if only humans increased their fertilizer inputs and listened to the wisdom of quantitative agronomists. Much later in our story, in the 1980s, Tüxen's ideas will be echoed by the concept of "human appropriations of primary productivity": the volume of plantmatter production consumed, destroyed, or otherwise forgone as a result of the workings of global civilization. The key difference was that Tüxen was concerned first and foremost with the particular species composition of these hypothetical ecologies, whereas the quantitative ecologists of the postwar era were principally concerned with the raw mass of photosynthetic output. This was in part due to the fact that the physiological methods favored by Heinrich Walter won out. Indeed, one of Walter's students from Stuttgart, Helmuth Lieth, a U-Boat radio operator during the war, would play a crucial role in the entrenchment of primary productivity as a key metric of ecological activity in American ecology from the 1960s onwards.

Tüxen deployed his concept of potential natural vegetation to argue against the commonly held view that in the absence of centuries of intensive agricultural cultivation Germany would primarily be composed of beech forest (*Buchenwald*). Tüxen's methods, which depended upon fixed associations of particular plant species that could then be reliably correlated with particular soil and climate types, suggested to him that the beech forest would actually be supplanted by mixed oak and hornbeam forest (*Eichen-Hainbuchenwald*. The underlying cause of this was that the humid climate would exclude the beech from many parts of Germany, would render the soil poor, and would, in Walter's words, allow the "ambitious beech to be supplanted by the weak oak and hornbeam."[8] However, Walter argued, the parts of the Harz mountains where beech forest was actually found were actually colder, wetter, and more humid than those where the alternative oak and hornbeam forest was found. It was in the dry regions of Germany where beech forest was supplanted by its competitor species. Tüxen's theoretical construct had not taken into account the actual correlation between the "climate curve"

[8] **walter1937**

The Usambara Mountains, Today

(*Klimakurve*) and the different plant associations. Moreover, Tüxen's experience with temperate and long-cultivated ecologies had left him with the view that humid regions with nutrient-poor soil could not support "ambitious" (*anspruchsvoll*) organisms such as the beech. Walter's commitment to the physiological view, which searched always for climatic dependencies before identifying reliably co-occurring species, was shaped by his experience beyond Germany's borders in the tropics of the Usambara Mountains of former (and future) German East Africa. On the other hand, Tüxen's work on Germany's temperate forests had led him to the conclusion that the erosion that accompanied high rainfall and humidity would lead to nutrient-poor soils and a "degredation" of the forest away from the healthy climax state, while Walter's own work in East Africa suggested otherwise.

> In fact, we find under natural conditions no degredation. We can learn this from the conditions in the most humid of all climatic regions, the tropical rainforest. I had the opportunity, to research the conditions in the Usambra

mountains (East Africa). If through the erosive effect of the rain in the humid regions a constant progressive impoverishment of the vegetation was caused, it must show itself here to an especially high degree. That is not the case. The forest is to the highest level vibrant and filled throughout with healthy plants. But it is true, that the earth is found in an unusually impoverished state. The deep laterite [aluminum and iron rich] soil is comparable to the poorest nutrient content of our worst clay soil. This apparent contradiction between vibrant vegetation on one side and poor soil on the other side will be understandable, if we consider, that under natural conditions all of the essential nutrients are stored within the vegetation itself. A part dies yearly, falls to the earth, decomposes, and the freed nutrients are immediately taken through the roots again. *The nutrients are in constant circulation Kreislauf.* The nutrient content of the soil are, as the result of the rapid decomposition in the tropics, almost zero.[9]

[9]**walter1937** Tatsächlich findet aber unter natürlichen Verhältnissen eine Degradation keineswegs statt. Das lehren uns die Verhältnisse in dem humidesten aller Klimagebiete- im tropischen Regenwald. Ich hatte Gelegenheit, die Verhältnisse daraufhin im Usambaragebirge (Ost-Afrika) zu untersuchen. Wenn durch die auslaugende Wirkung des Regens in den humiden Gebieten eine ständig fortschreitende Verarmung der Vegetation bedingt würde, so müßte sie sich gerade hier in besonders hohem Maße zeigen. Das ist nicht der Fall. Der Wald ist im höchsten Grade üppig und setzt sich aus durchaus anspruchsvollen Pflanzen zusammen. Richtig ist aber, daß der Boden sich in einem äußerst verarmten Zustande befindet. Der tiefgründige Lateritboden entspricht in bezug auf den geringen Nährstoffgehalt unseren schlechtesten Bleicherdeböden. Dieser scheinbare Widerspruch zwischen üppiger Vegetation einerseits und ärmstem Boden andererseits wird aber verständlich, wenn wir bedenken, daß unter natürlichen Verhältnissen der gesamte für die Vegetation unentbehrliche Nährstoffvorrat in der Vegetationsmasse selbst enthalten ist. Ein Teil derselben stirbt jährlich ab, fällt zu Boden, wird zersetzt und die freiwerdenden Nährstoffe werden sofort wieder durch die Wurzeln aufgenommen. *Die Nährstoffe sind also in ständigem Kreislauf.*Der Nährstoffspiegel im Boden ist aber infolge der raschen Zersetzung in den Tropen gleich Null.

The historian of biology Lloyd Ackert has argued for the central role of the work of the Russian microbiologist Sergei Vinogradskii in the 1920s and 1930s for introducing the concept of "the cycle of life" into the emerging science of ecology.[10] Walter's vision of nutrient uptake in the tropical rainforest of the Usambra Mountains owed much to this concept. The fact that Walter adduced these examples in an argument against Tüxen, plant sociology, and the American school of "climax" ecology is telling. Plant sociology differed from the "climax" ecology of the American Frederic Clements principally in the latter's preoccupation with syntaxonomy: the grouping of different types of reliably reoccurring plant communities into Latin-named taxa. Both partook of the fundamental theoretical concept of "succession" and "climax." Walter, Vinogradskii, and Arthur Tansley, the British inventor of the "ecosystem" and a man who shared Walter's willingness to press ecological research in Africa into imperial service, had a different vision of cyclical processes. However, they were all still locked into an understanding of nature as fundamentally balanced, even if Walter hinted at the chaos and nihilism that was to come in the postwar American ecology of the 1960s through the 1980s by disregarding the notion of a static "climax community." For the physiological ecologists, the cycle was one that could be understood in chemical and microbiological terms, and repeated itself daily. For the plant sociologists and ecologists in the tradition established by Clements, cycles were primarily a question of

[10] Lloyd Ackert. "The Role of Microbes in Agriculture: Sergei Vinogradskii's Discovery and Investigation of Chemosynthesis, 1880–1910". In: *Journal of the History of Biology* 39 (2006) and Lloyd Ackert. "The "Cycle of Life" in Ecology: Sergei Vinogradskii's Soil Microbiology, 1885-1940". In: *Journal of the History of Biology* 40 (2007)

vegetational composition, the changing species makeup of a community, and repeated themselves on much longer timescales. And, fundamentally, for the followers of climax ecology, those cycles eventually stopped, whereas for the physiological ecologists the cycles of interest repeated themselves into perpetuity.

Both Walter and Tüxen, however, as distinct from the Russian, American, and British counterparts, shared a commitment to cartography as a principle tool of biological research. For Tüxen, the mapping of his painstakingly named community taxa was paramount. For Walter, on the other hand, the primary concern was to map different climatic regions against far broader ecosystem types. The legendary German embryologist and Darwinist Ernst Haeckel had coined the word ecology (*Ökologie*) in 1866 to mean the branch of biology which concerns the relationship of an organism to the factors that sustain it. For Walter, climate was overarching in this regard. Walter's work on climate and nutrient factors that set the upper limits of plant productivity had clear agricultural applications for a hungry would-be German Empire looking to cultivate lands in Eastern Europe and Africa. It was this sort of work which brought Walter and the *Produktionskurve* to Africa. However, it would be their proficiency with biological geography that ultimately brought both Walter and Tüxen into the more direct service of Germany's war aims in Eastern Europe, once the conquest of Africa had to be put on hold after 1941. Yet before delving into those scientific efforts, we must go back into Walter's laboratory past. It was not only in the lab that Walter developed his overarching physiological view of plant communities, but it was there that he fostered a scientific interest in a subject of longstanding interest to Germany's interactions with Africa: the role of water in sustaining life.

Between 1926 and 1935, Walter worked extensively on the physiological adaptations of plants to limitations on water supply. This work metamorphosised gradually from experimental to ecological work. After 1935, as Walter became completely absorbed by ecological work in Africa, and even after 1942 when his work turned to propagandizing for the Third Reich and developing maps for the *Wehrmacht* in Eastern Europe, questions of aridity and water supply were never far from his mind. And it was questions of aridity that first brought the *Produktionskurve* to Africa in 1941.

But the curve was on Walter's mind even before he became fascinated by water physiology, and 17 years before he would apply it to the vegetation of the Southwest African Savannah. Writing in 1924, a 26 year-old Walter, five years out of his dissertation and newly a *Privatdozent* at Heidelberg, put forth some "Theoretical Considerations on the Relationship between Mitscherlich's *Produktionskurve* and the Weber-Fechner Law."[11] Therein, Walter compared the *Produktionskurve* to Blaauw's *Reizmengengesetz* for phototropic growth responses, Justus von Liebig's law of the minimum (*Minimumgesetz*) from the mid-nineteenth century, and, of course the psychophysical Weber-Fechner law. Yet Walter remained skeptical of the *Produktionskurve*'s value:

The metabolic process in the plant is a chemical process,

[11] Heinrich Walter. "Theoretische Betrachtungen über die Beziehung der Mitscherlichschen Produktionskurve und des Weber-Fechnerschen Gesetzes zum Massenwirkungen". In: *Die Naturwissenschaften* 2 (1924) is the article in question, Walter's memoirs, **walter1980** provide useful biographical information.

> that creates a chain of chemical equivalences. Therefore, the chemical equivalence or the mass effect action is the foundational principle (*Grundprinzip*), and it begs the question, whether this law reveals complicated metabolic processes of the plant, or whether these are hidden through secondary factors.[12]

For Walter, a law which established a proportionality between input and output had its uses, but his fixation with the physiological mechanisms underlying growth processes was unsatisfied by a superficial equivalence. When he left the lab for the field, Walter would become increasingly uninterested in proportional laws which claimed to hold fast in controlled settings such as the darkroom or the farm, finding an analysis of empirical data on vegetation forms, charted against an analysis of similar data on climate, to be the most useful tool for elucidating the factors that controlled photosynthetic production in extra-European ecologies.

Two years later, Walter produced a monograph on "The Adaptation of Plants to Water Deprivation: The Xerophyte Problem from a Causal-Physiological Viewpoint." Xerophytes are plants adapted to conditions of extreme aridity. Although his investigations into Xerophytes started from a physiological standpoint, Walter was already quick to invoke ecology. For Walter, ecology differed from physiology in that it asked "teleological"

[12] **1924** Die Stoffwechselvorgänge in der Pflanze sind chemische Vorgänge, die eine Ketter von chemischen Gleichgewichten bilden. Als Grundprinzip der Produktionskurve ist deshalb das chemische Gleichgewicht oder das Massenwirkungsgesetz anzusehen, und es fragt sich nun, ob dieses Gesetz im komplizierten Stoffwechselvorgang der Pflanze noch rein zum Vorschein kommt oder durch sekundäre Faktoren bis zur Unkenntlichkeit verdeckt wird.

questions about the long-term origins of an organism's adaptation. Physiology, on the other hand, was concerned chiefly with more immediate chemical causes in the reaction chain, such as those Walter had discussed in his 1924 article. An ecological analysis of the unique adaptations Xerophytes presented for dealing with the problem of aridity was concerned with the purpose of these adaptations. Not that there was any great mystery as to their ultimate purpose. Their ultimate purpose was to provide the plant an advantage in the struggle for existence (*Kampf ums Dasein*), as it is always translated in German). The question was only how a particular adaptation granted a particular organism an advantage in this struggle. Interestingly, at a time when large swathes of ecology in America were completely unconcerned with Darwinism, or, in their view of the collective function of the "climax community," essentially anti-Darwinian, Walter invoked Darwinism as the theoretical basis of ecology. The problem with traditional Darwinian ecology, from Walter's standpoint, was that it was primarily descriptive. On the other hand, while physiology was experimental and causal, it did not ask these kinds of fundamental teleological questions. Yet to ignore physiology in an ecological analysis was to ignore the direct causes of an adaptation:
Heinrich Walter. "Die Bedeutung des Wasser-sättigungszustandes für die CO_2-Assimilation der Pflanzen". In: *Berichten der deutschen botanischen Gesellschaft* (1928)

> Die Ökologie unterschied sich bis vor kurzem von der Physiologie durch die vorherrschend morphologisch-teleologische Betrachtungsweise, indem

> man nicht die direkte Ursache für das Zunstandekomen einer Anpassung festzustellen bestrebt war, sondern nach dem Zweck oder dem Nutzen suchte, den eine Anpassung für die Pflanze besitzt. Die teleologische Einstellung ist nur im Zusammenhang mit der vorwiegend darwinistischen Auffassung des Anpassungsproblems zu verstehen. Die nützlichen Anpassungen sollen den Pflanzen einen Vorteil im Kampf ums Dasein bieten und durch die natürliche Auslese erhalten bleiben: Auf diese Weise gelingt es, ohne Kenntnis der direkten Ursachen doch des Zustandekommen und die so auffallende Zweckmäßigkeit der Anpassungserscheinungen zu erklären.[13]

Walter was clearly interested in these ecological and Darwinian questions even in 1926. However, he also felt that going too quickly to the "struggle for existence" as the explanation for an adaptation could close off many important realms of scientific questioning:

> A causal physiolgical approach concerns itself only with the direct origin of the adaptation. Indirect adaptations do not originate without cause, but we break the causal chain with such ideas as the "struggle for existence," "chance," and "natural selection," which leave no room for a physiological approach.[14]

[13]Heinrich Walter. "Die Anpassung der Pflanzung an Wassermangel: Die Xerophytenproblem in kausal-physiologischer Betrachtung". In: *Naturwissenschaft und Landwirtschaft* 62 (1926), p.6

[14]Walter, "Die Anpassung der Pflanzung an Wassermangel: Die Xerophytenproblem in kausal-physiologischer Betrachtung", p.8 Eine kausal-physiologische Betrachtungsweise läßt sich natürlich nur bei der Annahme einer direkten Entstehung von Anpassungen durchführen. Indirekte Anpassungen entstehen zwar auch nicht ursachenlos; aber wir durchbrechen die

$$S_p = O_c - W_p$$
The Factors of Suction, 1924

In 1928, Walter conducted saturation experiments to control the amount of water sucked into the cells of the freshwater weed, *Elodea canadensis*. The osmosis equation appeared four years before Walter's experiments, where S_p is the cellular suction pressure, O_c is the osmotic (or solute) concentration, and W_p is the cellular wall pressure.[15] Drawing on this simple equation, Walter conducted a series of experiments in which he altered the sugar (solute) concentration in the aqueous medium surrounding the *canadensis* specimens. In accordance with Ursprung's 1924 osmotic suction equation, any increase in solute concentation (O_p) within a cell (that is, an increase in $\frac{\text{solute}}{\text{water}}$) would increase the suction pressure which sucked water from the surrounding medium into the cell. Increases in wall pressure (W_p) would decrease the suction pressure. Therefore, by increasing the solute concentration outside the plant, Walter hoped to lessen the pressure sucking water into the plant's cells, and chart this decrease in water uptake against CO_2 assimilation. He then determined CO_2 concentration using Ruttner's physical method, by which a decrease in the conductivity (*Leitfähigskeit*) of water surrounding the plant was correlated with increased CO_2 assimilation (*Assimilationsintensität*), while an increase in its conductivity was correlated with increased respiration (*Atmungsintensität*). As predicted, the increases in

Kausalkette doch mit solchen Begriffen wie "Kampf uns Dasein", "Zufall" und "natürliche Auslese", bei denen für eine physiologische Betrachtungsweise kein Raum bleibt.

[15] J. Van Overbeek. "Phototropism". In: *The Botanical Review* (1939), p.659 gives this equation, and credits A. Ursprung and G. Blum. "Eine Methode zur Messung des Wandes und Turgordruckes der Zelle nebst Anwendungen". In: *Jahrbuch Wissenschaft und Botanik* 63 (1924) with elucidating the quantifiable variables bearing on osmosis.

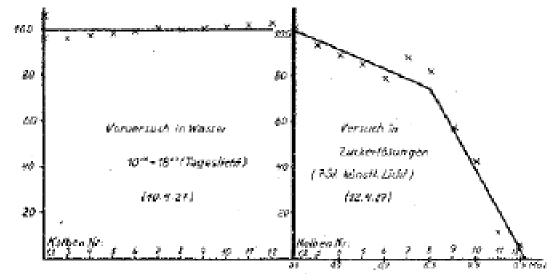


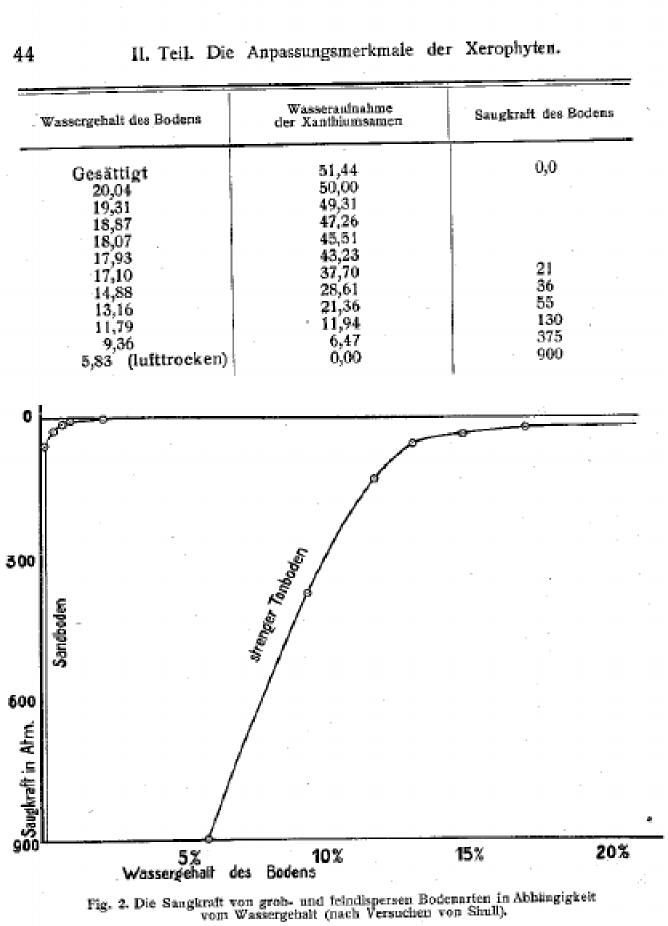
Abb. 1. Assimilationsversuch. Erklärungen s. im Text. Kolben Nr. 1 und 2 sind Wasserkontrollen.

CO_2 Assimilation Curve, 1928 (from Heinrich Walter. "Die Bedeutung des Wasser-sättigungszustandes für die CO_2-Assimilation der Pflanzen". In: *Berichten der deutschen botanischen Gesellschaft* (1928))

solute concentration in the surrounding medium (and corresponding decreases in water uptake by the plant cells) were correlated with decreased CO_2 assimilation. The results of Walter's first experiment are shown in the figure, where as the sugar concentration increases, the CO_2 "assimilation is strongly decreased, and by 0.5 Mol [mole, a basic measure of a substances quantity in physical chemistry] have sunk almost to zero."[16]

These were almost controlled laboratory experiments in the tradition of Utrecht and Copenhagen. However, Walter's 1928 experiments were not indifferent to uncontrolled natural conditions and local contingencies. His pre-experiment (*Vorversuch*) with pure water, represented by the horizontal line in the assimilation curve, used natural sunlight rather than the artificial light used for the experiments with sugar solution. Furthermore, in his explanation of the Ruttner method for determining CO_2 assimilation and respiration through the conductivity of a fluid

[16]Heinrich Walter. "Die Bedeutung des Wasser-sättigungszustandes für die CO_2-Assimilation der Pflanzen". In: *Berichten der deutschen botanischen Gesellschaft* (1928), pp.530-532



44 II. Teil. Die Anpassungsmerkmale der Xerophyten.

Wassergehalt des Bodens	Wasseraufnahme der Xanthiumsamen	Saugkraft des Bodens
Gesättigt	51,44	0,0
20,04	50,00	
19,31	49,31	
18,87	47,26	
18,07	45,51	
17,93	43,23	
17,10	37,70	21
14,88	28,61	36
13,16	21,36	55
11,79	11,94	130
9,36	6,47	375
5,83 (lufttrocken)	0,00	900

Fig. 2. Die Saugkraft von grob- und feindispersen Bodenarten in Abhängigkeit vom Wassergehalt (nach Versuchen von Shull).

Water Adaptation Curves, 1926 (from Heinrich Walter. “Die Anpassung der Pflanzung an Wassermangel: Die Xerophytenproblem in kausal-physiologischer Betrachtung”. In: *Naturwissenschaft und Landwirtschaft* 62 (1926))

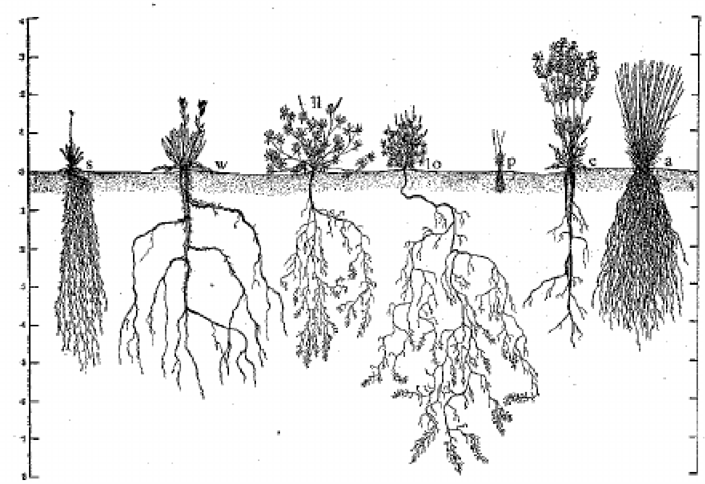


Fig. 4. Schematische Darstellung der Wurzelsysteme einiger Steppenpflanzen (nach Weaver). s = Sieversia ciliata, w = Wyethia amplexicaulis, ll = Lupinus leucophyllus, lo = Lupinus ornatus, p = Poa sandbergii, e = Leptotoenia multifida, a = Agropyrum spicatum. Die Zahlen links geben die Tiefe und Höhe in Fuß an (ein Fuß = 30,5 cm).

The Roots of Global Ecology, 1926 (from Heinrich Walter. "Die Anpassung der Pflanzung an Wassermangel: Die Xerophytenproblem in kausal-physiologischer Betrachtung". In: *Naturwissenschaft und Landwirtschaft* 62 (1926))

(positively correlated with its carbon content), Walter noted not the controlled laboratory conditions under which he carried out his experiments, but rather the town where they were undertaken, Lunz am See, in lower Austria. This was important to his method of CO_2 assimilation determination because the water there contained a high concentration of bicarbonate, thus effecting its baseline conductivity. This hesitant embrace of extra-laboratory contingency is interesting, given that in a year Walter would transfer his interest in the effect of osmosis on *Stoffproduktion* to plant samples from Hungary's 1928 arid period.[17] Ten years and numerous papers on osmosis and aridity after analyzing the

[17] Heinrich Walter and Erna Walter. "Ökologische Untersuchungen des osmotischen Wertes bei Pflanzen aus der Umgebung des Balatons (Plattensees) in Ungarn während der Dürrezeit 1928". In: *Archiv für wissenschaftliche Botanik* (1929)

Hungarian samples, Walter would report from the "eighth international congress for tropical and subtropical cultures in Tripoli (13-17 March 1939)" on "the biological foundations of the colonization of Libya."[18] For Walter, Italian-controlled Libya was an extremely arid area, where water restraints effected plant production, similar to (what Germans of the period called) German Southwest Africa (*deutsche Südwestafrika*). A few years after that, Walter deployed the Mitscherlich production curve to isolate the effect of a particular growth factor (*Wachstumsfaktor*), "in our case, water," on the productivity of the aggregate plant cover of (German?) Southwest Africa.[19] Half a century earlier, water had played a crucial role in another German expedition into Southwest Africa.

The Curve Goes to Africa

Between 1904 and 1907, the German military was responsible for the deaths of between 25,000 and 100,000 humans in Southwest Africa. As the historian Isabel Hull has shown, the German military transplanted tactics of encirclement and strategies of "decisive battle" from central Europe into the ruthless aridity of the Namib desert.[20] As a result, tens of thousands of members of the Namaqua and Herero peoples died of thirst, stranded in a wasteland from which the German army would not grant them

[18] Heinrich Walter. "Die biologischen Grundlagen der Kolonisation in Libyen". In: *Die Biologie* (1939)

[19] Heinrich Walter. "Produktivität der Pflanzendecke und Mitscherlichsche Ertragskurve". In: *Berichten der deutschen botanischen Gesellschaft* (1941), p.115

[20] Isabel Hull. *Absolute Destruction: Military Culture and the Practices of War in Imperial Germany.* Cornell University Press, 2005

exit. Three decades later, as Germany again cast its gaze upon Southwest Africa, the question of water supply remained.

A latecomer to the imperial game, Germany's frisky adolescent phase coincided with the languid middle-age of the French and British empires in Africa. The German overseas empire, halfhearted and short lived as it was, did not fail to inflict its fair share of death and destruction upon those humans who found themselves unwilling subjects of the Kaiser. Starting in 1884 with the creation of German East Africa and Southwest Africa, the empire grew to include Togo and Cameroon in northwest Africa, Samoa and part of Papa New Guinea in the south pacific, and a leasehold on the Shandong penninsula of northeastern China, centered on the German town of Qingdao.[21] German imperial interests ultimately turned back to contiguous agrarian areas in eastern Europe in 1914. The course of German imperial ecology, ultimately, both recapitulated this history, and presaged its repetition during Germany's second bid for Eurasian hegemony. What begin in the deserts of Southwest Africa and Libya would return to eastern Europe after 1941, as Germany's ecologists and geographers were summoned upon by the *Wehrmacht* to apply their skills to mapmaking in the ever-shrinking thousand-year Reich. But before turning our attention to that development, we must first look at how Heinrich Walter transplanted Mitscherlich's *Produktionskurve* to Southwest Africa.

We have seen that Walter had referred to the theoretical uses of the *Produktionskurve* in his youthful laboratory days. By 1936,

[21]**steinmetz2007**

Walter felt that laboratory work had taken him as far as it could in understanding the complex interrelationships between organisms and their environments. Moreover, according to his memoirs, he saw the opportunity to tap the Reich's colonial development funds to take research trips to Africa. While Walter's interest in African ecology may have lied at the intersection of scientific curiosity and an enthusiasm for world travel, he was, at the very least, aware of the practical applications of ecological research for his ambitious masters. Ecology could perform a function for the soon-to-be Reich comparable to that of Tüxen's plant sociology and Mitscherlich's agrobiology in the somewhat truncated already-existing one. It could both assess the current state of productivity, and answer crucial questions about how much higher that productivity could go. The articles that came out of Walter's first trips to Africa in the mid-1930s covered a range of topics in plant ecology, none of them far removed from a basic question. Namely, once the former German colonies had been reclaimed, how much biological rent could the fatherland extract from their soil. These topics included: the cultivation of sisal, an agave plant used to produce tough rope fibers, in East Africa; a study on the nutrient content of the soil in forest stands which used the tropical forests of East Africa (Tanzania) as a comparative for the temperate stands of central Europe; the water and electrolyte conditions (*Salzhaushalt*) of east African mangroves; and the role of atlantic clouds, generated by the northward Benguela current, in providing the Namib desert with its only moisture. **walter1936** **walter1936a** **walter1936b** and **walter1936c** Sisal cultivation was especially near and dear to the German imperial heart, as the sisal trade had, by the last days of German rule in 1913-14, led to the blanketing of 25,000 hectares (96 square miles) with the crop, producing an export of 20,835 tonnes worth 10.7 million marks and making of 30% of the colony's total exports.[22] Perhaps not an economy comparable to the British control of Malyasian rubber, but the Germans had to take their market-valued colonial primary products wherever they could. The German overseas empire, in its first iteration, had been a loss making economic enterprise. But you cannot put a price on glory.

By 1939, Heinrich Walter had produced an entire monograph devoted to "Grassland, Savannah, and Bush of the Arid Part of Africa in their Ecological Relations." The practical implications of Walter's ecological work in Africa for Germany's imperial ambitions were often more subtle than in his 1936 article on sisal cultivation. Similarly, the ideological symmetry between his scientific theories and the racial biology of Nazi Germany was not always so clear. For example, a 1939 article on the "biological foundations" of colonization in Libya dealt not with the population genetics of the North African population or the suitability of the climate for different sub-species of European *Homo sapiens*, as one might expect. Rather, it was the primary productive base of the ecology in question which concerned him. However, it is worth noting that all of his work in Africa between 1936 and 1941 dealt either with one of the two major former German colonies, Namibia or Tanzania (the other two, Cameroon and Togo, were much smaller), or with the Libyan colony of Germany's Italian ally. This was not a coincidence.

[22]**walter1936**

Walter's scientific interests touched not the racist, bellicose strand of Nazi ideology, but rather the Malthusian obsession with population/food ratios. This was, of course, inextricable from racial concerns in the Nazi *Weltanschauung*. The global (or even local) proportion between human organisms and organisms that humans eat was of little concern to Nazi demographers, geographers, and biologists. The Nazis started from the racially protectionist position that nations were associated with distinct sub-species of humanity (or even distinct species. As is often the case when biology is mobilized in the service of racial politics, the taxonomy gets a bit vague). At the top of the food chain were the Aryans, who were not only superior intellectually and physically (although, as Hitler noted after their athletes got stomped at the 1936 Olympics, not as well adapted for strength and speed as the "barbaric races" of Africa), but also more deserving of food, comfort, and life more generally. Inferior sub-species existing within the unnaturally (and temporarily) small political unit designated as "Germany" were parasites within the national ecology. Those who existed outside that unit were equally parasitic on capacity that could carry Arayans instead. The nation was an unnatural and arbitrary entity, lines drawn on a map by armies and treaties. The essential reality was the size of the biological population in question, and the scope of the resources it could bring to bear in expanding itself. Here then is where Malthusianism took hold. If population expansion in excess of food supply was inevitable, the goal of the Nazi military project was to ensure that as the right population expanded in both size and geographic range, the wrong ones simultaneously increased the size of the supportive base through their slave labor and bore the brunt of resource constraints. And here, beyond all the absurdity of racial biology and Aryan mythology, was an essential Darwinian insight: resource constraints are both friend and foe to any population, as they limit that population's growth, but also eliminate competitors in the grand game of getting as many biological reproductions of yourselves as possible into the next generation. Ultimately, beneath all claims to a higher purpose, reproduction within a world of ruthless ecological restrictions is the only game for plants and animals to play, no matter how inspirationally some animals might paint, sing, and speak.

The kind of production ecology which Walter's African work would evolve into in the postwar American world retained a Malthusian concern with the ratio of human population to food supply. However, Nazi ecological Malthusianism differed from the postwar iteration in three essential ways. The first was in its faith in racial biology, and in the greater right to earth's biological productivity of some living groups over others. The second was in the total indifference to absolute constraints on the human population as a whole (or, the totality of all animal life, the chief concern of primary productivity research). A world filled with three billion Aryans and four billion slaves laboring over fruit bushes and in electronics factories would have been no real concern to a properly indoctrinated Nazi ecologist in the year 2013. Finally, the Neo-Darwinism which animated postwar ecology regarded single species populations as nothing more than particularly similar competitors in the struggle for existence. Indeed, under a Neo-Darwinian regime, competition is often fiercest among members of the same population, because their resource needs are so similar. A bottleneck on the ecological supply of Schnitzel and beer might turn Aryan brother against brother, but could have little impact on the competition between Aryans as a whole and lesser organisms. The idea that a population could act in concert to achieve a total increase in its overall size, geographic dispersion, and resource allotment per individual at the expense of other populations without some extra-biological form of motivation, stemming from culture or the state, was anathema to virtually all biologists following the debates over group selection in the 1960s. Ultimately, the distinct individual genotype was agreed to be the only real unit of selection, and any biologically motivated cooperation was towards the end of preserving that genotype (either in the individual, or in those who shared as much of it as possible, siblings and offspring). But in 1939, many biologists in many countries, including those uninterested in wedding ecological science with the war aims of one nation or another as well as those with more bellicose views of nature, were open to the idea that populations, or even multi-species communities, could be units of selection as surely as the individual.

But that is the future, to be dealt with in due course. Returning to Walter's 1939 work on the grasslands and savannahs of Africa's arid regions, we can see how the localized sciences of Mitscherlich's agrobiology and Tüxen's plant sociology were converging via the matchmaking efforts of Nazi imperialism to lay the groundwork for a new global ecology. While those sciences existed first to serve the immediate practical needs of agriculture and forestry in Germany proper, the grander ambitions of Walter's global ecology conveniently paralleled the grander ambitions of the Nazi state. That said, it is important to note that there were many other strands that went into global ecological science, many of them distinctly non-fascistic. These strands cut through Walter's own work, and he was not provincial or chauvanistic in either his research or his scientific interactions. Indeed, following his physiological work as a young experimentalist in the 1920s, he spent two years, 1929-1930, researching the Sonoran desert as a Rockefeller fellow under the American ecologist Forest Shreve at the University of Arizona, Tucson. His postwar career would be no less international, bringing him to the University of Ankara, Turkey for four years between 1951-1955. One of his most important students, Helmuth Lieth, would go to the University of North Carolina, Chapel Hill. Another, Siegmar-Walter Breckle spent part of his career at the University of Kabul, Afghanistan in the late 1960s. In his study of African aridity, he opened with a reference to the experimental work of Frederic Clements, the forefather of North American ecology, and his co-worker John Weaver on the Great Plains in the 1920s. Looking forward to the work that would preoccupy him after 1941, he referred also to the another great arid grassland: the Russian steppes. Steppes, Prairie, and Savannah: these three vast near-deserts were a constant comparative trinity in Walter's research. Moreover, Walter and his fellow ecologists, agronomists, plant sociologists, geographers, soil scientists, and so on, could do no better and no worse than any other living thing. Organisms adapt to their environment, fill the niches available, or risk losing out in the struggle.

What was new here, what Walter took from his work in physiology and his earlier interest in proportionality laws like the Mitscherlich curve, was a fascination with "productivity." The larger Nazi concerns with population and food supply were reflected in Walter's ecological research, as were their colonial dreams, yet Walter himself focused on the productive base, and not, for the most part, the economic uses to which it might be put. Yet in this adoption of a language of productivity, a new scientific goal was identified, which set Walter's work apart from that of the American and German scientists who shared his preoccupation with the relationship between organisms and their environment. For Tüxen, the study of complex multi-species systems in nature was largely a question of taxonomic composition. His language was that of classical botany, and any pretense to dynamic change in the system was captured by his adherence to Clements's theory of succession and climax in an unpreturbed (by the technological action of humans) plant community. Clements, for his part, focused most of his career on long-term studies of successional systems, coupled with field experiments in which the impact of a particular environmental variable on the communities progression was studied.[23]

Walter, on the other hand, was only secondarily interested in

[23]Ronald Tobey. *Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology, 1895-1955.* University of California Press, 1981 is the main historical work on Clements's scientific program.

taxonomic composition, and, as addressed above, believed that succession was a purely theoretical model seldom born out in actual observation. His research program focused then on productivity, quantified as the total drymatter produced by an ecosystem. In this, he was closer to Mitscherlich than his relative lack of interest in agricultural ecosystems (indeed, his relative lack of interest in central European ecology as a whole) and his critical treatment of the *Produktionskurve* might have suggested. The individual characteristics of distinct species were secondary to gross productivity in relation to a particular input in both Mitscherlich and Walter's research. His 1939 monograph is notable as the moment when the language of biological productivity, and the effort to survey the productivity of different ecosystems, took over his research program. His secondary interest, closely related, was in climate, and its role in governing the ecology of a particular region. After the war, climatic classification would become his primary research focus, with his student Lieth (also a partner on much of his 1970s climate mapping work) taking over the increasingly ambitious efforts to chart global productivity. For the moment, it is important to note how felicitously the focus on productivity fit with the economic and military ambitions of Nazi Germany. The Nazi state, like the other primary belligerents of World War II, was in effect a giant system for extracting labor, food, and minerals from all of the land and people under its control, and devoting them to the goals of territorial expansion, war, and (unique to the German case) genocide. "Productivity" was thus a simple and all-encompassing statistic for measuring the base of the German military metabolism Yet after the war, as so many of the intellectual pathogens the Nazis had propagated saw their virulence reduced, productivity would an incredibly useful statistic for the growing forces of global neoliberalism. In this way, the seed that had originated in Mitscherlich's research on the domestic German agricultural economy, and now flourished in the arid regions of Africa, would survive.

> Betrachtet man die Lage der einzelnen Punkte, so ist man wohl berechtigt zu sagen, daß tatsächlich die Produktivität der Pflanzendecke annähernd proportional mit der Niederschlagsmenge ansteigt- ein Ergebnis, das Zwar vermutet wurde, für das aber bisher Zahlenbelege volkommen fehlten.[24]

Walter's 1939 data on aboveground productivity would be the basis for his 1941 study on the applicability of the Mitscherlich curve to the ratio of rainfall to biomass yield in arid ecologies. Longer term, his student Helmut Lieth would cite the "Walter ratio" from the 1939 study in a 1973 review article on "the history of growth in understanding of primary productivity and in making estimates of biosphere production."[25] The ratio predicted two grams of drymatter production per square meter for every millimeter of rain. Lieth's review was a part of the International Biological Program, which took the quantification of global primary productivity as one of its main research goals. Yet Walter's ambitions for his productionist ecology were not limited to

[24] Heinrich Walter. "Grasland, Savanne und Busch der ariden Teile Afrikas in ihrer ökologischen Bedingtheit". In: *Jarhbüchern für wissenschaftliche Botanik* 87 (1939), p.856

[25] Helmut Lieth. "Primary Production: Terrestrial Ecosystems". In: *Human Ecology* 1 (1973), p.303

Southwest Africa, and while his dreams of ecological globalization would eventually be born out, albeit under a quite different political economic regime, he lacked the patience necessary to wait for that possible future. Attending the Eighth International Congress for Tropical and Subtropical Agriculture in Tripoli, Libya in 1938, Walter openly addressed the imperial applications of his global ecology under the auspices of a cosmopolitan scientific gathering. A few short years later in 1941, the political situation had reached a point where scientists from the family of imperialist European nations could not necessarily attend conferences together and share the fruits of their research. By then, Walter's pronouncements on the relevance of ecology to colonial power had gone from *The Biological Foundations of the Colonization of Libya*, presented to an international congress in Latin script with a few English translations peppered throughout, to *The Meaning of Botany for the Exploitation of the Colonies*, presented to a purely German audience in the distinctively Germanic Fraktur typeface.

Libya, in various political configurations, had been under Italian control since 1912. Shortly after Mussolini's rise to power in 1925, a campaign against the native Bedouins begin that lasted from 1928 to 1932, and killed as much as half of the local population. Nearly annihilating an indigenous African culture through starvation and thirst, this opening move in Fascist Italy's expansion of their New Roman Empire in North Africa was reminiscent of Imperial Germany's campaign against the Herero and Namaqua people from 1904 and 1907.

Walter's 1939 article on Libya briefly reviewed the general environmental conditions in the colony, before moving on to agricultural issues.

> Diese Konzessionen stellen sehr intensive Großbetriebe dar, bei denen viel Maschinenkraft verwendet wird (Bearbeitung mit Traktoren), die aber keinen Raum für Siedler bieten. Deshalb entsprechen sie nicht den Zielen, die der Faschismus in bezug auf die Kolonisation erreichen will. Aus diesem Grunde ist die italienische Regierung seit 1932 zur Vergebung von Kleinsiedlungen übergegangen und hat gerade in vergangenen Jahre durch die reibungslose Unterbringen von 20,000 Siedlern einen glänzenden Erfolg zu verbuchen.[26]

The coming decade would be the last in which agricultural primary production would be Libya's primary economic export. By 1956, the fossilized deposits of billions of years of past primary production would begin to be sucked out of the dry sands of the newly independent Libya. However, Libya nonetheless occupied a crucial strategic position in the Nazi quest to feed their starving war engines. Many of the nearby states were either already pumping oil, or had dormant fields owned by western firms. One of these, Iraq, was largely owned by Deutsche Bank, one of the earliest investors in middle-eastern oil fields at the end of the nineteenth century. Timothy Mitchell. *Carbon Democracy: Political Power in the Age of Oil.* Verso, 2011 Deutsche Bank's interest in middle-eastern oil intersected with their financing of the Berlin-Baghdad railway. More importantly for the economic and

[26] Walter, "Die biologischen Grundlagen der Kolonisation in Libyen", p.298

military concerns which animated Walter's scientific activity, Libya would in one year's time be the site of Germany's attempt to cut off British oil supplies by attacking the Suez canal using General Rommel's *Afrikakorps*. An attempt to manipulate Arab hatred of Jewish settlers and British imperialists via General Helmuth Felmy's covert activities in Iraq and Jerusalem accompanied this overt military project. Closer to Walter's own near-future, however, were the Libyan map-making efforts of the geographer and SS officer Otto Schulz-Kampfhenkel.

Schulz-Kampfhenkel was the scientific and propagandistic spearhead of Germany's most ambitious colonial dreams. As those aims became more circumscribed by the awkwardly constricting walls of macroeconomic possibility, so too did Schulz-Kampfhenkel's research. From 1935-37, Schulz-Kampfhenkel led the Jary Expedition down the Brazilian Amazon. Brazil had been home to isolated colonies of German settlers since the early nineteenth century, and SS chief Heinrich Himmler fantasized about formalizing this relationship and creating a transatlantic Reich in South America. While Schulz-Kampfhenkel's three-man expedition did little to expand the Reich's global reach, he did experiment with aerial photographic techniques that showed some promise for military expeditions. It was the refinement of these techniques as an aide to the drive across North Africa that brought him to Libya a few years after Walter's presentation at the Eighth International Congress of Tropical and Subtropical Agriculture. By 1942, however, Germany was beginning to put not only their Amazonian colonial plans but also their ambitions in the Middle

/home/adam/Documents/PhD/PhD2/phd2_schulz-kampfhenkel.png

The Jary Expedition, 1935-37 (from Jens Glüsing. *Das Guayana-Projekt: Ein deutsches Abenteuer am Amazonas*. Ch. Links, 2008)

East on hold. Following this military trajectory, Schulz-Kampfhenkel returned to Europe to head the *Forschungsstaffel zur besondere Verwendung des Oberkommando Wehrmachts*. This was a civilian annex to the military's own mapmaking division, tasked with using scientists to develop new geographical techniques so as to aid the army in more efficiently withdrawing across Eastern Europe. The scientists employed by the Forschungsstaffel included geographers, plant sociologists, and, of course, ecologists, of which Heinrich Walter was one.

Walter's shift back to Eastern Europe would see him leaving behind much of his concern with productivity ecology. As the geographical ambit of Germany's colonial aims shrunk, so too did the ambitions of its science. A global calculus of biological productivity was a less pressing need for the Thousand-Year Reich in 1942 than reliable maps that pointed out passable fields, impassable forests and swamps, and, most crucially, food. However, Walter would continue to draw upon his production work in subtle ways throughout his time with the *Forschungsstaffel*, and in the years afterward. More importantly, the relationship of organisms to their water supply remained a crucial thread in Walter's research. The fascination with aridity and water use gave continuity to a career that spanned physiological bench work in the

1920s, productivity research in Africa in the 1930s, and military geographic work in eastern Europe in the 1940s.

But before his return to Europe, Walter made his debt to Mitscherlich's production ecology explicit, while drawing on the data from his 1939 monograph. Walter's 1941 paper "Productivity of the Plant Cover [*Pflanzendecke*] and Mitscherlich's Yield Curve" set about critiquing the usefulness of the curve in understanding Namibian aridity. Referring to the area now annexed to British control via South Africa repeatedly as "German Southwest Africa," Walter set about using the *Produktionskurve* to analyze the increase in plant yields relative to water inputs. Substituting water for Mitscherlich's potash, Walter reached a dim conclusion about the equations utility for such ecological work. Nor was he overly generous in his assessment of the applicability of plant sociology to the Namibian grasslands.

> Die pflanzensoziologische Betrachtungsweise hat in die Hochschule noch so gut wie keinen Eingang gefunden und begegnet sehr geringem Verständnis, nur weil das Objekt-die Pflanzengesellschaften-den meisten fremd ist. Heinrich Walter. "Produktivität der Pflanzendecke und Mitscherlichsche Ertragskurve". In: *Berichten der deutschen botanischen Gesellschaft* (1941), p.115

For Walter, the "plant society" was a purely theoretical unit, abstact and alien to most people's perception. Moreover, to the degree that such distinct entities did exist, a hypothesis which his focus on continuous ecological gradients was skeptical of, they were an artifact of centuries of European tree cutting and cultivating.

Walter went on to clarify the differences in the kinds of experiments Mitscherlich and others had done, in which both the nutrient input and the size of the single-species *Versuchsflächen* could be manipulated, to the tricker work of discerning input/output relationships in natural plant societies. Invoking Darwinism, Walter alluded to ideology of productivity which animated so much of Germany's war planning. In the case of arid plant societies, the struggle for existence may have been aimed at individual survival and reproduction, but its larger effect was to maximize the total productivity of the multi-species unit:

> Befindet sich die natürliche Pflanzendecke mit ihrer Umgebung im Gleichgewicht, so ist wohl die Annahme berechtigt, daß sich infolge der durch Jahrtausende fortgesetzten Auslese jeweils die Artenkombination zusammengefunden hat, die in bezug auf die Bildung neuer organischer Substanz das Maximum dessen leistet, was unter den gegebenen Bedingungen überhaupt möglich ist.[27]

This was a view that fit nicely with the overall functioning of Nazi society. Where as Darwinism in liberal England stressed the striving of the individual, the group-focused view of Darwin's sadly unremembered socialist junior partner Alfred Russell Wallace aside, the version that was showing up in German biological literature at this point stressed the total productivity of a complex unit. However, in a twist with an interesting analogy to Nazi ideology, this larger productive unit was made up not only of

[27]Walter, "Produktivität der Pflanzendecke und Mitscherlichsche Ertragskurve", p.116

individuals, but of multiple species. The Germans certainly employed what were, from their standpoint, distinct species (or at least sub-types) in their use of the slave labor of supposed "lesser races." And, in the world of actual biological reality, horses, dogs, and of course millions of domesticated prey species, were central to the war effort's relentless drive towards sustained productivity. Horses mobilized more German army units than trucks and tanks, the German Shepard was fixed by cavalry officer and eugenicist Max Stephanitz in the late nineteenth century, and the German people would not abandon their love of meat until the wolf of famine was no longer at the door, but through it.

Yet Walter did not limit the social implications of his studies in Southwest Africa to such subtle invocations of Darwinism, open to interpretation by a readership at once biologically astute, yet also accustomed to conceiving of all references to *naturliche Auslese* as inhrently social. He compared the intensity with which plants assimilated carbon, water, and soil nutrients to economic spending and saving. The plants with the higher intensity of assimilation did not necessarily produce a greater total yield of biomass than those with a lower intensity. Rather, they tended to devote their carbon to building new flat leaves, rather than dense woody matter, so that they could continue to maintain their higher level of assimilation intensity relative to their denser, woodier counterparts. Walter compared this propensity to reinvest in new assimilating surfaces for absorbing light and carbon to the economic activity of saving and investing profit so that the money would continue to work for the individual or firm in question.[28] At

[28]Walter, "Produktivität der Pflanzendecke und Mitscherlichsche Ertragskurve", p.119

a time when the memory of the hyperinflation of the early 1920s, and the subsequent global economic collapse of the early 1930s, was so fresh in the minds of so many Germans, this metaphor must have resonated.

After 1941, Walter would transport these tools to eastern Europe, where the Nazi dreams of empire in Africa would collide with the reality of war in eastern Europe.

Chapter 4

The Cracks in the Earth: Bioeography and Military Geography in Eastern Europe in Nazi Germany's Final Years

Here in the Ukraine one is always aware of the problem of whether the Ukrainian earth could be employed for the improvement of the European food foundations [Ernährungsgrundlagen], when it is possible to influence

> *the water conditions [Wasserhaushalt] of the Steppe-earth [Steppenböden]. All means of obtaining higher yields [Ernten] are in the end limited in their effect by the dampness of the earth [Bodenfeuchte]. Where artificial hydration [künstliche Bewässerung] is possible is where the Ukrainian earth will first show what it can truly give. I have often experienced a sky full of clouds, but it would not rain. Such weather cannot bring the necessary moisture to the all too dry earth, and when it finally rains, the rain runs over the earth, without sinking in, and shortly the burning sun has evaporated the water, and soon the finger-width dry cracks [Trockenrisse] are open again. Large areas must be forested. The forests would save the water run-off, and hinder the the opening of the cracks in the earth, which are often deeper than a man.*Werner Jahns, 1942[1]

Mapmaking played a central role in the calculation of biological productivity. Cartographic technologies also cut across a wide range of scientific disciplines, binding together ecologists, plant sociologists, soil scientists, geologists, and, of course, geographers. From the ecological standpoint, cartography united the two fundamental strands in this narrative of primary productivity's genesis: ecological quantification and geopolitical maneuvering. Just as primary productivity developed in the biological sciences alongside other large aggregate quantifications, such as Gross Domestic Product, the division of the world into distinct

[1] /Universität Hannover/Institut für Geobotanik/Reinhold Tüxen Papers/Rundbriefe 10 1942, p.60/Werner Jahns, 28.06.1943.

environmental regions paralleled the evolving geopolitical view of swathes of culturally, economically, and politically differentiated territories. After the war, these broad geographical classifications would become increasingly important. In geopolitics, the "Soviet Bloc," "Red China," "NATO," and the decolonizing "Third World" were central to the American vision of strategic conflict. In the International Biological Program, on the other hand, creating a global picture of primary productivity depended upon a spatial extrapolation of statistical samples of the average productive output of different regions. As with the creation of any big geographic statistic, sampling a large enough area, and then assuming that similar production factors would produce similar output in other like regions was an essential technique. Vast biogeographies of the world, many undertaken by Walter and his student Helmuth Lieth, were essential to this project. By breaking the world up into distinct "biomes," it became easier to extrapolate production statistics over much larger regions than those actually measured. While the plant sociologists had sought to place distinct communities into a taxonomy based around community species composition, the broader approach that correlated climate with specific rainfall ultimately won out. The late nineteenth century work of the Crimean-born, German-educated biologist and meteorologist Vladimir Köppen was essential to creating these broad classification systems. Walter's forebearer Andreas Schimper was also important to this global classificatory effort. Schimper was the founding father of German ecology (and one of the first self-proclaimed ecologists, along with the Danish botanist Eugen

Warming), who also coined the term "rain forest" (*Regenwald*) in 1898 while blazing the German trail down the Amazon which Otto Schulz-Kampfhenkel would follow over 30 years later. Once the world had been divided into deserts, temperate forests, arctic zones, grasslands, and rain forests, creating global production estimates for each biome became much easier. It is therefore of more than passing interest that one of the first calculators of biological productivity, Heinrich Walter, would find himself a part of a vast mapmaking effort in the latter days of World War II.

The Nazi role in the story of biological productivity ends in the same place as the dreams of a greater German empire ended: in Eastern Europe. As seen in the preceding chapter, the globalization of primary productivity measurements was presaged by Nazi plans of a German empire in Africa. This is not to suggest there is anything inherently racist, militarist, or imperialist in the measurement of primary productivity. However, it is undeniable that some of the first efforts to quantify ecological output in non-agricultural systems beyond the borders of western "civilization" occurred as efforts at ecological reconnaissance by a Nazi-funded scientist in a region of Africa where the German military had nearly driven two peoples to extinction four decades prior. Yet this was not due to any particular ideological affinity the Nazis had for quantitative measurements of ecological productivity. Rather, biological productivity fit with a more general trend towards aggregate production measurements among all the combatants of World War II. Measures of national economic productivity, the ancestors to today's Gross Domestic Products, had their origins in this time. It was a time for large aggregate measures. World War II pitted the largest nations with the largest economies and the largest armies against each other in the largest armed conflict before or since. And, while its human toll would hardly register on the upward trend of global population, it remains the largest concentrated episode of mass human death in history.

In western Eurasia, the center of that storm of violence was the area between western Poland and eastern Ukraine, where the vast majority of the war's European fatalities occurred.[2] This was the area where Germany's imperial dreams had always been most intense, their genocidal fin de siecle adventures in Southwest Africa not withstanding. It is to this area that their ecologists, geographers, and plant sociologists were directed as the Russian winter closed in on the *Wehrmacht* in 1942. At Reinhold Tüxen's *Zentralstelle für Vegetationskartierung*, the construction of a scientific mapmaking unit in eastern Europe under the leadership of the biological explorer and SS officer Otto Schulz-Kampfhenkel was welcomed as a "sudden and unexpected opportunity":

> The establishment of a new department has given us extrodinary possibilities. ...Through the action of Dr. Schulz-Kampfhenkel's *Forschungsstaffel* we have found a sudden and unexpected opportunity. I take great pleasure in using this opportunity to give heart-felt thanks to the leader of the *Forschungsstaffel*, Lieutenant Dr. Schulz-Kampfhenkel, for his energetic action in all areas. In the *Forschungsstaffel* Schulz-Kampfhenkel three

[2] **snyder2010** documents how the majority of both Stalinist Russia and Nazi Germany's victims were killed in this region.

> [plant] sociological groups are working on economic and military efforts [wirtschaftliche und Wehrmachtsaufträge] in Russia. In the east Preising's group, with Hansen, Hölscher, [Werner] Jahns...has been extremely sucessful. Friend [Heinz] Ellenberg will also lead a special group. He is at the moment working with friend Preising. In the Ukraine, Zeidler's group works with great success.[3]

Heinrich Walter was part of this special unit, and he brought with him his fascination with aridity, as applicable to Germany's dreams of a future development of the Russian Steppes as to their hope of a return to Africa. The young botanist Werner Jahns, writing back home from the front in 1943, alluded to these issues as well, and to the need to apply German ingenuity and artificial irrigation (*künstliche Bewasserung*) to the Ukrainian earth in order to improve "European food foundations." Jahns's dramatic description of the Steppe environment, the epigraph to this chapter, shows the full impact that this aridity had on a person used to the wet and green temperate environment of central Europe. More importantly, it displays the increasingly intense German preoccupation with food and starvation. While Walter's productivity studies would take a back seat to the mapmaking efforts of the *Forschungsstaffel* during this period, their central animating concern with food supply was ever present. Germany had gone into each stage of its war knowing that a rapid victory would be necessary, because only once the resources of conquered and violently pacified territories were turned towards feeding and

[3] /Universität Hannover/Institut für Geobotanik/Reinhold Tüxen Papers/Rundbriefe 10 1942, p.54.

fueling the expanding Nazi empire could Germany continue to fight. The fear of starvation and resource depletion had been both one of Nazi Germany's primary domestic propaganda tools and a genuine motivator behind the actions of the Nazi elite. Hunger had played a major role in Germany's surrender in 1914, when their military was still essentially intact and as capable of continuing the conflict as any of the other major belligerents (and when Russia was defeated, occupied, and torn apart by internal political strife). Moreover, more than guns, germs, or gas, starvation was the primary mechanism by which Nazi Germany murdered millions of humans across eastern Europe. It was no accident, than, that environmental scientists would have a part to play in the penultimate chapter of the story of European imperialism. And it was only fitting that, in the end, the slow death of hunger would be inflicted upon German soldiers and civilians alike.

The actions of the *Forschungsstaffel* are largely ancillary to our central story of primary productivity's journey from the geopolitics of autarchy to the internationalism of global ecology. Moreover, they have largely been documented in Mechtild Roessler's studies of German geography's role in the theory and practice of eastern expansion.[4] However, the practical deployment of so many of Germany's ecological scientists in the development of new cartographic methods in eastern Europe is indicative of several larger features of Germany's concept of resource war. First, it represents the increasing conviction that German ingenuity and technological innovation could circumvent the increasingly

[4]Mechtild Rössler. *"Wissenschaft und Lebensraum": geographische Ostforschung im Nationalsozialismus, ein Beitrag zur Disziplingeschichte der Geographie.* Hamburger Beiträge zur Wissenschaftsgeschichte, 1990

catastrophic resource constraints the country faced in the final three years of their war. Heisenberg's nuclear project, von Braun's rockets, and the new models of improved submarines and jet fighters produced under Albert Speer's reign as armaments minister are the most well known manifestations of this inventive period. However, the organization of civilian scientists into a special section for developing new cartographic methods is illustrative of the exact same impulse. Indeed, in the postwar era, this belief in the capacity of technological innovation to deliver humanity from one ecological bottleneck or another would often reappear. Yet just as primary productivity transitioned from a tool of militarist self-sufficiency to a measure of humanity's global trophic base, these innovationist narratives would more often be applied to human destiny than any singular national one in the postwar era. Secondly, the *Forschungsstaffel* hints at the wide range of scientific disciplines devoted to natural resource productivity in Germany during this period. One of these was forestry, a science that was both an important precursor to ecology, and a particular aptitude of the Germans since the seventeenth century. As Russia harbored some of the largest forested lands on earth, and as the German traditions of both practical and theoretical forestry were so strong, the role of this science in the genesis of biological productivity measurements is worth dealing with in this chapter. Indeed, one of the young scientists employed in the *Forschungsstaffel* was Heinz Ellenberg, a student of both Tüxen and Walter whose controlled ecological experiments in the forests of the Hartz mountains would find a place in the International Biological Program of 1964-1972, the principle vehicle of primary productivity's globalization. Finally, one of the main arguments of this study is that the Nazi vision of a global slave empire was perversely instrumental in bringing about the era of so-called globalization which we now inhabit. This is not to say that the Nazi war of conquest was a "necessary evil" to instantiate globalization. Indeed, the human suffering and environmental degradation wrought by the expansion of the global economy are the mark of globalization's imperial ancestor, and the Nazi drive to world power was in many ways 400 years of European imperialism taken to its nightmarish yet logical extreme. And, regardless of how one fills in the ledger of costs and benefits of American-led globalization since 1945, there could have been many other paths to that goal that did not involve mass murder on a scale that would have driven any other large mammal to extinction. The movement of primary productivity measurements from autarkic racist-nationalist Malthusianism to global ecological Malthusianism is a microcosm of this larger transformation. Given the central role of the eastern European war and subsequent Warsaw settlement to the two-power global world that followed, the involvement of several German scientists central to postwar global ecology in desperate cartographic efforts in the region, most notably Walter, Heinz Ellenberg, and the geographer Carl Troll, is a more than passing concern.

Walter's work on the "struggle against aridity" (*Durrebekampfung*) between Africa and Russia demonstrates clearly the relationship between Germany's African colonial dreams and the brutal Russian reality. Subsequent postwar work by Walter and Troll on the region, as well as on Africa, elaborated upon this, although now in the context of global "development." Finally, the question of related sciences of quantitative biological productivity and their relevance to the Russian war is dealt with using the important example of forestry.

Geographic Science in the Eastern Occupation

Distinguishing between military geography, long-term agricultural development planning, and the planned extinction of millions of human beings is difficult when dealing with the planning and execution of the eastern European occupation. By the time Heinrich Walter joined the *Forschungsstaffel* in Spring 1943, the battle of Stalingrad had been lost, the planned Spring 1941 *Blitzkrieg* of Russia had failed, and the question was when, rather than if, the German army would be driven out of Russia. However, since more people died under Nazi occupation than in the actual advancement of the front lines, the maps that allowed the Wehrmacht to hold territory for as long as possible, retreating as slowly as they could, also allowed the various elements of the deadly ecology of German-controlled eastern Europe to do their work for as long as possible. Moreover, the Nazis' long-term plan of agricultural development involved not simply exploiting the laboring peasants of the black earth region, as France and Britain did in their Asian and African colonies, but exterminating them and replacing them with "Aryan" peasants. This was in part necessitated by their short-term agricultural development planning, which hinged on Herbert Backe's so-called "hunger plan." This amounted to feeding the invading German locusts at the expense of the indigenous people of eastern Europe. Backe had himself written a (failed) dissertation on the grain economy of Russia, and the primary body responsible for the planning of the agricultural economy in the region, the *Wirtschaftsstab Ost*, was deeply implicated in this planned starvation.

As nicely summarized by the historian of Nazi food policy, Gesine Gerhard:

> On 23 May written guidelines were circulated that reiterated the conclusions from the earlier meeting. The twenty-page document was authored by the agricultural section of the Economic Staff East (Wirtschaftsstab Ost) under the directive of Hans-Joachim Riecke. Germany would extract large amounts of agricultural produce from the surplus territories, while Soviet citizens in the deficit areas would face terrible famine. Ultimately, the grain-producing areas of the Soviet Union would become part of the larger continental European market dominated by Germany. In case there were any questions left with regard to what would happen to the Soviet population in these territories, the document stated, "Many tens of millions of people in this territory will become superfluous and will die or must emigrate to Siberia. Attempts to rescue the population there from death through starvation by obtaining surpluses from the

> black earth zone can only be at the expense of the provisioning of Europe. They prevent the possibility of Germany holding out till the end of the war, they prevent Germany and Europe from resisting the blockade."[5]

This was "development" in the narrow sense of altering an economy to suit its inclusion in a larger and highly dynamic "market," but only a hopelessly cynical author would attach that label to Nazi agricultural policy in the east. However, the Nazis did have more conventional "development" goals in mind, as Susanne Heim has shown in the case of German plans to create natural rubber plantations in the east. Here is where the scientific expertise of ecologists, plant sociologists, soil scientists, agronomists, and breeders became directly relevant. And it was this sort of work, Walter claims, which brought him to the *Wirtshaftsstab Ost* in Berlin in 1943. By this point, Germany's plans for the east belonged in the "realm of fables" (as Mitscherlich described conventional agronomy which ascribed strict limits to productive potential) every bit as much as the African re-colonization dreams which led the state to support Walter's work in Libya and the future Namibia. Yet Walter continued to find employment in that hallowed realm, whose intersection with the reality of what Germany was capable of had already spawned so much suffering. He worked an office job there, filtering through enormous bundles of files, all related to the support of agricultural institutes in the east. What future these agricultural institutes had by 1943 was debatable.

[5] Gesine Gerhard. "Food and Genocide: Nazi Agrarian Politics in the Occupied Territories of the Soviet Union". In: *Contemporary European History* (2009), p.58

Decades later, Walter professed to have been bored by his work at the *Wirtschaftsstab Ost*, where neither his scientific knowledge nor his knowledge of Russian were utilized. Walter was an erstwhile traveller, and practical goals and even meticulous scientific research (of which he produced a lot, and would continue to produce well into the 1970s) sometimes seemed to be secondary to his desire to explore as widely as possible. Like the late-nineteenth-century plant geographer and foundational German proto-ecologist Andreas Schimper, whose encyclopedic work Walter would take to updating after the war, he was rather bored by the environs of central and western Europe. His genuine fascination with the variability of the planet's ecosystems is difficult to dispute. Even eastern Europe was more of a practical nationalist commitment than a passionate scientific one for him. After the war, he would return to African and other sub-equatorial researches. Walter was born in Odessa in 1898, when the Ukraine was part of the Russian Empire, and studied there and then in Dorpat before coming to Germany (Jena) at age 21. He had been traveling around eastern Europe ever since finishing his African work in 1941, undertaking various jobs of translation and agricultural administration. His geographical acumen, knowledge of plant physiology, and fluency in Russian made him a rather useful tool to the military and economic masters of the occupied east.

> Durch Zufall traf ich Botaniker, die bei einer Sonderstaffel waren und sich für einen kartographischen Einsatz in der Ukraine vorbereiteten. Ich erfuhr, daß die Sonderstaffel Dr. Schulz-Kampfhenkel unterstand, einem

> Zoologen, der am Amazonas den Film "die Grüne Hölle" gedreht hatte, während des Krieges eine Erkundungsexpedition zum Tibetsi-Gebirge in der Sahara leitete und jetzt Wissenschaftler, und zwar Geographen und Geobotaniker sammelte, um sie auf dem Balkan und im Osten zwecks allgemeiner Erkundung der Länder einzusetzen. So sollte z.B. die große bodenkundliche Karte von Prof. Machow in Kiew zusammen mit ihm selbst im Gelände auf einer Fahrt von Kiew zur Krim von einem deutschen Bodenkundler überprüft werden. Prof. Machow konnte nur russisch, ein wissenschaftlicher Dolmetscher war notwendig, ich kannte schon die Gegend und Bodenkunde interessierte mich als Ökologen sehr.[6][p.151]walter1980

Archival evidence suggests that Tüxen too visited the *Forschungsstaffel* section in Kiev, as a notebook labeled "Ukraine, 1942" can be found among the many field notebooks in the *Zentralstelle*'s Hannover archive, complete with a dried vegetation specimen, perhaps preserved for over 70 years (see 4.1). While many of the ecologically-minded scientists on the *Forschungsstaffel* came from Tüxen's *Zentralstelle*, the research group was staffed by a far broader cross-section of the nascent environmental sciences. Indeed, in this it was not unlike the wide range of scientific disciplines who would make use of "primary productivity" in the postwar age of environmental catastrophism. Each section of the *Forschungsstaffel* included scientists from the disciplines of:

[6] **"par** ff

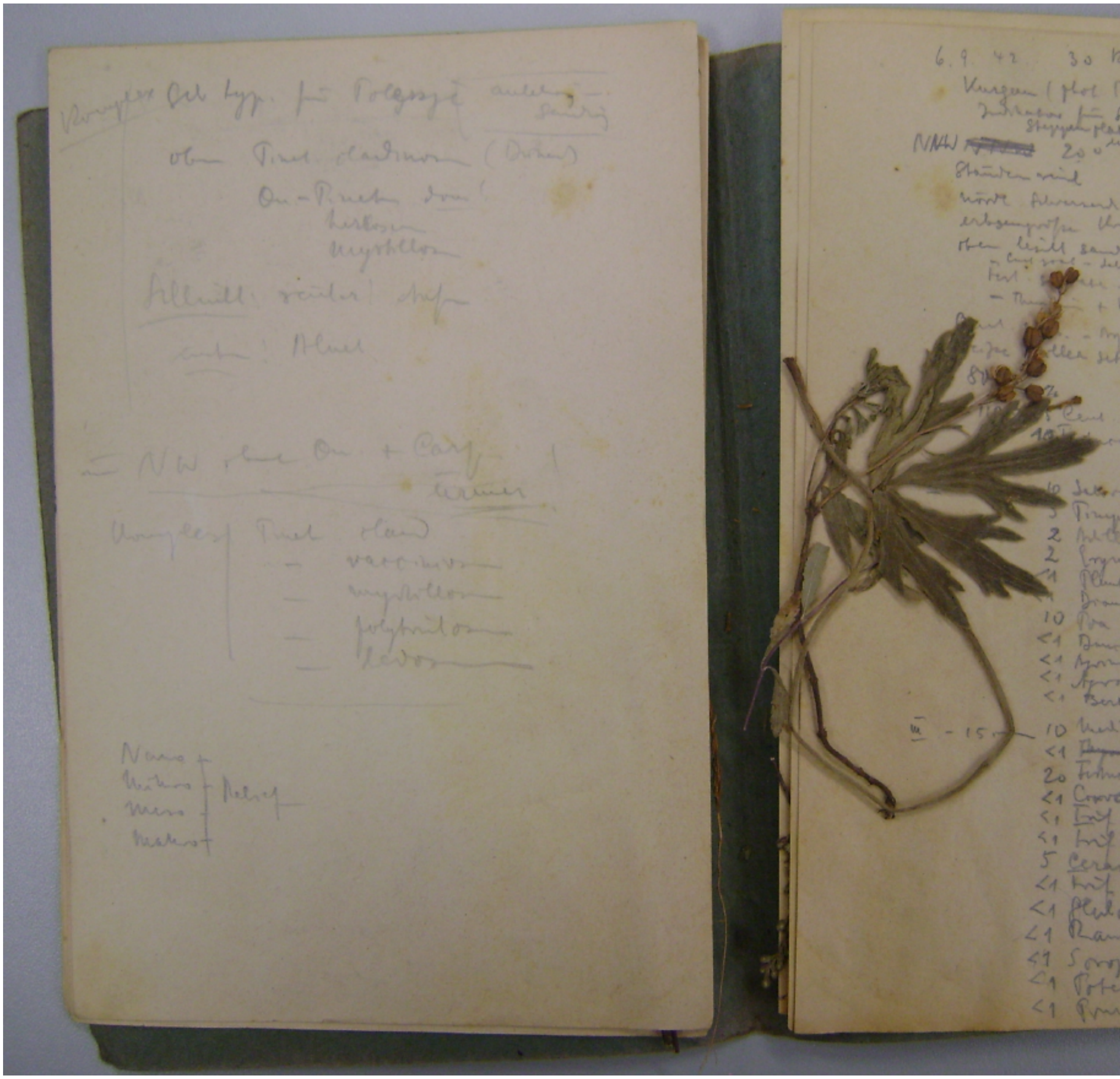


Figure 4.1: Tüxen's Field Notebook from Ukraine, 1942 (from /Universität Hannover/Institut für Geobotanik/Reinhold Tüxen Papers/Field Notebook Labelled Ukraine, 1942)

geography, ecology, hydrogeography, geology, soil science, cartography, and photogrammetry (identifying referance points and their pathways of movement on a moving object or surface).[7]he *Forschungsstaffel* was one of the three primary instruments of martial geography in Nazi Germany. The other two were the *Militärisches Geowesen* (MilGeo), the army's internal cartography department, and the *Marinisches Geowesen* (MarGeo), who developed nautical maps for the navy. The *Forschungsstaffel* was differentiated from these two bodies primarily by its extensive employment of civilian scientists, and its dedication to the development of both new cartographic and surveillance technologies, and its application of the environmental sciences to agricultural and mining projects. Thomas Smith and Lloyd Black. "German Geography: War Work and Present Status". In: *Geographical Review* 36.3 (1946), pp.401-402

In 1946, two American geographers, Thomas Smith and Lloyd Black, conducted a survey of the role of German geography in the war effort as part of the Allies' project to document what was useful and what was useless in German military science. The *Forschungsstaffel* included at least 80 scientists divided into several sections, which could be grouped broadly under military geography (mapmaking and aerial photography) and build-up (*Aufbau*) in the occupied East.[8][p.205]roessler1990 Again, while there is no evidence that the measurement of primary productivity or the Mitscherlich curve were invoked during the *Forschungsstaffel*'s work, the broader concerns with natural food and fuel productivity

[7]T

[8]**"par** ff

that created such a receptive environment for this particular type of biological quantification animated much of the groups work. The "build-up in the occupied East" section of the *Forschungsstaffel* included a range of diverse research projects, all related in some way to the fundamental Malthusian question of resource production. The different projects were: building material exploration in the area of the army group north and central and the *Reichskommissariat* eastern and the Ukraine, vegetation and soil mapping in the Baltic lands and revisions of the Russian vegetation and soil maps of the Ukraine for land planning in the occupied east, documenting medically useful palnts in the Ukraine, and research into fiber plants and cellulose sources in the Ukraine. Finally, and most interesting given the intertwining history of biological productivity measurements and the nascent fossil fuel economy, there was a project on the study of industrial relocation sites, factory construction, oil shale (*Ölschiefer*), petroleum (*Erdöl*) prospecting, quartz mining, wood harvesting and transportation, and the division of collective farms (*Kolkhoz* in Russian, *Kolchose* in German) in the Baltic states, White Russia, and the Ukraine.[9]

Initially marginal, Estonian oil shale supplies played an increasingly important role in Germany's increasingly desperate energy strategy as the war advanced. Otto Schulz-Kampfhenkel had formed the *Forschungsstaffel* in Libya, where General Erwin Rommel's *Afrikakorps* made their final grasp after England's petroleum lifeline. With the failure of the North African campaign, and the inability to consolidate Russian gains and push past

[9]Rössler, *"Wissenschaft und Lebensraum": geographische Ostforschung im Nationalsozialismus, ein Beitrag zur Disziplingeschichte der Geographie*, p.205

Stalingrad into the Caucusus, where the majority of Russia's oil supplies originated, the necessity to tap every possible hydrocarbon resource became increasingly dire. Germany's pursuit of oil autarky closely paralleled their pursuit of food autarky, the latter of which had been a crucial enabler of the rise to prominence of both Mitscherlich's curve and Walter's biological productivity measurements. The Nazis mounted a consolidated drive to wean Germany off oil imports in the build up to war, going from importing over 70% of their oil in 1936, to domestically producing over 70% by 1944. Over half of that domestic production employed the Fischer-Tropsch process for liquifying coal, one of the mined commodities, along with potash (a central ingredient in Mitscherlich's plan to increase German agricultural production), that Germany had plentiful supplies of. Raymond G. Stokes. "The Oil Industry in Nazi Germany, 1936-1945". In: *Business History Review* 59 (1985), pp. 254–277, pp. 255-56

Between 1940, when Romania joined the Axis powers in advance of the April 1941 invasion of the Balkans, to 1944, when they were expelled, control over their primary foreign petroleum supplier (other than pre-1941 Russia, of course), further helped the situation. The significance of Romanian oil is attested to by the extensive German-language scientific work in petroleum prospecting undertaken by the German geologist and paleontologist Karl Krejci-Graf.[10] Although ancilary to the story

[10] Karl Krejci-Graf. *Die rumänischen Erdöllagerstätten.* Schriften aus dem Gebiet der Brennstoff-Geologie. F. Enke, 1929,Karl Krejci-Graf. *Grundfragen der Ölgeologie.* Schriften aus dem Gebiet der Brennstoff-Geologie. Ferdinand Enke, 1930,Karl Krejci-Graf. *Erdöl.* Springer, 1936, and Karl Krejci-Graf and Walter Wetzel. *Die Gesteine der rumänischen Erdölgebiete in lithogenetischer und ölgeologischen Beleuchtung.* Preussichen Geologischen Landesanstalt, 1936

of the *Forschungsstaffel* and primary productivity being told here, Krejci-Graf's role in both the development of prospecting techniques and the gaining of unimpeded access to Romanian oil supplies demonstrates another aspect of the larger structure this study is describing. Namely, the manner in which shifting geopolitical relationships have been motivated in part by access to the carbohydrate and hydrocarbon primary products of photosynthesis, and the way a wide range of environmental sciences have been both mobilized by these shifting alliances and oppositions, and have also played a keystone role in defining what it is that geopolitical organisms were struggling over.

> In verantwortungsreicher Stellung und mit viel sterreichisch-diplomatischem Geschick hatte er auf die fr Deutschland so wichtige Erdlfrderung Einflu zu nehmen. Dort begegnete ihm der Verfasser zum zweiten Mal anllich seiner wirtschaftsgeologischen Arbeiten im Sdosten.[11]

Survival of the Unfit: Path Dependence and the Estonian Oil Shale Industry. Linkoeping University, 2008

The Global Struggle against Aridity

The effect of drought on food supply, and the limitations aridity placed on the expansion of agriculture, were global problems in the 1930s and 1940s. We have already seen how Walter's early

[11] W.E. Petrascheck. "Karl Krejci-Graf Obituary". In: *Mitteilungen der Österreichischen Geologischen Gesellschaft* 81 (1988), p.260

physiological interest in water uptake translated into his ecological work in the field in Hungary, Libya, and Southwest Africa. Born in Odessa and fluent in Russia, applying his knowledge of aridity ecology to the Russian context came naturally. Yet he was not alone in confronting the dilemma of drought, one of the greatest drivers of mass human movement. Some historians think that drought played at least as much of a role as intentional confiscation of grain in famines of the 1930s in Ukraine and other parts of the USSR[12] In North America, drought of truly epic proportions destroyed the agricultural economy of the continent, just as America's financial and manufacturing sectors collapsed. The Dust Bowl drove half a million humans from their homes in a desperate search for irrigated land.

Meanwhile, in Palestine, Zionist immigrants fleeing Europe had to struggle against a desert landscape to create a sustainable agricultural infrastructure. One of these immigrants was the Czech-born, German educated plant ecologist Michael Zohary. Zohary's dissertation on the mechanisms by which desert plants dispersed their seeds was published in Munich in 1937. Zohary's case is an interesting one, which is worth a brief diversion. It is relevant to the issue of ecology's role in wartime development in several general and specific ways. Specifically, despite being forced from his home by the Nazis, Zohary considered himself an ecologist in the German tradition. Not only was his 1937 dissertation written in German and published in Germany (surely an unusual occurance for a scientist based at the University of Jerusalem in 1937), but Zohary maintained close ties to the German ecological

[12] **tauger1991**

and plant sociological community, publishing his magnum opus, *Geobotanical Foundations of the Middle East*, in a series edited by Reinhold Tüxen in 1973. Tüxen, of course, was the head of Germany's *Zentralstelle für Vegetationskartierung* during the war, a state institute which supplied much of the scientific labor for the *Forschungsstaffel*. More generally, the creation of Israel represented one kind of development project that offered an alternative to the old European geopolitical order that had begun crumbling away in 1914. The Nazi program of genocide and conquest which necessitated the acceleration of Israel's development represented another alternative. Both programs drew on the expertise of ecologists, geographers, and agronomists, and both had the transformation of arid land into productive soil as one of their principle concerns. Finally, I touched briefly on Nazi meddling in Iraq, Palestine, and Libya in the previous chapter. Libya was of special significance, as it was there that Walter discussed explicitly the relevance of ecological science to Fascist (in this case Italian) colonization, it was there that Germany's tanks would make one of their final stands in a desperate bid to turn the tide of the war by cutting off Britain's oil supply at the Suez, and it was there that Otto Schulz-Kampfhenkel, having returned from his expedition through the Brazilian amazon, further developed the aerial mapmaking techniques that would be the focus of his *Forschungsstaffel*'s efforts in eastern Europe.

Perhaps not coincidentally, Zohary the immigrant to Israel was interested scientifically in the dispersal of spores and seeds. Generally, this process is called "telechory." This study is not overly concerned with the place of metaphor and personal experience in scientific change, but the symbolism is unavoidable. However, Zohary was interested specifically in the conditions that would compel adaptations to limit seed dispersal, namely, the desert conditions of extreme aridity. In an ecology like that of the Negev, limiting dispersal could actually be an evolutionary advantage to a plant. This is due to the fact that by its very existence, the parent plant "knew" that it had found water. However, if it sent its offspring too far afield, the probability that they would land in a place with water decreased exponentially. Zohary coined the term "antitelechory" to refer to this particular plant adaptation to arid desert environments. He then set about documenting cases of antitelechory in the specific morphology of different native seed casings of the Negev.

Forest Productivity

Primary productivity measurement, or the "productivity of the plant cover (*Produktivität der Pflanzendecke*) as it was generally called in this period, grew in part out of the practical sciences of biological resource management. Laboratory plant physiology also played a role, as demonstrated back in Chapter 1, and I have focused up to this point on the synthesis of agronomy, physiology, and field biology which led to production ecology. Yet other practical resource sciences besides agronomy and its sub-fields soil and fertilizer science also played a role in laying the groundwork for conceptualizing macrobiological systems in terms of their total productive output. Fisheries biology, in which Peter Boysen-Jensen had published his earliest studies before turning to CO^2 uptake and physiological *Stoffproduktion* in the 1920s, was one such science. More crucial to the lush temperate forests of Germany, however, was forestry. Given the immense amount of forested land in Russia, arguably the largest in a single country in the world, and the fact that at least one scientific traveler from the *Zentralstelle für Vegetationskartierung* to the eastern front, Fritz Reinhold, published an extensive study of Russias forest resources, scientific forestry must be touched upon here. German forestry was a fascinating nexus of practical resource management, economic theory, nascent ecological concepts, and nationalist ideology.

Like primary productivity, German forestry followed a path from localized domestic measurements to global aggregate quantification. And as with primary productivity's journey, this expansion of the sciences geographic scope was facilitated in large part by Germany's imperial aims. Yet with Walter's measurements of productivity in Southwest Africa, and with his work on eastern European agricultural policy, his focus remained relatively local. The localities he was dealing with were far removed from the German domestic ecosystem with which Mitscherlich had concerned himself, but the basic scale of his work was no greater. If anything, he perhaps scaled back from Mitscherlich's 27,069 field experiments, although he certainly dealt with far larger systems than the plant sociologists with their highly specific community taxonomy. Primary productivity would have to wait until the postwar period to graduate to genuinely global aggregate measurements. German forestry, on the other hand, was already realizing those ambitions by 1941, and Franz Heske's *Institut für Weltforstwirtschaft* (Institute for Global Forestry Economics) in Hamburg. Heske's institute grew with the Nazi state, like Reinhold Tüxen's *Zentralstelle*, which started as a local institute attached to the Hannover vetinary school to a *Reichsinstitute* ordained as such by the office of Hermann Goering in 1939, wearing his *Reichsforstminister* hat:

> Ich habe davon Kenntnis genommen, daß Sie bereit sind, die Leitung der Zentralstelle für Vegetationskartierung des Reiches in Hannover zu übernehmen und danke Ihnen für Ihre Bereitwilligkeit.[13]

In Heske's case, what started as the *Institut für ausländische und koloniale Forstwirtschaft* in the town of Tharandt, became an urban *Reichsinstitut* the same year Tüxen's *Zentralstelle* born.

For Heske, German forestry represented both a practical tool of resource management and a spiritual stronghold where the Germany had remained immune to the pernacious influence of Anglo-Saxon liberalism. On the ideological front, after all, Nazi Germany was at war with the "decadent" western capitalist democracies as much as they were at war with eastern communism and the Jewish people. For Heske, this meant that forestry was an area where both individual gain and the immediate profit motive were ignored in favor of the good of the larger national community and its future needs. Ironically, it was a German forester, Martin

[13] /Universität Hannover/Institut für Geobotanik/Reinhold Tüxen Papers/Briefe 1938-75/Reichsforstminister to Reinhold Tüxen, 22.07.1939

Faustmann, who in 1849 had formulated the most ruthlessly captalist mathematical solution to the economic question of "when to fell a forest stand?" in the history of forestry economics. Quantification initially found its way into seventeenth-century German forestry in the form of geometry, which allowed foresters to calculate the amount of wood different sized trees would yield by employing formulas for determining the volume of a colummn or sphere.[14] However, the economic quantifications of Faustmann in the mid-nineteenth century were quite different. Paul Samuelson. "Economics of Forestry in an Evolving Society". In: *Economic Inquiry* 14 (1976)

> Various angles of [the industrial revolution in Germany starting in the mid nineteenth century] have had a marked influence on forest land use in Germany... First in importance was the rapid development of means of communication... The second aspect of the industrial revolution that affected forestry was the far-reaching change from the use of organic to the use of inorganic materials. Thereby wood lost in relative importance. [As Werner Sombart put it] "Whereas wood was the essential raw material of earlier times, and material civilization emanated mainly from the forest, coal now moved to focal point." The third factor was *the rapid increase in population* and the simultaneous industrialization of the economic structure, especially since the founding of the

[14] Henry Lowood. "The Calculating Forester: Quantification, Cameral Science, and the Emergence of Scientific Forestry Management in Germany". In: *The Quantifying Spirit in the Eighteenth Century*. University of California Press, 1990. Chap. 11 elaborates on this first chapter in German quantifying forestry.

> Reich (1871). These greatly increased the economic power of the German people, but at the same time made very heavy demands on the raw materials of the homeland, including the forests. Home supplies could not long continue to meet these demands, so that the importation of foreign raw materials early acquired special importance... The growth of commerce and of material civilization made capitalistic enterprise the typical form of economic life, and thinking in terms of money and profit became increasingly the dominant spirit of the departing nineteenth century and of the period just preceeding the World War. No branch of economy and culture could remain aloof from these influences. The doctrines of liberal capitalism for a time dominated even German forestry... In the course of this development the scientific foundation and the technique of various branches of *primary production*, including forestry, were worked out.[15]

With the war's end, so ended biological productivity's career as a tool of imperial quantification. In the dawning American age, it would have to be adapted to a new, American-led, global order.

[15]Franz Heske. *German Forestry.* Yale University Press, 1938, pp.36-37 My emphasis.

Part II

America and Global Ecology, 1945-1989

Chapter 5

A Member of the Food Chain, or Trophic Class and Population Control in the Cold War

> *I am frequently asked about the carrying capacity of the earth for humans. I wagered a few times such guesses. I enclose the latest one. I think we are entitled to use ecological logic and treat man as a member of the food chain. I am sure I shall be criticized for my calculations but that does not matter much. We should probably include in the book all honest assessments of population sizes for the world.*

-Helmut Lieth, 1974[1]

'I will suggest the predicament of our society," remarked Professor Robert Whittaker at the close of his talk in 1969.

> A system of accelerating growth and increasing complexity is stretching ever tighter its means of organization, while producing social and environmental problems ever more difficult and beyond realistic prospects of solution, while increasing the tensions and frustrations of the human beings who must maintain the organization and try to deal with the problems, while producing increasing numbers who scorn the system and its complexities without a rational sense of the limitations on alternatives, while producing small but increasing numbers of human beings sufficiently damaged as such that they desire the ruin of the society which, for all they can understand, is responsible. I find this, if true, an unencouraging system of simultaneous, nonlinear, differential equations. One need blame no single development or factor which might reasonably have been different-whether overpopulation, or infatuation with technology, or wealth and parental indulgence, or decline of religion and moral restraint, or ruthless commercialization of young people's entertainment-for these processes interlink and intensify one another. Tragedy, or its potentiality, too, can be an

[1] /Cornell University Special Collections/Robert Whittaker Papers/Box 1/Primary Productivity Folder/Helmut Lieth to Robert Whittaker, 22.10.1974

> evolutionary product.[2]

"The very real possibility is being raised that this is the last time [the world has gone to hell]," queried Professor Lawrence Slobodkin.

> You pointed it out, Dr. [Garrett] Hardin pointed it out, and we have all pointed it out in print and in classes; but I feel that unless we have a political path indicated, or at least make apparent the political difficulties associated not only with the problems but with the attempts at their solution, we may find ourselves in the very embarassing position of being a toll either of repressive political acts or of revolutionary agencies that we would rather not be enslaved by. The second of these is obvious...the revolution is all around us... The possibilities of our being a tool for repressive political agencies are somewhat subtler because the things that are being...properly condemned on ecological grounds, are the things that are normally labeled as progress, advance, and attempts at solution of social problems... we condemn suburban sprawl, and suburban sprawl is ecologically disasterous and has social tragedies associated with it, but the slums are full of people now who would like nothing better than the opportunity to engage in suburban sprawl. They will take this opportunity one way or another unless some alternative is provided. By pointing out the dangers of suburban

[2]Whittaker, "Evolution of Diversity in Plant Communities", pp.192-193

> sprawl, we can provide an excuse for inaction in the area of housing, and inaction in the areas related to social justice, unless we provide alternatives or at least warn of the political dangers associated with ecological benefits.[3]

"I suspect...that we are indeed trapped in these things and they will work themselves out with a relentless logic," replied Whittaker.

> ...both those who are more optimistic and those who are less optimistic should try to understand what is happening to our environment and civilization, and...try to guide these processes where intelligence and foresight and political technique can be applied to gain some kind of benefit, either a temporary and local one or a prolongation of the term of life that our civilization has... we must apply to fundamental problems- not just symptoms- fundamental solutions if Western civilization is to escape self-destruction. In regard to the ecologist's alarm being used for purposes of repression- no more than you, would I want this. And yet...the voice of the ecologist is very small before the enormous power of this system of ours, this great juggernaut that we have created, that by its own internal dynamics, regardless of what the ecologist says, will produce the repression if repression comes.[4]

[3] Whittaker, "Evolution of Diversity in Plant Communities", pp.195-196
[4] Whittaker, "Evolution of Diversity in Plant Communities", pp.196

Population Control

was an issue central to both political ecology and its more scientific cousins from the 1960s through the 1980s. However, just as primary production had a very different meaning in economic discussions than in ecological ones, population control was a different beast depending on whether the discussion was sociological or zoological. The reader will remember that social scientists used primary production to refer to the agricultural and raw material sectors of an economy, while natural scientists used the term to refer to the aggregate plant matter produced through photosynthesis. Similarly, population control designated more or less coercive attempts to restrict human reproduction around one conference table, and the factors which regulate demographic growth among animals and plants around another. This chapter will focus on the latter biological use of the term, yet it cannot be understood without reference to the geopolitical milleu in which the former played a role. Indeed, many of the scientists involved in researching biological population control were also vocal advocates for its social varient, not least the afforementioned Professor Whittaker. Not coincidentally, those scientists whose view of society suggested a need for political population control, such as Whittaker and the famous Stanford butterfly biologist and public neo-Malthusian Paul Ehrlich, also devoted much of their research to quantifying primary production. Meanwhile, scientists such as the population ecologist Lawrence Slobodkin, who was politely skeptical about the implications of political population control, focused on the dynamics of trophic relationships within a multi-species community, rather than simply the size of the total photosynthetic resource base.

In this chapter, I will deal with the political and scientific differences between American ecologists in the period from 1960 (when Slobodkin and two of his colleagues published their controversial article on biological population control) through 1986 (when Ehrlich and friends quantified the *Human Appropriation of the Products of Photosynthesis* in an influential publication). I will argue that the political differences between these scientists paralleled their disciplinary differences and their research foci. On one side were the population ecologists like Slobodkin, who advocated for a view of animal and plant demography as a self-regulating system in which growth was controlled by the relationships between different trophic classes of the food chain. Although these scientists made more direct use of the demographic methods inherited from the Malthusian human demographers of the pre-war era, they were much less active in Malthusian politics. On the other side were the systems ecologists like Whittaker, who focused huge amounts of time, money, and energy on quantifying primary production, and took a more traditionally Malthusian view that the population would always run up against the threshold of food supply, and therefore it was the aggregate size of this base that was the main regulator of growth. This focus on the quantification of plant production, rather than the counting of individual organisms, borrowed more from the German agricultural science of the 1920s and 1930s than it did the human demography of the same period. Yet while human demographic science gave methodological birth to population ecology, it was the primary production ecologists, led by Whittaker and Professor Heinrich Walter's Stuttgart student Helmuth Lieth, who carried forward the banner of political population control held high by the pre-war generation of demographic social scientists.

I should be clear from the outset that I do not mean to suggest that *politics*, *economics* and *science* are three mutually exclusive groups, and that there is some great wonder in one discovering a relationship between the three discrete areas. This is because they are not discrete. As many other researchers have made clear, and as should be apparent from the preceding pages of the current study, politics, economics, and science are always interrelated. In the most minimal case, well-meaning and disinterested scientists must still operate within a particular economic infrastructure, secure funding for their research projects, and curry favor with the political powers that be in their lab, university, think tank, and so on. In more extreme cases, political ideologies, and economic necessities find their way into the basic theoretical structure of the science at hand. The way a boundless Utopian hope for the German future, free from complicating differences between individuals and groups, created a receptive breeding ground for Eilhard Alfred Mitscherlich's Yield Law (*Ertragsgesetz*) and its accompanying Production Curve (*Produktionskurve*) is an example of this kind of extreme case.) Humans function within particular political economies wherein certain options are closed off and others are opened up. The notions of agency and free will are closely related to the regime of liberal democracy, free-market capitalism, and rational choice economics in which those voices who ascribe these characteristics to historical individuals have spent their careers.

For the researchers at the Utrecht plant physiology lab during the 1920s and 1930s, the Buitenzorg Botanical Gardens in the Dutch East Indies were a crucial waypoint on their professionalization path. Frits Went credited his time at Buitenzorg with closing off the opportunity to do rigorous experimental work, because the apparatuses would not give reliable readings in the tropical heat and moisture, and with opening up the opportunity to do ecological field work, because the rainforest landscape of Java was far more complex and interesting than the woods and fields of Holland.[5] Later, after he emmigrated to California, this kind of ecological work would become an increasingly important part of Went's research program. Just as the conditions of Dutch imperialism created the structure within which Went and many other Utrecht plant physiologists would function, Nazi imperialism was central to the development of early primary production research. In Denmark, fisheries economics and fisheries biology developed in tandem as a response to the problem of overharvesting, while German foresters such as Franz Heske were able to set their sights on World Forestry (*Weltforstwirtschaft*) once the possibility of German control over the nearly quarter of the world's forests lying within Russia was mooted.[6] And Eilhard

[5]Sharon Kingsland. "Frits Went's Atomic Age Greenhouse: The Changing Labscape on the Lab-Field Border". In: *Journal of the History of Biology* 42 (2009), pp. 289–324

[6]Stephen Brain. *Song of the Forest: Russian Forestry and Stalinist Environmentalism, 1905-1953*. University of Pittsburgh Press, 2012 gives a detailed account of how Russian forestry was similarly responsive to the politics of Stalinism, as well as much useful information on the Russian forests which many German scientists so coveted.

Alfred Mitscherlich's work only rose from scientific obscurity when the commissars of the Four Year Plan, the German Potash Syndicate, and IG Farben sponsored 27,069 field tests of the equation from 1934 through 1938.[7] Mitscherlich's Yield Law then traveled into Southwest Africa alongside the ecologist Heinrich Walter, where the colonial ambitions of the German state gave birth to primary production research. When those ambitions became slightly more circumscribed by the events of the first half of the 1940s, Walter and many other German ecologists, Plant Sociologists, and geographers turned their scientific attention to the military needs of the *Wehrmacht* on the eastern front. Finally, the fossil fuel powered western economy that emerged after 1945 created fertile conditions for both the intellectual development of a systems ecology that saw sunlight as primary to all subsequent transfers of energy, as well as the culture of international conference travel which enabled a forgotten German science to gain new life among American ecologists. These are just a few of the examples of the kind of interaction between changing political economic conditions and the biological and earth sciences that this chapter will elaborate upon in the area of postwar primary production calculations and political neo-Malthusianism.

What I will show in this chapter, then, is that areas of activity generally seen as political and economic related to areas generally seen as scientific in asymmetric ways. The chief proponents of a biological theory of population control, and the most direct heirs to the techniques of the pre-war Malthusian demographers, were largely agnostic towards ecological Malthusianism. This was due in

[7]Willcox, "Meaning of the Great German Soil Fertility Survey"

large part to the fact that their theory and their research suggested that mortality within a herbivore population would be induced by those organisms higher up the food chain. Thus, a given population would never get the chance to eat up to the limits of the supply of primary producing organisms lower down the food chain.[8] Meanwhile, the critics of the theory of biological population control were vocal advocates of social population control. These scientists, most importantly the systems ecologist Robert Whittaker, his co-editor Helmut Lieth, and Paul Ehrlich, invested heavily in the global scientific project of quantifying primary production. Perhaps this effort was so important to them because of their belief that food supply, and not predation or other causes of mortality, was the chief regulator of voracious populations. Or perhaps their conviction that humankind had eaten its way to the limit of the planet's primary productive base stemmed from the capital they had sunk into quantifying and analyzing that base. In any event, the belief that *Homo sapiens* had burned through earth's photosynthetic credit using not only their collective stomach and their three billion mouths, but also their roads, wasted fields, and diverted water supplies, was a powerful one among ecological scientists from the 1960s forward. As in the pre-war period, primary production research interacted in intricate ways with Malthusian theories of population growth. However, it now did so in the context of a world where resources

[8] Nelson Hairston, Frederick Smith, and Lawrence Slobodkin. "Community Structure, Population Control, and Competition". In: *The American Naturalist* 94 (1960), Paul Ehrlich and L. C. Birch. "The "Balance of Nature" and "Population Control" ". In: *The American Naturalist* 101.18 (1967), L. Oksanen et al. "Exploitation Ecosystems in Gradients of Primary Productivity". In: *American Naturalist* (1981), pp. 240–261, and S.D. Fretwell. "Food Chain Dynamics: The Central Theory of Ecology? " In: *Oikos* (1987), pp. 291–301 are some of the most useful sources for tracing this debate.

were ostensibly shared amongst the former “great powers,” now transmuted into “first world nations,” a world where the racist population policy of the Third Reich had been buried in the rubble of Berlin and the isolationist dreams of many American politicians and intellectuals had given way before the expansion of an American empire of military bases and unfettered corporations. The most subtle and advanced areas of ecological theory and empirical research in this period cannot be understood without also understanding the geopolitical context of global population growth, and the domestic context of American neo-Malthusianism, even as the latter failed to hold onto the loyalty of the masses and the political and economic elites.

The Political Fortunes of Ecological Malthusianism

These fortunes waxed and waned between 1960 and 1986. Population control has a tricky history, with a blurry line always running between those concerned only with quantity and those preoccupied chiefly with eugenic “quality.” The rise and fall of ecological Malthusianism in America from the 1960s forward has been confronted by several scholars. One compelling set of explanations pertain to domestic American demographic shifts, and the resulting mass political responses. The historian Donald Critchlow, the journalist Roy Beck, and the forester Leon Kolankiewicz have made this argument. While global population headed towards a doubling from two billion in 1900 to four billion by the end of the 1970s, the American fertility rate declined from

1960 to 1967, spiked briefly from 1968 to 1969, then leveled off from 1970 through 1972.[9] The eschatological cries of biological public intellectuals such as Paul Ehrlich and Professor Garret Hardin in the late 1960s were prompted by global demographic shifts, not domestic American ones.[10] Yet they were addressed chiefly to an American audience mired in the cessation of the Baby Boom. This made it difficult for them to maintain political traction in the face of declining fertility at home.

Secondly, those same scholars argue that the increase in migration rates to America after the immigration act of 1965 forced ecological Malthusians into a difficult position.[11] The reaction against the influx for foreign immigrants gave birth to a mass movement far more successful and long-lived than ecological Malthusianism: anti-immigrant nativism. While men such as Ehrlich, Robert Whittaker, and Helmut Lieth stressed features such as aggregate population growth and per-capita consumption (and production, if poisonous waste output is seen as productive) per capita, it was too easy for them to be lumped in with the nativists.

Garrett Hardin, a University of California, Santa Barbara biologist

[9] Roy Beck and Leon Kolankiewicz. "The Environmental Movement's Retreat from Advocating U.S. Population Stabilization (1970-1998): A First Draft of History". In: *Journal of Policy History* (2000) and Donald Critchlow. *Intended Consequences: Birth Control, Abortion, and the Federal Government in Modern America.* Oxford University Press, 1999 make the argument for a change in demographic rhetoric as a result of actual demographic shifts, as Derek Hoff. ""Kick That Population Commission in the Ass": The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb". In: *Journal of Policy History* 22 (2010), p.26 points out.

[10] P.R. Ehrlich, D.R. Parnell, and A. Silbowitz. *The Population Bomb.* Buccaneer Books New York, 1968 and G. Hardin. "Commentary: Living on a Lifeboat". In: *BioScience* (1974), pp. 561–568 are two iconic examples of these scientist's output.

[11] Again, the work of Beck and Kolankiewicz, "The Environmental Movement's Retreat from Advocating U.S. Population Stabilization (1970-1998): A First Draft of History", lucidly emphasized by Hoff, ""Kick That Population Commission in the Ass": The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb", p.26.

with a public voice comparable to Ehrlich's, did little to help this with his own claim that giving food aid to third world nations only exacerbated the problem of poverty by allowing their citizens to continue to breed up to "the threshold of Malthusianism," as the "agrobiologist" O.W. Willcox claimed back in 1935. By 1974, as ecological Malthusianism receded from the public consciousness, Hardin would argue against the admission of immigrants for the same reasons that he argued against foreign food aid, although he clearly denounced racism and eugenics, noting that "it will be assumed that immigrants and native-born citizens are of exactly equal quality, however quality may be defined. The focus is only on quantity."[12] Whittaker might hasten to explain that it was not pressure on a particular nation's food supplies that concerned him, but rather the global food supply. Nonetheless, writing with Professor Gene Likens in 1973, Whittaker noted that "Given fish populations that are limited and ever-increasing demands on these sources for food by competing and largely unregulated national fisheries, excessive harvest is inescapable. The overharvest is, in fact, a paradigm of man's relation to the biosphere, as it is an example of the principle stated by Hardin (1968) as the 'tragedy of the commons."'[13] In the same article, a summary of the social implications of years of research on primary production, Whittaker and Likens evinced a skepticism towards food aid that presaged Hardin's own formulation of "lifeboat ethics" a year later. However, their skepticism stemmed not from a concern with the fertility enhancing effects of demographic development assistence

[12]Hardin, "Commentary: Living on a Lifeboat", p.566

[13]R.H. Whittaker and G.E. Likens. "Primary Production: The Biosphere and Man". In: *Human Ecology* 1.4 (1973), pp. 357–369, p.363

from the richest countries to the poorest, but rather from the effect of increasing fertilizer inputs in an effort to increase food output:

> For the poor or developing nations, growth leads ultimately toward overpopulation and a national life on the edge of hunger. It is in this perspective that the effects of the new agricultural technology of the green revolution should be viewed. The success of this technology in increasing food production is being accepted as if it were the solution to the problems of the poor countries. The food is a great short-term benefit to the peoples of those countries, but the revolution may bring long-term intensification of their problems. Among environmental effects (Brown, 1970), the fertilizers and pesticides that increase food production on land are likely to decrease the smaller, but sometimes critical, food production in coastal and inland waters.[14]

Throughout their careers, the Malthusian prognostications of Whittaker and his fellow primary production researchers were tied to global population growth, global food supplies, and global pollution. The concern with the effect of food aid and immigration on the economy and ecology of one particular nation which so occupied Hardin was absent. Indeed, this was a fundamental aspect of the shift from a science of primary production focused on gaining and increasing national autarky for the benefit of a particular mythical racial group, to one focused on defining the limits of the growth of the human species as a whole. However,

[14] Whittaker and Likens, "Primary Production: The Biosphere and Man", p.367

such nuanced arguments fell on deaf ears, and were particularly awkward for the ecological Malthusians to make, given the complicated eugenic history of demographic science and related attempts to apply biological reasoning to human social affairs.[15]

The historian Derek Hoff has given another explanation for the political oscillating path of ecological Malthusianism. Without completely dismissing the arguments of Critchlow, Beck, and Kolankiewicz, he suggests that changes in both the American political economy and its concomitant neo-liberal economic science were as important as shifts in American fertility and immigration rates.[16] In a “Special Message to the Congress Regarding Problems of Global Population Growth” in 1969, President Richard Nixon called it one of the most serious challenges to human destiny in the last third of this century claiming that he believed that many of our present social problems may be related to the fact that we have had only fifty years in which to accommodate the second hundred million Americans.[17] Hoff claims that Nixon’s fleeting interest in domestic population control stemmed from a briefly favorable public climate, a strong bipartisan interest among many congressmen in the issue, including George H.W. Bush, the

[15]Robertson, *The Malthusian Moment:Global Population Growth and the Birth of American Environmentalism* gives an excellent and unusually polyvalent account of the relationship between demography and eugenics in his history of ecological Malthusianism in twentieth-century America.

[16]Hoff, “”Kick That Population Commission in the Ass”: The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb” gives the compressed version of this argument, Hoff, *The State and the Stork: The Population Debate and Policy Making in US History* offers an excellent book-length treatment of the vicissitudes of American Malthusianism among economists in the twentieth century.

[17]Cited from Hoff, “”Kick That Population Commission in the Ass”: The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb”, p.25,28, Hoff’s original source is R.M. Nixon. “Public Papers of the Presidents of the United States”. In: *Washington DC: Government Printing Office* (1971), p.529, 524.

continuing influence of the population lobby, most importantly the Population Council, and the need to buttress America's third world demographic development schemes with examples of domestic fertility discipline.[18] On this last point, Nixon's Office of Economic Opportunity head Donald Rumsfeld declared that the credibility of [the administration' support for overseas demographic development] hinges in part upon the degree of responsibility we in the United States display in population affairs here at home.[19]

Nixon was concerned enough about Malthusian issues to convene a Commission on Population Growth and the American Future, under the direction of the Republican John D. Rockefeller III, who founded the Population Council in 1952. Yet the Commission's mandate was focused on planning for future domestic demographic growth, rather than on controlling the growth rate itself. Following the Watts riots in Los Angeles in the summer of 1965, domestic population policy at the highest political levels was increasingly associated with issues of urban planning and the geographic distribution of America's 200 million citizens. These concerns were reflected at the biological level by Lawrence Slobodkin's 1969 comment, in response to politically charged paper by Robert Whittaker on "The Evolution of Diversity in Plant Communities," that ecologists rightly regard suburban sprawl as a blight upon every ecosystem in which it appears, yet in doing so might aid those oppressive forces that would close off the options of urban

[18]Hoff, ""Kick That Population Commission in the Ass": The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb", p.29

[19]Cited by Hoff, ""Kick That Population Commission in the Ass": The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb", p.28, from his archival research in the records of the Commission on Population Growth and the American Future.

slum dwellers who could only dream of sprawling out of bedlam and into the suburbs.[20] Yet by the time the Commission presented its report to Nixon in 1972, he had lost all interest in the matter, and made no effort to enact any of the Commission's recommendations.[21] This was in part due to the rising tide of anti-abortion sentiment in the aftermath of the Roe vs Wade court decision of 1973, led by the powerful Catholic Church and its associated voting bloc. Donald Critchlow. *Intended Consequences: Birth Control, Abortion, and the Federal Government in Modern America.* Oxford University Press, 1999 tells the story of the anti-abortion movement's rise in the context of his larger narrative of American federal family planning, and Hoff draws upon this work. However, Hoff also claims that the mainstream scientific construction among America's dominant neo-liberal economists was one in which the Keynesian valoration of growth was a forgone conclusion. With this conclusion came the celebration of population growth as integral to economic growth, a process that was indispensable for its ability to create new consumers, rather than simply adding greater demand for non-essentials on top of a satisfied demand for basic necessities. This argument regarding the changing shape of economic science relative to demographic growth is the primary arc of Derek Hoff. *The State and the Stork: The Population Debate and Policy Making in US History.* University of Chicago Press, 2012 and Derek Hoff. "”Kick That Population Commission in the Ass": The Nixon Administration, the

[20] Whittaker, "Evolution of Diversity in Plant Communities", pp.195-196

[21] Hoff, "”Kick That Population Commission in the Ass": The Nixon Administration, the Commission on Population Growth and the American Future, and the Defusing of the Population Bomb", p.28

Commission on Population Growth and the American Future, and the Defusing of the Population Bomb". In: *Journal of Policy History* 22 (2010) In an America which was becoming increasingly dependent on domestic consumption and less dependent on industrial production, this growth was most important.[22] While economic science went one way, biological science went another. The scientific debate on biological population control was conducted side by side with the political debate on social population control, with key ecologists playing a role in both. At both debate's foundations were questions over the size and importance of earth's primary productive base, a research program which came out of the forgotten smoke of Germany's failed drive after national autarky to win a second lease on life as one of the centerpieces of the internationalist global ecology of the 1960s and 1970s.

"The Methods Whereby Natural Populations are Limited in Size,"

wrote Professors Nelson Hairston, Frederick Smith, and Lawrence Slobodkin in 1960, "have been debated with vigor during three decades, particularly during the last few years."[23] This paper was fundamental to all subsequent debates regarding biological population control. I will deal with the relationship between

[22] J. Stein. *Pivotal Decade: How the United States Traded Factories for Finance in the Seventies.* Yale University Press, 2010 argues for the 1970s as the crucial turning point in America's move away from manufacturing and towards finance and services.

[23] Hairston, Smith, and Slobodkin, "Community Structure, Population Control, and Competition", p.421

biological population control and its social analogue shortly. Before hand, I will address the development of primary production research in postwar global ecology through the work of Robert Whittaker. However, it was not these relationships alone, between biological and social population control and between population ecology and primary production research, that gave this scientific debate its fire. Whether the world was characterized by equilibrium and stasis or chaos and change was at stake. The argument put forth by Hairston, Smith, and Slobodkin regarding the auto-regulation of populations came down in favor of the former view. Leveled against their argument were counter-attacks by Paul Ehrlich and the Australian ecologist L.T. Birch. Writing seven years after the initial 1960 article, Ehrlich and Birch cast their lot in with chaos and change:

> The idea that there is a "balance of nature" is commonly held by biologists. They feel that the organisms in a community are harmoniously adjusted to one another so that a state of dynamic equilibrium exists. In this equilibrium the numbers of the individuals of each species in the community remain relatively constant, and significant changes in numbers occur only when something upsets the natural "balance." This view of the "balance of nature" is perpetuated by popular magazines and nature films, and thus is part of the lore of the man-in-the-street. In our opinion, it is more difficult to explain why it persists in the writings of ecologists. In this paper we will first examine this idea as it appears in

> the ecological literature, and then present a realistic basis for models of "population control."[24]

At no point in his career had Robert Whittaker undertaken the study of sociology. Nor had Garret Hardin done his graduate work in economics, any more than Paul Ehrlich had written his dissertation on human demography. Whittaker had cut his teeth correlating plant species changes with changes in altitude in the Great Smokey Mountains.[25] Hardin did his PhD in biochemistry, while Ehrlich was a butterfly specialist. Yet by the end of the 1960s, these men, among many other biologists, had turned their attention to questions of human struggle. The interaction between the sciences of human life and those of the planet's non-human types was nothing new. Indeed, many of the techniques used by the pioneers of population ecology had their origins in human demography.[26] What was new in the 1960s was an insistent emphasis on global, rather than merely local, overpopulation.

Moreover, the effort to create a comprehensive account of the total productivity of the planet's plant life was without precedent. Whittaker was central to this accounting effort. By his side was Helmut Lieth, a student of Heinrich Walter's at Stuttgart who had since come to work in the US. Walter, had undertaken some of the first aggregate plant productivity measurements in 1941 in Southwest Africa. Walter had been supported by the *Deutsches Kolonialamt*(German Colonial Office), which, along with many

[24]Birch, "The "Balance of Nature" and "Population Control" ", p.97

[25]Basic biographical information on Whittaker comes from **westman+1980**

[26]Kingsland, *Modeling Nature: Episodes in the History of Population Ecology* and Greg Mitman. *State of Nature: Ecology, Community, and American Social Thought, 1900-1950.* University of Chicago Press, 1992 give an account of the origins of population ecology, with the former emphasizing its roots in the social sciences.

other Nazi elites, had dreamt of a re-conquest of the African colonies Germany had lost to Britain and France after the First World War. The renewed efforts to quantify the earth's plant productivity were motivated by slightly more benign concerns. These efforts began at a 1960 conference in Stuttgart, hosted by Lieth and Walter.[27] They culminated in the International Biological Program of 1964 through 1974, an effort funded by US and other national funding bodies which was widely reguarded as a failure.[28] The program that nurtured Walter's initial Southwest African measurements was also widely regarded as a failure. But the ideas and methods marched on, indifferent to the fleeting political goals of this or that organization, or the personal career objectives of this or that scientist.

Primary productivity was at the center of the International Biological Program (IBP), whose stated mission was to chart "the biological basis of productivity and human wellfare."[29] Photosynthetic productivity was the basis of economic productivity. The measurement of primary production unified human and non-human biology, fossil fuel quantifications, and solar thermodynamics. Conveniently, it also placed plant biologists, who had done more than any other single group to create modern

[27] Helmut Lieth, ed. *Die Stoffproduktion der Pflanzendecke*. Gustav Fischer, 1962

[28] Elena Aronova, Karen Baker, and Naomi Oreskes. "Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present". In: *Historical Studies in the Natural Sciences* 40.2 (2010) and Chunglin Kwa. "Representations of Nature Mediating beteen Ecology and Science Policy: The Case of the International Biological Programme". In: *Social Studies of Science* 17 (1987) discuss the IBP in detail. Taylor, "Technocratic Optimism, H.T. Odum, and the Partial Transformation of Ecological Metaphor after World War II" demonstrates the relationship between ecological rhetoric and the technocratic ideal.

[29] Aronova, Baker, and Oreskes, "Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present", p.199

ecology, in an indispensable position between the sun and human society. So even as the IBP collapsed in a haze of funding cuts and scientific apathy, primary productivity escaped, no more scathed than it had been after Germany failed to get around to husbanding Southwest African plant production to the greater good of filling German stomachs. Whittaker and Lieth's 1975 edited volume *Primary Productivity of the Biosphere* spent far more time on technical questions of measurement on land or under water, outside the lab or inside a computer, than it did on human social issues. Nonetheless, the collection opened with Lieth's pronouncement that

> The last decades of biologic, and especially ecologic, research have made it clear that
> 1. The notion that man's can increase without limit is self-deception and an invitation to self-destruction.
> 2. The unregulated increase of the human population beyond the world's sustainable carrying capacity must be considered a moral crime.
> 3. The relentless increase in the gross national products of the industrial nations, at the expense of the world population, must be considered a social crime.
> 4. The reckless exploitation of our fossil fuel sources for short-term profit and growth, rather than careful planning for a reasonable use for a long-term future, is a crime against our own children.[30]

By 1986, Paul Ehrlich, who's 1968 *The Population Bomb* made

[30] Helmut Lieth and Robert Whittaker, eds. *Primary Productivity of the Biosphere.* Springer, 1975

him the most publicly recognized ecologist in the US, had taken up primary production as a weapon in the fight against mass reproduction. With his wife, Anne Ehrlich, and his colleagues Peter Vitousek and Pamela Matson, Ehrlich estimated the *Human Appropriation of the Products of Photosynthesis.* At the high end, they found that 40% of the earth's photosynthetic production was either appropriated directly by humans and their domesticated prey species, or forgone through such activities as deforestation and covering potentially fertile soil with cement and asphalt.[31]

Primary productivity invoked the trophic stratification of the living world. Whether things ate each other down a simple chain, more or less great, or within a tangled web, the trophic hiearchy depended on the photosynthesizers at the bottom. Like human toilers at the economy's extractive bottom, pulling minerals from holes and plants from fields, the primary producers and the scientists who spoke them were often overlooked for the more glamorous feeders near the hiearchy's top. Back in 1910, while H.L. Blaauw and Eilhard Alfred Mitscherlich were doing the research that started this story, the German biologist Hermann Reinheimer had suggested this stratification:

> Bio-economically speaking, it is the duty of the plant world to manufacture the food-stuffs for its complement, the animal world... Every day, from sunrise until sunset, myriads of (plant) laboratories, factories, workshops and industries all the world over, on land and in sea, in the earth and on the surface soil, are incessantly occupied,

[31] Peter Vitousek et al. "Human Appropriation of the Products of Photosynthesis". In: *BioScience* 36.6 (1986), p.372

> adding each its little contribution to the general fund of organic wealth.[32]

Together with the reigning thermodynamic conception of the solar system, wherein the sun's light provided the majority of the new energy inputs into the earth system, the stratification of heterotrophs and autotrophs laid the theoretical groundwork for the practical business of measuring primary production. Yet weighing leaf and twig matter, measuring the dimensions of trees and bushes, and extrapolating from these measurements to larger regions held less appeal for those biologists, demographers, and economists focused on consumers. Primary production measurements gave the account within which heterotrophs had to work, but how and how many of those heterotrophs were working was another issue. Reproduction provided both a complementary and alternative biological quantification to primary production. The former counted individuals, a unit far more intuitively defined for animals than for the decidedly anti-liberal plant kingdom, while the latter weighed carbon.

Robert Whittaker's life and work gives a unique vantage point on the postwar theory and practice of primary production measurement. As with Nazi-era agrobiology and reconnaissance ecology, it can sometimes be difficult to know where the biology ends and the politics begin. Obviously there are many ways in which 1960s America differed politically from 1930s Germany. But

[32]Donald Worster. *Nature's Economy: A History of Ecological Ideas.* Cambridge University Press, 1994, p.291 contains the quotation from Reinheimer's 1910 source, Hermann Reinheimer. *Survival and Reproduction: A New Biological Outlook.* London, 1910. Jan Sapp. *Evolution by Association: A History of Symbiosis.* Oxford University Press, 1994 contains a wealth of detail on Reinheimer's life and work.

on a more global scale, one of the main changes was the increasing importance of fossilized hydrocarbons, especially petroleum. In a seminal 1960 paper in population ecology, Nelson Hairston, Frederick Smith, and Lawrence Slobodkin wrote:

> ...the accumulation of fossil fuels occurs at a rate that is negligible when compared with the rate of energy fixation through photosynthesis in the biosphere... The rate of accumulation when compared with that of photosynthesis has also been shown to be negligible over geologic time. If virtually all of the energy fixed in photosynthesis does indeed flow through the biosphere, it must follow that all organisms taken together are limited by the amount of energy fixed. In particular, the decomposers as a group must be food-limited, since by definition they comprise the trophic level which degrades organic debris. There is not a priori reason why predators, behavior, physiological changes induced by high densities, etc., could not limit decomposer populations. In fact, some decomposer populations may be limited in such ways. If so, however, others must consumer the 'left-over' food, so that the group as a whole remains food limited; otherwise fossil fuel would accumulate rapidly. Any population which is not resource-limited must, of course, be limited to a level *below* that set by its resources.[33]

Suggestively, this 1960 exercise in a class analysis of the relationship between nature's photosynthesizing base and its fungal

[33] Hairston, Smith, and Slobodkin, "Community Structure, Population Control, and Competition", p.421 Their emphasis.

and zoological super-structure was titled "Community Structure, Population Control, and Competition."

Primary productivity and the trophic hierarchy fit neatly with the theory that the hydrocarbon deposits that human beings were burning more of every day were left behind by decayed plants and animals. As with living things consuming other living things, the ultimate source for the energy derived from dead carbon was photosynthesis. Moreover, the biologists who spent their lives on production and reproduction tended to have concerns over hydrocarbon depletion and pollution at the top of their political agenda. Hairston, Smith, and Slobodkin wrote on the place of fossil fuels in the food web in the year that the Organization of Petroleum Exporting Countries (OPEC) was formed. By the time Helmut Lieth and Robert Whittaker published their collection of primary production methods and measurements in 1975, the world had gone through an unprecedented climb in global oil prices. Therefore, the suggestion that fossil fuels may in fact have had a decidedly un-fossiliferous origin deep in the earth's crust, was one with powerful biological and economic ramifications. Especially when it came not from a crank on the fringes of scientific discussions, but rather from one of the leading post-war astrophysicists, Thomas Gold:

> If hydrocarbons from the deep Earth were responsible wholly or in part for this large supply of carbon, then we might be dealing with far larger quantities than were ever contemplated to be present in biological deposits. In that case the problem of the origin of the hydrocarbons which

> we use as fuels would not only be one of great scientific interest, but also one of great practical significance. The estimate of the quantities yet to be discovered, the possible locations and the techniques and strategies of search, may all be greatly affected. In recent years the judgement that oil and gas are running out has had a profound influence on the world economy and on world politics. The dramatic rise in the price of these fuels, the shift in the wealth of nations and the political tensions that centre around the access to the great oil-fields of the world- all these have resulted from the *prediction* of a shortage and not from a shortage itself. Thomas Gold. *Power from the Earth: Deep Earth Gas- Energy for the Future.* J.M. Dent & Sons, 1987, pp.3-4 Gold's emphasis.

The measurement of primary production, the explication of biological and economic phenomena in terms of competitive exclusion, and the debate over the biogenic or abiogenic origin of hydrocarbons, as always, took place against the vast backdrop of global population growth and more-or-less violent conflicts over food and fuel.

The Evolution of Tragedy

> All joy is brief and shadowed, tinged with grief,
> For man and all man's joys will perish fast;
> And shadowed joy and grief alike are brief.[34]

[34]/Cornell University Special Collections/Robert Whittaker Papers/Box 2/Literature Folder/A Poem by Whittaker, c.1980

Like Karl Pearson, the Victorian statistical polymath, Robert Harding Whittaker's outward demeanor of quantifying rationality masked an inner life of passion and torment. The lines above were found among some fragments of unpublished poetry in is archives. Whittaker's unhappy views of modern civilization paralleled a frequently difficult and unhappy life. His social views suggest that while much of ecological science aligned with "left" political causes, certain elements of the modern ecological thinking were deeply conservative. Given that conservation is, in a certain sense, actually conservative, this is not necessarily a surprise. Whittaker distrusted not only the most obvious heralds of environmental apocalypse, but also many modern social trends of the 1960s and 1970s which he saw as interacting dangerously with modern technological changes. And his view of both the prospects for society, and the influence that scientists could effect upon these developments, was dim.

Whittaker's career passed through several key waystations of postwar American modernity, including the Hanford and Brookhaven national laboratories and the endlessly metastasizing suburbs of southern California. His 1948 dissertation at the University of Illinois established his reputation as an important theorist. Therein, based on research in the Great Smokey Mountains of Tennessee, he disconfirmed his hypothesis of species cooccurance along an ecological gradient that shifted with elevation. Rather, he concluded that species occurrence in correlation with shifting altitude was highly individualized, and cooccurance was an artifact of shared environmental needs, not coadaptation.[35] Following his PhD, Whittaker preceded to lecture at Washington State University while working on the Siskiyou Mountains and the Columbia basin. From 1951 to 1954 he worked at Washington state's Hanford National Laboratory, where he met his wife Clara and researched the use of radioactive isotopes for tracking nutrient flow in microcosmic marine ecosystems. While his wife had a Master's degree in biology, marriage and reproduction doomed her scientific career. In 1954 he took a job at Brooklyn College, where he would return to his PhD work on the ecology of the Great Smokey Mountains. From 1963 to 1964 he worked on Arizona's saguaro cactus communities. Perhaps coincidentally it was in the saguaro occupied region of Tucson, Arizona that Heinrich Walter had worked during his Rockefeller Fellowship period of 1929-1930. From 1964 to 1966 he would continue this research with Gene Likens at the Brookhaven National Laboratory. There, they developed methods for quantifying aggregate biomass output in the Great Smokey Mountains of Tennessee. This work refined methods from quantitative forestry that Whittaker would apply globally in the 1970s. Whittaker and his colleagues also experimented again with radioactive isotope tracking within the forest ecosystem, using techniques taken from his time at Hanford. In 1966 he left for a job at the University of California, Irvine. Yet the suburban sprawl running rampant in southern California at that time disgusted him, and in 1968 he reached the high point of his career when he took a job at Cornell University. It is during this time that he

[35] Walter Westman, Robert Peet, and Gene Likens. "Robert H. Whittaker, 1920-1980". In: *Biographical Memoirs of the National Academy of Sciences* (1980), p.427

turned to aggregate assessments of primary productivity. Like his colleague in this work, Walter's student Helmuth Lieth, Whittaker was an early pioneer in the use of computers to record and analyze ecological data. Yet, at the summit of his scientific career, Whittaker's wife Clara took ill with cancer and died in 1977. Whittaker remarried to one of his graduate students, Linda Olsvig, yet in 1979 cancer attacked his lungs as well. He died in 1980 at age 60. It is somewhat of a coincidence that a man possessed of increasingly dark political prophecies in the 1960s and 1970s would suffer such a tragic turn of personal fortune just as his scientific career was at its greatest height.

This study has never concerned itself with the personal lives or individual psychology of its scientific "actors." Indeed, to the extent that there is a method to its methodology, it has treated the very concept of "actors" with skepticism, and preferred to view scientists as functions of a changing apparatus of scientific techniques and rhetoric. This apparatus is, in the momentary view of the study's eyeblink, a function of a shifting global political ecology, largely indifferent to the theories and practices of an assortment of German and American biologists. That said, it is worth taking a moment to consider what the modern environmental ideology's effect on an individual mind might be, and what kind of mind might seek out such an ideology. To the extent that the present author's subjectivities do or do not matter, it may be worth noting that he subscribes to some version of this ideology. Environmentalism mutated gradually along side environmental policy from its origins as an ideology of conservation. Conservation of landscapes, of species, of singular monuments to nature's creativity; as limitless as it is purposeless. What it became was an ideology that saw human activity as fundamentally corrosive, degrading both the global biosphere and the daily lives of millions of organisms, human and otherwise. The "discovery" of anthropogenic global warming in the 1960s and 1970s, as historian Spencer Weart has described it, played a major role in both globalizing and universalizing what had been a local and comparatively humble political outlook. The genesis of neo-Malthusian ecology in the 1960s and 1970s took place alongside the rise of a scientific consciousness of global warming. With these scientific developments came an awareness of the fact that environmentalism was not simply a question of "fortress conservation." Rather every choice a person made, as a consumer, a driver, a reproducer, had largescale environmental repercussions. Primary productivity fit perfectly into this new worldview, as it calculated aggregate production regardless of whether it occurred in protected natural landscape, a city, or an agricultural system. The ecology was everywhere, not only was it global but it was universal, it pervaded every facet of human life. For a mind that recognized this worldview, and saw the net effect of human civilization's continued functioning to be destructive, it might be hard not to be gloomy, and hard not to blame one's own actions in part for the growing global environmental catastrophe.

In its connection to practical forest management concerns, the trajectory of primary productivity work in the US bore some familial resemblance to its prewar trajectory in Germany. We have seen how primary productivity traveled from German physiology labs to agriculture and forestry, and how its movement into large-scale ecology was facilitated by Germany's imperial aims in Africa and eastern Europe. The economic drives which motivated early US productivity aggregates were not so destructive, but no less concerned with practical questions of resource management. It is one of the great ironies of the history of science that activity so closely tied (like so much else) to capitalist and statist management goals would end up yielding findings and polemic so fiercely opposed to the status quo. Yet Whittaker's work, like Walter's, was never satisfied with mere aggregate quantification. Rather, he was consistently preoccupied also with the factors that control community composition, and how ecologies change along a gradient. This was another strand of Walter's work which Whittaker's mirrored. Whittaker was also concerned, however, with theoretical and taxonomic questions. Yet his work in kingdom-level taxonomy, community analysis, and human social questions was all tied together by a concern with "production" and its limits, as befitting a child of the world's pre-eminent industrial power. In taxonomy, Whittaker suggested in 1957 that a three kingdom distinction between plants, animals, and fungus (rather than the old two kingdom distinction between plants and animals) would be more appropriate. His reasoning replaced both the classical taxonomic logic of grouping by shared traits and the evolutionary logic of grouping by shared descent with a logic derived directly from production ecology. This analysis looked first and foremost at the position of an organism in system of trophic production and consumption. What mattered in an ecological worldview was not superficial traits or common descent, but whether an organism was a photosynthetic autotroph or a heterotroph that consumed autotrophs and other heterotrophs. This mode of thinking had, he noted, already removed bacteria from their traditional association with plants, at least those bacteria that were not capable of photo- or chemosynthesis. Now, he posited a third kingdom for fungae on the basis of their position as non-photosynthetic "decomposers." Despite their superficial resemblance to plants, fungae actually bore more in common with animals when one looked at their place in the productive system (although calling mushrooms "animals" seemed to be too far even for Whittaker).

"Ecologists," Whittaker wrote in 1957, "[make] the fundamental distinction between autotrophs and heterotrophs, by which the bacteria and fungi are separated from their traditional association with the plants, and grouped with the animals."

> A further division recognizes three major groups of organisms in the living community: producers, which use solar or chemica energy to synthesize organic compounds from inorganic and provide all the food energy available to the community; consumers, which harvest the productivity of these by eating either producers or other consumers; and reducers, which break down the dead remains of both producers and consumers to soluble or finely particulate form in soil or water, and amke available some nutrients for uptake by producers and

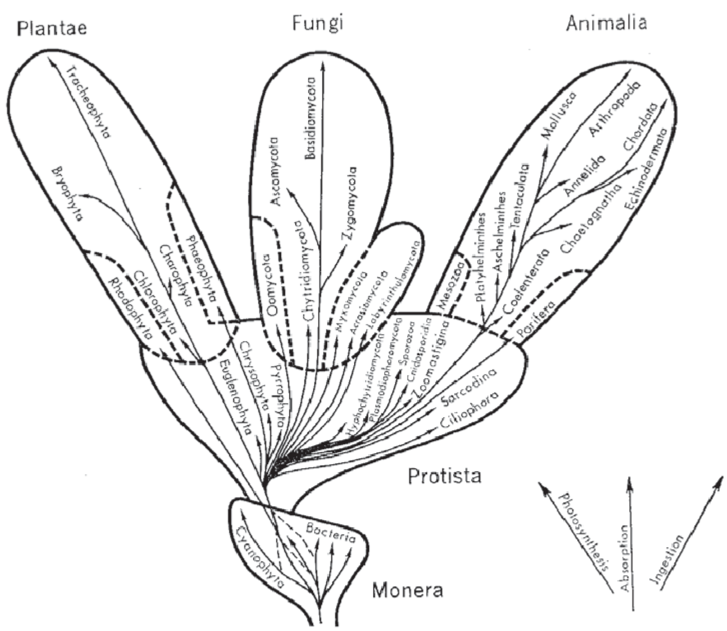


Fig. 3. A five-kingdom system based on three levels of organization—the procaryotic (kingdom Monera), eucaryotic unicellular (kingdom Protista), and eucaryotic multicellular and multinucleate. On each level there is divergence in relation to three principal modes of nutrition—the photosynthetic, absorptive, and ingestive. Ingestive nutrition is lacking in the Monera; and the three modes are continuous along numerous evolutionary lines in the Protista; but on the multicellular–multinucleate level the nutritive modes lead to the widely different kinds of organization which characterize the three higher kingdoms—Plantae, Fungi, and Animalia. Evolutionary relations are much simplified, particularly in the Protista. Phyla are those of Table 1; but only major animal phyla are entered, and phyla of the bacteria are omitted. The Coelenterata comprise the Cnidaria and Ctenophora; the Tentaculata comprise the Bryozoa, Brachiopoda, and Phoronida, and in some treatments the Entoprocta.

Figure 5.1: The Three Kingdoms of Life, 1969 (from Robert Whittaker. "New Concepts of Kingdoms of Organisms". In: *Science* 163 (1969))

recirculation through the community."[36]

While not as politically charged as his later work on production and productivity in the late 1960s and 1970s, this work in theoretical taxonomy, which has had a lasting impact and structured the modern three kingdom hierarchy which all biologists accept, was clearly intricately related to a productivist view of nature.

Some historians, such as Donald Worster, have suggested that thinking of ecology in productivist terms make it a handmaiden to a capitalist system which asks of the natural environment only what parasitic civilization can extract from it. In the case of Whittaker and the ecologists with which he interacted the situation appears to be a bit more complicated. While productivist ecology clearly resonated with a capitalist world system, it had done so in a fascist system where the state strongly curtailed the freedom of industry to seek profit wherever and however it might find it. I suggest that productivism was injected into ecology from its close association with agronomy, forestry, and fisheries management, and Whittaker simply elaborated this tradition. Yet working within that framework, by the 1970s he and the legions of other ecologists who had taken up a productivist view of nature came to the conclusion that demand was outstripping supply, and unlike a textbook example of a market, the photosynthetic factory (and the surplus it had stored underground as hydrocarbons) could not simply rise to meet that demand. At least not without dire costs to the overall productivity of the entire global ecological system. It is

[36]Robert Whittaker. "The Kingdoms of the Living World". In: *Ecology* 38 (1957), p.537

no wonder that much of the apparatus of science and technology has served the interests of capital and the state. What is surprising is how certain slivers of the scientific community can come to openly oppose the ideologies of relentless growth and innovation endemic to postwar American society. It is particularly interesting in the case of primary productivity's American career that a seemingly industrial and capitalist language for talking about nature could be turned against those very doctrines. What is specifically interesting in the case of Robert Whittaker is that his political views were in many ways conservative and utterly cynical about the possibilities of positive change. If "progress" was a fundamental component of the capitalist culture of postwar America, then to oppose progress could make one at once reactionary and subversive. The rural, agrarian roots of ecology led to many discrepancies of this nature. This would be a mere curiosity if Whittaker had not played such a crucial role in the modernization and globalization of primary productivity research, and if that tradition did not have such strong roots in the "reactionary modernism" of Nazi Germany.

As early as 1956, while teaching at Brooklyn College, Whittaker was lecturing on undergrad biology by way of "man in the biological world," as the folder containing his course lecture notes is labeled. As he moved to one of his own main areas of interest, the place of photosynthesis in large ecological systems, both his developing social concerns and his fascination with the productive potential of natural systems took center stage:

5. Man is totally dependent on plants

a.All the food man eats, all the energy of life he obtains, is derived from plants- even though some of it comes from animals which have eaten plants

b. Man, along with all other animals, is a parasite on the plant world

c. Most of the industrial energy with which civilization runs is derived from plants

d. The energy of coal and oil is the energy of photosynthesis, stored in the earth as organic compounds for millions of years

e. These are the principal sources of the energy of industry and our civilization; water power is minor and energy of atomic fission (and fusion) trivial as yet

f. Many of the other substances of civilization- wood, fibers for clothes, rubber, medicines, many plastics- are derived, if indirectly, from plants

g. Man does well, as lord and master of creation, to remember this

h. One of the most difficult, and potentially terrible problems of human life is that of providing these substances and energy in sufficient amounts to support human life in decent conditions through future centures and millenia

6. For man is a heterotroph

a. Green plants are capable of making all groups of organic compounds from inorganic with the energy of light

> b. Man must obtain all from food; he can synthesize higher compounds from simple sugar, but with some limitations, and he must have certain co-enzyme vitamins
> c. Man is a _heterotroph, as are all animals, bacteria, and fungi; green plants are _autotrophs[37]

Slobodkin, Hairston, and Smith would not have disputed this fundamental view of the trophic structure of the planet. However, in the analysis presented in their 1960 paper, they argued that ultimately predation, and not the total mass of primary production, was the limiting factor on the growth of herbivore heterotroph populations. This view diminished the importance of the massive effort to quantify global primary productivity which Whittaker and many other biologists would soon embark on as part of the International Biological Program. Moreover, it set limits on the utility of Malthusianism as both an ecological concept and a social one. If, ultimately, what might be termed "positive checks" by an orthodox Malthusian were sufficient to keep populations from ever outstripping food supply, then predicting large ecological and social changes solely as a function of a predicted decline in the resource base was a faulty approach. Not surprisingly, by 1967, seven years after Hairston, Smith, and Slobodkin's seminal essay, the leading ecological neo-Malthusian Paul Ehrlich was refuting their theory. And, fortuitously for the claims of the current study, by 1986 Ehrlich was putting the IBP's global primary productivity measurements to work in claiming that humans were at the absolute limit of how much of that production they could

[37]/Cornell University Special Collections/Robert Whittaker Papers/Box 16/Man in the Biological World, 1956/Science III Lectures, pp. 19-20

"appropriate" before global ecological collapse became a reality. It is to the genesis of global primary production measurements, and their interplay with both population politics and conflicting views of stability and chaos in complex ecosystems, that I now turn.

The IBP & the Primary Productivity of the Biosphere

It was the International Biological Program of 1964-74 that globalized primary productivity as a fundamental ecological measure. The IBP was an odd phenomenon, a failed entry in "big biology" that nonetheless had a lasting impact in certain unexpected areas. In an era when biology was becoming increasingly molecular, and increasingly capitalized, and on the cusp of the rise of genetic engineering and the biotech industry, the National Science Foundation and the public scientific funding bodies of many other nations chose instead to sink money into global production ecology. The universality of "primary productivity" as an quantitative measure, coupled with a culture of growing unease regarding the stability of humanities resource base surely played a role in this odd orientation of the IBP towards one of the more esoteric and potentially subversive areas of biology. However, given what we now know about the German state's patronage of production ecology as an adjunct to its military aims abroad and domestic food policy, it should not be totally surprising. In many other countries as well, including the US as early as the 1920s, ecology has marched hand in hand with agricultural and forestry policy. Moreover, in an increasingly hydrocarbon dependent world, a way of quantifying the planet's resource base that fit perfectly with the by then completely dominant fossil fuel theory of hydrocarbon production had a deep appeal. Conservation has often played a surprisingly minor roll in the genesis of ecological thinking, with practical questions of resource management, of interest to both the state and capital, often playing are far more important roll in the genesis of this highly heterogenous group of biological sciences. In the end, the IBP was deemed a failure by many of its participants, an atavistic insult by many molecular biologists, and starved of funding by the end of its life. Yet thinking of the entire planet as a single interconnected "global ecology" which could be accessed by a range of productivist metrics, has persevered and perpetuated itself across a vast range of scientific disciplines, as well as the popular consciousness. The Gross Domestic Products of modern macroeconomics, the oil output predictions of geologists like M. King Hubbert, the CO^2 emissions statistics of climatologists, the population projections of demographers, and rainfall estimates of meteorologists could all fit together into this productivist analytical framework. Primary productivity and the IBP were hardly the sole initiators of this worldview, but they fit seamlessly into its totalizing logic. Thinking of ecological stability and chaos as something other than global and productive is almost impossible for millions of scientific, political, economic, and military elites today, and this mode of analysis has also had a significant impact on the public consciousness in the rich world. For this reason, an understanding of the particular work that Robert Whittaker, Helmuth Lieth, Gene Likens, Eugene Box, and many other scientists did under the auspices of the IBP in the 1960s and 1970s is of political, economic, and social importance And this understanding begins and ends with the politics of global population.

Summarizing their findings in 1973, Whittaker and Likens were quick to note that "man's harvest" was seemingly inconsequential in terms of total primary productivity:

> The energetic magnitude of world primary production, estimated as $6.9 \times 1017 kcal/year$ by Lieth, far exceeds that of any of the works of man. Man's total use of fossil fuels and other industrial energy in 1970 was $4.7 \times 1016 kcal/year$ (Cook, 1971), hence about 7% of net production and 3.5% of the gross primary production that supports the world's life. The doubling time for world consumption of industrial energy is approximately 10 years, a rate of increase that does not imply exhaustion of presently available energy resources in the near future (Hubbert, 1969, 1971) but that does imply a formidable and accelerating rate of release of heat and materials from industry into the environment.[38]

Yet, in both his private correspondence with Lieth, and in the summation of their findings, Whittaker made it clear that his intuition led him to believe that humanity was close to the limit of how much it could appropriate. Writing to Lieth in 1973,

[38] Whittaker and Likens, "Primary Production: The Biosphere and Man", p.361-62

Whittaker explained his uncertainty about the ability to make precise predictions about the upper limit of the human population that the earth could support, or “carrying capacity”:

> I don’t disagree with [Lieth’s] arithmetic, even to some kind of hypothetical upper food limit of 180-250 [billion people]. But that...is not a real carrying capacity. I regard it as essentially impossible to define a real one. We do not know what fraction of that productivity could really be harvested and used without some global retrogression; we do not know what standard of living we must choose and what pollution effects to allow for; and we do not know what to make of man’s tendency to overshoot whatever limits _ought to apply to him, and to involve himself in wars. I tend myself to retreat from arithmetic to intuition regarding two possible worlds:
> 1) High density, low standard of living, a Chinese-Indian world, with Africa and Latin America similarly overpopulated, and the present industrial world probably by then reduced to something like the same conditions. Carrying capacity, perhaps 10-15 [billion] even though in theory more could be sustained. This world would, I think, be characterized by rather chronic warfare now involving atomic weaponry; and war and famine together would act to regulate population. It would, I think, be an unpleasant as well as an unstable world.
> 2) Low density, high standard of living. Assume instead a world all the peoples of which are industrialized. My

> intuitive guess for a carrying capacity is then one [billion], considering the pollution stress now exerted by somewhat less than that number in industrialized populations. Even to support this [billion] on a long-term basis, controls on accumulation of persistent pollutants and measures to conserve scarcer resources would be needed. With more stringent controls more industrialized people (two [billion]) could be supported for quite a while.
> Between these are various intermediates, such as our present and apparently unstable situation of 3.7 [billion] part industrialized and part poor.[39]

Although not dealing directly with climate change, Whittaker dealt with the ramifications of the "accelerating rate of release of heat and materials into the environment." Yet such details were not foremost in Whittaker's mind. It was ultimately not the massive quantifying effort that these scientists had just completed which compelled his doomsaying. Rather, it was a deep-seated sense of the hopelessness of human civilization. That is not to say that Whittaker's belief that was not guided by his extensive knowledge of the biological sciences and the numerical indicators of the planet's health. But prognostications of ecological collapse can be treated similarly to M. King Hubbert's prophecies of peak oil, as large-scale scientific hypotheses. Like any large hypothesis, confirmation is difficult. Amassing the IBP's productivity measurements alongside many other facts, Whittaker's scientific

[39]/Cornell University Special Collections/Robert Whittaker Papers/Box 1/Primary Productivity Folder/Robert Whittaker to Helmut Lieth, 30.01.1974

intuition combined with his generally pessimistic personality to create the most negative possible interpretation of the data.

Still, it is difficult to escape the notion that the primary productivity measurements did not end up being the weapon against the existing economic status quo that the IBP ecologists might have hoped. More than a decade later, Paul Ehrlich and Peter Vitousek would dramatically expand the "harvest of man" in an attempt to fashion the productivity measurements in a more potent political weapon.[40] And thirty years later, NASA scientists led by biologist Marc Imhoff would generate localized measurements of local productivity as a percentage of primary consumption. Urban and desert environments showed consumption rates over 1,000 times their production rates.[41] Thus, the IBP data continued to be reinterpreted and used as a tool in the fight against over consumption. Yet, as I suggest above, the most significant effect of the IBP's productivity-focused initiative was to instantiate a productivist and global mode of quantifying ecological activity alongside many similarly productivist and global measurements in many other scientific fields. Keeping that in mind, it is worth looking at the notable post-IBP uses of primary productivity as both a political and scientific tool to see how that class of quantifying measures evolved in response to changing historical conditions.

However, before moving into the future, a brief consideration of Ehrlich's rebuttal of the 1960 Hairston, Smith, and Slobodkin

[40] Vitousek et al., "Human Appropriation of the Products of Photosynthesis"

[41] Marc Imhoff et al. "Global Patterns in Human Consumption of Net Primary Production". In: *Nature* 429 (2004)

paper discussed at this chapter's start is merited. Ehrlich was both a prominent utilizer of the productivity data (although not a contributer to the initial IBP research), and the most public and iconic of the postwar ecological Malthusians. As hinted at by the 1969 discussion between Whittaker and Slobodkin, Slobodkin's ecological views suggested a sympathetic yet quite distinct view of the political meaning of ecological science. The scientific debate between him and Ehrlich opens up the political differences within the ecological community, and provides a base for the shifting ecological fortunes of both neo-Malthusianism and the concept of primary productivity.

Paul Ehrlich and Charles Birch's attack on Hairston, Smith, and Slobodkin's earlier paper was characteristically ferocious, displaying the same polemic intensity that Ehrlich would bring to bear on his bestselling *The Population Bomb* a year later.

> 1. The notion that nature is in some sort of "balance" with respect to population size, or that populations in general show relatively little fluctuation in size, is demonstrably false.
> 2. The thesis of Hairston, Smith, and Slobodkin that "populations of producers, carnivores, and decomposers are limited by their respective resources in the classical density-dependent fashion" is based on a series of assumptions about these trophic levels which are, in all probability, false. Even if the assumptions are true, this conclusion does not follow from them.
> 3. A realistic basis for building models dealing with the

> changes of numbers in populations would include the following propositions:
>
> a. All populations are constantly changing in size.
>
> b. The environments of all organisms are constantly changing.
>
> c. Local populations must be recognized and investigated if changes in population size are to be understood.
>
> d. The influence on population size of various components of environment varies with population density, among species, among local populations, and through time.[42]

Here, Ehrlich and Birch struck not only at the idea that herbivore populations were limited by pressure from higher up in the food chain, and not by their photosynthetic base, but at the whole idea of a "balance of nature." This was a fundamental philosophical difference in ecology going back into the 1920s. As the reader might recall, both classical American ecology and its European counterpart, *Pflanzensoziologie*, hinged on the concept of the "climax state." This was a hypothetical stable assemblage of species, which, when reached, would not fundamentally change unless preturbed by a sudden environmental shift (such as those often produced by humans through agricultural transformations, species introductions, and so on). Heinrich Walter and the physiological ecologists who followed in his steed tended to argue against this view. This was one form of "natural balance." It depended not on the demographic size of a single species

[42] Birch, "The "Balance of Nature" and "Population Control" ", p.106-07

population, but rather on the fixed ratios of different species to one another in a community. Yet even specific quantitative efforts such as that were less important than recognizing the specific type of ecology: rainforest, grassland, desert, temperate forest, and so on. In the UK, contemporaneous with Walter (and similarly motivated by imperial resource management interests in Africa), the ecosystem school of Arthur Tansley did not directly endorse this view. However, they did suggest that the fundamental property of an ecosystem was stability. This tradition, which treated the living world as a complex system of equilibria between organisms, populations, and hydrological, edaphic (soil), climatic, and chemical properties, continued in the US under the tutelage of G. Evelyn Hutchinson and Eugene and Howard Odum in the 1950s. However, by the 1960s the conflict between the school of balance and the school of chaos (or at least constant fluctuation) had reoriented itself from "climax communities" and "ecosystems" to demographic populations.

For Ehrlich and the neo-Malthusians, not only were populations highly dependent on food supply, they were also highly unstable. Ehrlich and Birch attacked Hairston, Smith, and Slobodkin in 1967 with incisive scientific reasoning, and showed little mercy or empathy for the logic of these respected scientists. Yet the political meaning of Ehrlich's view of natural population dynamics cannot be ignored. A stable human population would suggest a potentially stable human relationship with the environment. For Ehrlich, neither human demography nor the human-dominated ecology were remotely stable. A decade later, working with Peter Vitousek, his wife Anne Ehrlich, and Pamela Matson, he would use primary productivity measurements to make this case.

"We are interested in human use of [Net Primary Productivity] both for other species, which must use the leftovers, and for what it could imply about limits to the number of people the earth can support."[43] Vitousek and company went on to produce three estimates of the human appropriation of the products of primary productivity. They managed to go far beyond the original 1973 estimates of Whittaker, Likens, and Lieth by incorporating not only "man's harvest," but also all of the productivity forgone as a result of appropriated water, pollution, and the development of potentially arable soil for non agricultural purposes. Back in 1973, Whittaker and Likens estimated that, in terms of energy, less than 1% of the planet's productivity went towards human food:

> Man's harvest of food is also small compared with biosphere production. The 14×10^6 km z of arable land produced in 1950 about 8.5% of land surface net production (Table I), and roughly 9% of the total production of agricultural plants on land was available to man as harvested food. Production and the fraction harvested in 1970 were higher, probably 11×10^9 tons/year and 12% to give a yield of 1200×10^6 tons/year of cereal grains and 570×10^6 tons/year of other food crops in fresh weights (FAO, 197 la), approximately 1000 and 220 × 106 tons dry weights. A larger fraction of the land surface, about 30 × 106 km 2,

[43]Vitousek et al., "Human Appropriation of the Products of Photosynthesis", p.368

> is used as pasture and range land. World harvest of food from animals is important for its protein content, but small in quantity compared to that from plants (Kovda, 1971); it includes, in millions of tons fresh weights (and approximate dry weights), 80 (20) of meat, 20 (4.7) of eggs, and 400 (48) of milk... World harvest of aquatic organisms for food was 69(17) $\times 10^6$ tons in 1970 (FAO, 197 lb), with about 88% of this from the oceans... The marine yield to man of about 15 $\times 10^6$ tons/year dry matter is only 0.027% of total marine net primary production but represents a much larger fraction of that production concentrated through animal food chains. Man's total food harvest of about 1220 $\times 10^6$ tons/year of plant and 90 × 106 tons/year of animal dry matter (of which some of the latter has been produced by feeding on the former) is about 0.8% of the energy of net primary production of the world. R.H. Whittaker and G.E. Likens. "Primary Production: The Biosphere and Man". In: *Human Ecology* 1.4 (1973), pp. 357–369, p.362

They pointed out that the upper limits on how much human civilization could harvest might not be as high as arithmetic suggests, because of the limits on the kind of food humans can eat, and the kind of land they need to grow it on. However, even Vitousek, Ehrlich, Ehrlich, and Matson's low estimate put human consumption at 3% of total net primary productivity. Their intermediate estimate was 19%, and their high estimate 40%. For this, they focused on several mechanisms by which primary productivity is diminished. These included: the conversion of natural systems into agricultural ones, deforestation and replacement with pasture land, desertification, and the replacement of natural systems with human habitation zones. It is important to note that Ehrlich and his colleagues adopted a particularly broad interpretation of “appropriation” in arriving at their conclusion that up to 40% of primary productivity was channeled towards human ends. They included not only that amount of the earth’s total primary productivity that continued to exist but served human interests, but also that part that served human interests by not coming into being at all. Therefore, they were, perhaps unwittingly, invoking Reinhold Tüxen’s old idea from 1930s German “plant sociology” of “potential natural vegetation.” They were not taking their 40% out of the actual productivity of the earth, but out of some estimated productivity that was not actually occurring due to human activity. In this, Vitousek et al 1986 made clear the way in which the productivist rhetoric of capitalism had been subverted by scientific Cassandras like Whittaker. Increases in other productivist measurements- Gross Domestic Products, population sizes, rates of technological innovation- were directly hindering the natural productivity of the planet. Humans, for the neo-Malthusian ecologists of the 1960s through the 1980s, were not simply a greedy species. They were a fundamentally destructive and ultimately counterproductive one, in the most literal sense of the word.

For Ehrlich, then, “instability” in ecological science had a dual meaning. These two meanings were related. On one level, he felt that claims for population level stability were overstated, and that population ecology tended to be characterized by extreme fluctuations. On a higher level, he felt that the entire ecological system of the planet was subject to extreme instability as well, and this was due in large part to human population growth. This view reflected a larger trend in the natural sciences, particularly those relative to human interactions with the environment. This tred was towards an understanding of many natural systems as inherently unstable, and of human action as an agent that increased that instability. Writing on the climatologists and oceanographers of the 1970s who developed the first detailed models of anthropogenic global warming, historian Spencer Weart could just as easily have been writing of Robert Whittaker, Helmuth Lieth, Gene Likens, and Paul Ehrlich:

> As evidence mounted that global harm could be inflicted by such human products as chemical pesticides or dust, the traditional belief in the automatic stability of biological systems faltered. Concerns were redoubled by the African drought of the early 1970s. Was the Sahara desert expanding southward as part of a natural climate cycle that would soon reverse itself, or was something more ominous at work? For a century, African travelers and geographers had worried that overgrazing could cause such changes in the land that "man's stupidity" would create a "man-made desert." In 1975, veteran climate scientist Jule Charney proposed a mechanism. Noting that satellite pictures showed widespread

> destruction of African vegetation from overgrazing, he pointed out that the barren clay reflected sunlight more than the grasses had. He figured this increase of albedo would make the surface cooler, and that might change the pattern of winds so as to bring less rain. Then more plants would die, and a self-sustaining feedback would push on to full desertification.[44]

The question thus emerged, contemporaneous with the debates over ecological balance, of both how stable, and how effected by human action, the planet's climate system was. While this thread of scientific research would come to dominate scientific concerns over "the harvest of man," productivist thinking continued to pervade many diverse areas of the ecological, geological, and earth sciences. Indeed, given the tight relationship between primary productivity and the "locking up" of atmospheric carbon, the growing focus on climate change only served to enhance productivity's status as a key ecological statistic. In many ways, climatology and oceanography developed along a parallel and closely related path with production ecology. All developed into increasingly global, both in the sense of taking a single global system as their subjects, and in the sense of employing researchers and measurements from all over the world. They also became increasingly digital and mathematical disciplines from the 1970s on, using computers and equations to draw meaning out of a vast sea of data. Philisophically, the nexus of scientific practices that swirled around the question of man's impact on the global climate

[44]Spencer Weart. *The Discovery of Global Warming.* Cambridge: Harvard University Press, 2003, pp. 101-02

and the global ecology all sought to understand the complex array of interacting variables that made up their subject. Yet simultaneously, they sought to generate a single set of numbers that could suggest towards what future the system was trending without erasing or fully explaining its inherant complexity and unpredictability. And both climate science and quantitative ecology came to understand human "productivity," whether it be of atmospheric carbon or the bound varient locked up in human agriculture, as antagonistic to the overall potential productivity of the planetary ecology. Furthermore, prediction and modelling became intrinsic to both. Indeed, while not up the level of sophistication of 1980s climatology, the work of Vitousek, the Ehrlichs, and Matson represented a kind of predictive modeling. They extrapolated backwards from a hypothetical upper limit of global photosynthetic production to the lower limit that was supposedly the result of human action.

This kind of "production modeling" was epitomized by work on the economic geography of imports and exports of "primary products" undertaken at NASA in the early twenty-first century. Economists had used "primary products" to refer to all unmanufactured commodities taken directly from the land. The "primary sector" encompassed agriculture, meat production, fisheries, forestry, mining, and, the growing global energy industry which grew out of nineteenth-century mining practices. Marc L. Imhoff, Lahouari Bounoua, Taylor Ricketts, Colby Loucks, Robert Harriss, and William T. Lawrence, a team of biologists and earth scientists, took as their subject that subset of economic primary products that fit the definition of ecological primary products. Namely, goods produced either by photosynthesis or through the immediate consumption of photosynthetic products by organisms that were than themselves sold for consumption. In this way, they (perhaps unwittingly) unified the ecological and economic meanings of "primary production," and in doing so created a map of structural inequality and unsustainability.

Imhoff et al 2004 shows both the longevity, versatility, and political significance of productivist thinking in the natural sciences. Satellite imagery had been used since the 1960s to further climatological and oceanographic science.[45] In ecology, the use of the technology was newer, but had an important predecessor in aerial photography. The reader might remember that aerial photography had been instrumental to the operations of the *Forschungstaffel* in the 1940s. Indeed, the ability to develop and interpret aerial photographs of eastern European plant cover was one of the principle skills that ecologists and geographers brought to Nazi Germany's wartime ecological reconaissance. By the early days of the twenty-first century, however, the political economic vicissitudes of primary productivity had disappeared. It had become a basic measurement of the ecological and earth sciences, stripped of political meaning, providing one of many objective quantifications of a rapidly decaying planetary system.

[45]Weart, *The Discovery of Global Warming*, p.110

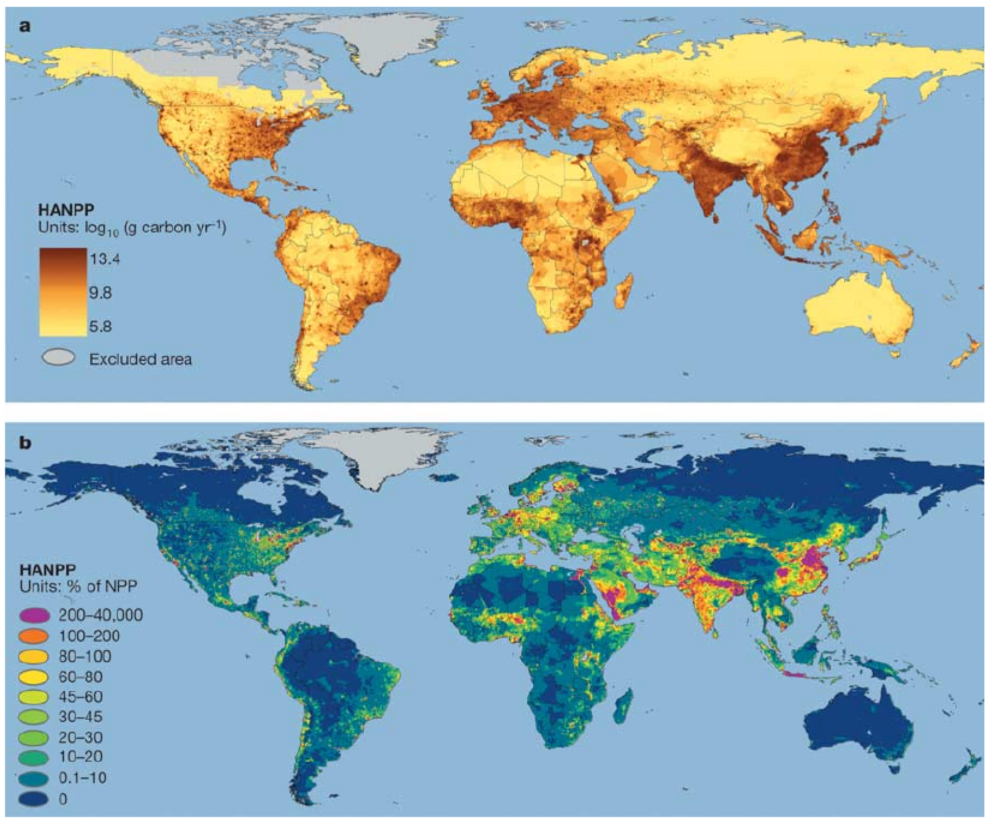


Figure 1 Spatial distribution of the annual NPP resources required by the human population. As measured by **a**, HANPP and **b**, HANPP as a percentage of local NPP. Both maps use the intermediate estimate for HANPP and are in units of carbon.

Figure 5.2: The Global Economy for Primary Products, 2004 (from Marc Imhoff et al. "Global Patterns in Human Consumption of Net Primary Production". In: *Nature* 429 (2004))

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