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UNIVERSITY OF CALIFORNIA
SANTA CRUZ

**TIME MACHINES:
MAKING AND UNMAKING RICE**

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

DOCTOR OF PHILOSOPHY

in

FILM & DIGITAL MEDIA
with an emphasis in ANTHROPOLOGY

by

Elaine Gan

September 2016

The Dissertation of Elaine Gan is
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ABSTRACT

TIME MACHINES: MAKING AND UNMAKING RICE

Elaine Gan

Time plays a significant role in analyses of social relations. Understanding the rhythms and cycles of collective life is one of the most important aims in studies of ecological and economic change. But these are often undertaken with the unquestioned assumption that human systems of time reckoning and historical periodization can be adopted as universal frames of reference for all social phenomena. Temporal measures of years, months, weeks, days are applied, rendering insensible ways of life that do not follow or synchronize with the forward marching beat of Western modernity.

This dissertation argues that critical-creative attention to multiple more-than-human temporalities opens up new possibilities for addressing historical and emergent effects of anthropogenic disturbances on biogeochemical diversities. Agriculture has entangled and rooted humans, plants, animals, microbes, insects, and land formations for centuries. *Oryza sativa*, cultivated rice, is among the most important crops; rice fields today are sites articulated by great violence and overwhelming creativity that feed half of the world's human population, with irreversible and uncontrollable impacts on lives considered nonhuman. To unpack their temporalities concretely, I

follow six types of rice and the assemblages of humans and nonhumans that gather around their cultivation in six disparate yet interrelated landscapes. Across radical difference and beyond human intention, modes of creative coordination emerge, making and unmaking six conjunctures. Like language, coordinations become meaningful through articulations of timing that enact continuities and ruptures. All six exist today. Rather than a chronology of causes and effects, they offer multiple points of situated encounter with contemporary relations of force.

Attention to timing, or capacities for multispecies coordination, is the heart of this work. I use an interdisciplinary approach — methods from the arts, sciences, and humanities — to propose an experimental analytic, which I call a *time machine*. Each time machine follows rice through an unusual conjuncture. Grounding each in multispecies coordination helps to move beyond a human-centered unilinear temporality. Importantly, it enables a critical-creative apparatus for specifying *which constitutive relations matter, when and for whom*. Considered together, the six time machines articulate sympoietic and autopoietic processes through which notions of history, agency, and language might become otherwise.

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for
Marean, Thaddeus, Wanda
life times

PREFACE

This is a story told through a flowering grass that has been cultivated over centuries. *Oryza sativa* is known by as many names, scents, tastes, charms, and practices as the countless fields and landscapes in which it finds its place. Most call it simply *rice* in English or *mǐ* in Mandarin. To follow the specificities of rice is to wander through a complex and contingent tangle of life ways, histories, and geographies. Rice is an entanglement of relations, a crisscrossing of political economies and biogeochemical ecologies. Here, rice appears as plant, crop, property, cycle, memory, security, subsistence, salvation.

This is a story about the making and unmaking of significant others. Relationalities are more than human, situated by difference that is impossible to contain and necessary to articulate for the crucial question of ongoing livability. This story embodies a process of learning how to think historically through the cultivation of plant life by many species — not only human farmers — and how to make sense of the many rhythms that flourish through cycles like rainfall — not only the forward-marching and homogenizing beat of Western modernity.

What might the world look like if we read and reread its workings through specificities of rice *as* socialities between various companion species? How might we

read specificities of rice that exceed or escape the ways in which our senses have been trained to recognize sociality, biopolitics, and historicity? Learning how to notice and recognize rice as many modes of being-with begins to render a very different world. It changes who we regard as "we". It changes how "we" becomes thinkable and workable.

I suggest that reading and writing about relationalities that are more than human pushes for expanded notions of temporality. It calls for a language that might describe differential timing that emerges when bodies and landscapes meet. Attention to timing, or capacities for multispecies coordination, is the heart of my story. Grounded in the materialities of rice cultivation, the timing that I describe is not a fixed, abstract period imposed by mechanical clocks or modern planners, but a historically situated and socially defined interval. It is contingent and creative, structured by incommensurability.

To foreground temporalities in multispecies relations, I offer an experimental analytic to configure my story: six types of rice in disparate yet interrelated landscapes appear as the leading figures in six time machines. Each time machine situates a conjuncture, a tangle of aleatory encounters that arises from multiple historical trajectories and socialities. The conjuncture becomes significant as differences attune and intensify particular capacities; the effects of these encounters and attunements begin to change and break the conjuncture itself. Humans are one force in a tangle of biotic and

abiotic forces. Capacities for making and unmaking that coordinate with land, light, water, energy take center stage. Differences do not synthesize but rather, become eventful when they begin to play.¹ Each time machine, thus, articulates relations of force that come to matter in a changing field. It diagrams an interval of time that is made eventful by worlds otherwise. It is an attempt to understand, not only complexity, but entanglement through emergent structures of timing.

Following Rice

From 2010 to 2016, I followed different types of rice. In many ways, I stumbled upon this project. Research began by accident. A travel grant from the Jerome Foundation in 2010 afforded me two trips to Manila for a series of field visits through liminal landscapes left over by American and Spanish colonization and somehow shifting with neoliberal industry. These included garbage mountains of Payatas, squatter settlements of Tondo, special economic zones in former American military bases, Subic in Olongapo, and Clark in Angeles. Subject to long histories of war and dispossession, as well as contemporary political economies, conditions in each are harsh and unjust, but also dynamic and emergent.

¹ I use the term "play", following Donna Haraway's concept of nonmimetic attunement — or simply, joy. In her book, *When Species Meet* (2008), Haraway and her dog Cayenne engage in the sport of agility, which Haraway describes thus: "Like language, play rearranges elements into new sequences to make new meanings... Like copresence, joy is something we taste, not something we know denotatively or use instrumentally. Play makes an opening ...Unexpected conjunctions and coordinations of creatively moving partners in play take hold of both and put them into an open that feels something like an eternal present or suspension of time, a high of "getting it" together in action, or what I am calling joy" (240-1).

I took the first trip over a long Christmas break and it proved difficult to plan interviews or site visits. On a whim, I got on a night bus for a ten-hour ride high up the mountains to Banaue, to see the famous Ifugao rice terraces. To walk the terraces is to follow the many trails shaped by intimate collaborations between plants, farmers, rainfall, rivers, and mountain ranges. The terraces were placed on a UNESCO watch list for endangered world heritage sites in 2001, calling attention to their gradual collapse and disrepair. I am only one among many who wondered: how can ways of life so enmeshed in the cultivation of plants through hydraulic engineering of land forms over centuries become endangered? What makes conditions so different and destructive today? And, most puzzling perhaps: How do such diverse land forms and ways of life relate with and articulate each other to constitute a contemporary condition?

Upon returning to University of California, Santa Cruz, I met a professor of anthropology, Anna Tsing who, with professor of science studies Donna Haraway, was co-teaching a seminar called "Multispecies Storytelling." It so happened that during the same Spring quarter, I was also taking two other seminars: studio critique with professor of contemporary visual cultures, Jennifer Gonzalez; and a software studies seminar with professor of digital media arts, Warren Sack. Thinking across these seemingly incommensurable interdisciplinary fields, I wanted to experiment with assembling a multispecies story around the Ifugao rice terraces. Tsing kindly lent me a beautiful hardbound monograph by anthropologist Harold Conklin, titled

Ethnographic Atlas of Ifugao: A Study of Environment, Culture, and Society in Northern Luzon (1980). Conklin's fine-grained details, ethnobotanical mapping, and intensive use of images, cultivated over decades, provided an important opening. It offered a model for considering rice as a composite of productive relations that unfold over multiple temporal, spatial, and ecological axes. It combined the sciences of empirical observation and quantitative methods, with the fine arts of high-resolution description and imaging.

I took my second trip to follow more rice trails in late 2010: seed banking and crop breeding at the International Rice Research Institute (IRRI) in Los Baños, Philippines; archival research at the oldest library in Asia, the University of Santo Tomas; boat rides along the Mekong delta and interviews at Cuu Long Rice Research Institute (CLRRI) in Can Tho, Vietnam. A research fellowship in 2011-12 from UCSC Science & Justice Research Center co-directed by Karen Barad and Jenny Reardon allowed me to research rice in California's Central Valley, including plant sciences at University of California, Davis. A research grant in 2012 from UCSC Porter College Fund enabled field visits to rice farms, wildlife refuges, and field stations in Biggs, Cosumnes, Richvale, Sacramento, and archival research at Chico State University. A fellowship from 2014-15 from Aarhus University Research on the Anthropocene (AURA) enabled a trip to the seed vault in snow-covered Svalbard in Norway. The more I followed various trails, the more it became clear that thinking through rice and its multiple capacities offers alternate frameworks for articulating

how shared life and death become possible.

Assembling Time Machines

My research does not only result in written text as its primary expression of scholarship. It comes together through an expansive range of critical-creative, art-science experiments. In recent years, I have written papers, created art installations, coded web browser-based projects, curated an exhibition, sketched diagrams, and animated video shorts.² All are attempts to render social dynamics vividly.

Importantly, each balances a commitment to *not* reduce or essentialize species and subjects, with an ongoing search for methods of articulating meaningful and compelling relations in concrete situations.

Here, working within the formal structure of a dissertation, I combine text and images in a creative form of speculative writing and critical storytelling. Decentering the human as maker and marker of time and history calls for an experimental mode of scholarship, a different kind of figuration, an inventive structure. In place of an enlightened *anthropos*, the Greek term for human, I offer an assemblage of relations,

² *Considering Rice* (2010), my first web-based experiment in multispecies storytelling, later became an installation for a solo art exhibition at Real Art Ways, CT. *Rice Child (Stirrings)*, originally created as my MFA Digital Arts & New Media thesis project, received the Chancellors Award, the highest award for graduate research at University of California, Santa Cruz in 2011, and has since been exhibited in both arts and academic venues. Documentation is online; links to these projects are included in the section titled "Supplemental Files."

articulated, and entangled through multiple conjunctures.³ While I follow rice as my lead figure, it is not the only player. There is no singular protagonist or hero, but a changing field of characters — none of whom are necessarily trying to communicate with or be responsible for another. A major figure in one might reappear as a minor figure in another. Companions in one are not the same in others. There is no singular God's eye view, no linear plot, no essentialized nature, no teleological end. Instead, I narrate a plurality of encounters, trajectories, coordinations, and contaminations that appear to constitute a heterogeneous and contemporary condition. Nature and culture are not defined by species, but capacities for being and belonging, qualities of haecceity and quiddity. Neither living nor dying are privileged. Sometimes sociality becomes downright deadly. Sometimes creativity destroys everything in its wake.

I do not present case studies, extensive natural history observations or empirical data gathered from a prescribed field or localized setting. I have no grand social or evolutionary histories that narrate rice as hero or victim. Instead, I research highly specific trails, fragile mobilities, and unspoken logics that gather around particular

³ This experimental form and analytic builds on physicist/philosopher Karen Barad's critical concepts of entanglement and intra-action. For Barad, entanglement is a more-than-human superposition of matter, meaning, and form that is intra-active and hauntologically indeterminate. Not a fixed totality composed by individual species or clear-cut parts, but an iterative ontoepistemology from which emerges queer *naturecultures* or what Barad calls *spacetime mattering*. Barad's important theorization appears in her book, *Meeting the Universe Halfway* (2007), and in a number of essays, particularly "On Touching — The Inhuman that Therefore I Am" (2012), "Nature's Queer Performativity" (2012), and "Quantum Entanglements and Hauntological Relations of Inheritance" (2010). Barad's radical ontoepistemology is increasingly being taken up across the arts, sciences, and humanities.

forms of rice cultivation. I focus on weaving together curious threads that might begin to trace a multispecies patterning.⁴ One thread leads to another. One cycle might intensify or intervene with another. One moment might unhinge a century. By changing the analytical frame — from local or global spread, social group, or historical period, to a temporal opening or interval defined by rice cultivation — each time machine situates continuities and discontinuities across multiple spatiotemporal scales. Each is an ontoepistemological attempt to trace an unusual conjuncture of events.

Writing Otherwise

This story is split into two asymmetrical parts: Part 1 attends to rice and Part 2 attends to the definition and analysis of time machines as a critical-creative analytic.

PART 1 describes the making and unmaking of rice through six paradigms. This is the order in which I encountered them; it is not the order in which they appear in the story that follows: annual *Ifugao rice* selected over centuries for prized pond field terraces that work within an array of cultivated land forms in the mountains of northwestern Philippines; high-yield, fertilizer-dependent *miracle rice* of the green revolution in the 1960s, bred in research labs and distributed by extension agencies

⁴ I follow science studies scholar Hannah Landecker's research approach to her book on cell technologies, *Culturing Life* (2007). Using mostly archival and published sources, Landecker does not attempt a thick description of the history of cell technology, or empirical observations that come from years of fieldwork in localized settings. Rather, she writes: "I do not want to do a case study and then generalize; I wanted to do highly specific empirical work on the general" (23).

throughout Southeast Asia; *floating rice* that elongates with the seasonal monsoon rains and the powerful flood surges of the Mekong River even as the river was paved over by colonial infrastructure; *irrigated rice* grown in the Central Valley of northern California with massive dams, water policies and federal bureaus, mechanized labor, and precision agriculture in the arid desert over the last century; *rice genomes* tied to patents, intellectual property regimes, and U.S. biotechnology industries incorporated in the 1980s; and, *frozen rice* currently being stored in a seedvault in Norway along with hundreds of thousands of crop seeds as insurance policies against future Doomsday scenarios. All six exist today.

In some, practices of humans and nonhumans align and synchronize with multiple cycles. These are time machines of reciprocal yet nonmimetic attunement. In others, agriculture dominates and rice is a workhorse, a means of producing calories and food supply for human populations. These are time machines of acceleration and forced labor. Then, there is the proliferation of rice as data and intellectual property. These are time machines of accumulation through dispossession and enclosure. And certainly, not everything is subsumed by capitalism or war; there are the emergent and uncontrolled feralities, time machines that seep through and flourish in contaminated fields and waste dumps of industrial postwar life. These are neither mutually exclusive nor transcendental categories. I distinguish these few for analysis based on working with rice.

Each of the chapter titles consists of three terms: the first identifies a historical interval; the second identifies the type of rice; and the third is a temporal figure or logic. Together, the three terms expand on conventional representations of past, present, and future as unilinear succession or infinite repetition of uniform periods, which have been historicized and problematized by scholars in the arts, humanities, and sciences. Spanning a *longue durée* that reaches from the emergence of agriculture in the Neolithic to an imaginary Doomsday, the time machines intervene with figurations of geological time as an arrow and cycle,⁵ phenomenological or lived time as a flowing river or a string of pearls,⁶ and social time as inadequately measured through calendar dates and astronomical observations.⁷ They are situated in specific historical intervals (the first term of three) and geographic locations, but aim to articulate a contemporary condition that is dispersed and incongruent in time and space. They may be read in any order.

PART 2 offers a definition of the concept of time machines. Why is it necessary to reconfigure and deconstruct *anthropos*, the human as maker and marker of time and history, as an entangled and generative relation that is more than human? Why is it inadequate to identify the relation as a proliferating multiplicity? How does

⁵ Stephen Jay Gould, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge, MA and London: Harvard University Press, 1987).

⁶ David Couzens Hoy, *The Time of Our Lives: A Critical History of Temporality* (Cambridge, MA and London: MIT Press, 2009).

⁷ Pitirim A. Sorokin and Robert K. Merton, "Social Time," *American Journal of Sociology*, 42:5 (March 1937): 615-629.

temporality work as an ontoepistemological analytic for taking social formations and aleatory encounters further, for articulating ecologies and economies together, for situating historical worldmaking capacities through multiple scales? How might it open up methods for enacting expanded fields for language *and* proposing vital modes of coordination?

In the pages that follow, I offer a story of a flowering grass known as rice, configured through critical-creative devices which I call time machines. It is a search for methods of articulating a contemporary condition as historical contingency and more-than-human emergence. It is a search for methods of making and unmaking habitability, or collective living across difference, a turn away from the death march of homogeneity.

No single species or modern subject survives or shapes worlds autonomously or teleologically. There is a lot at stake in considering modes of being and belonging that exceed human-centered stories of production and accumulation, domestication and extinction, salvation and apocalypse. Close attention to timing, or capacities for multispecies coordination that are historically situated and emergent, offers an alternative approach.

PART ONE:

MAKING AND UNMAKING RICE

GREEN REVOLUTION — MIRACLE RICE — AN UNINTENDED RACE⁸

Figure 1. Rice seedlings that are ready to be transplanted into different test fields at the International Rice Research Institute in Los Baños Philippines (Elaine Gan, 2011).

In the 1960s, farmers throughout Southeast Asia began planting varieties of "miracle rice" developed by agronomists at the International Rice Research Institute (IRRI) in the Philippines. Miracle rice varieties were high yield, quick growth crops with harvest times dramatically accelerated by synthetic fertilizers, pesticides, and irrigation, as well as agricultural extension agencies, mechanical equipment, and rural village banking. Scholars, scientists, and activists describe miracle rice as a key

⁸ This chapter was presented under the title "Rhythms and Cycles: Aleatory Attunements of Miracle Rice", as part of *Engineered Worlds*, a conference organized by Joseph Masco, Department of Anthropology, Neubauer Collegium for Culture and Society, University of Chicago, October 2-3, 2015.

protagonist in a green revolution that changed world food production and consumption. It marks a shift from the cultivation of rice as a way of life to rice as technoscientific package, a machine engineered to feed humans who are now conditioned to hunt and gather according to price points at supermarkets.

Considering a historical conjuncture — the green revolution in postwar Southeast Asia — as a more-than-human sociality enables a temporal figure to emerge: an unintended race between multiple temporalities. Situating miracle rice in a tangle of relationships that are made and unmade through recursive difference moves us away from considerations of human agency as the exclusive mover and shaker of historical change, and human mastery as its exclusive goal. Here, modernist values of speed and efficiency, inscribed onto miracle rice, meet nitrogen, a planthopper, and a virus.

Grass

The genus *Oryza* includes at least twenty species and thousands of varieties of flowering grasses that most of us call rice. A highly adaptable grass, rice flourishes in many kinds of climatic, soil, and water conditions: from swampy wetlands and river deltas to dry savannas, tropical to temperate climates, flat lowland gardens to highland complexes and rain-fed mountain terraces. It grows in heavy clay, wet soils, or poor sandy soils, in fresh or brackish water. While extremely mobile and fungible as seed or grain, rice is largely immobile as a growing plant and relies on plasticity to survive. Observable variations for example, include plant heights that range from 0.3

to 10 meters, maturation periods that range from 90 to 260 days, and dormancy that can last for up to five years. There are annuals and perennials with different flowering times, shattering or non-shattering seeds, aromatics, hard, soft, or sticky rice, with grain colors that range from violet and red to yellow, white, and black. One might say that rice is ontologically metamorphic. It gets along by playing with time.

Of the twenty named species of rice, eighteen are classified as "wild" and have not depended on human intervention to thrive. Two of the twenty are classified as "domesticated", or cultivars that humans have selected and planted over many iterative cycles in the past ten millennia. These cultivars are *Oryza sativa* or Asian rice, and *Oryza glaberrima* or African rice. With every cycle of seed to grain, patterns of energy come together, making and unmaking the bounds of possibility and impossibility. The right mix of water, nutrients, and temperature ruptures the seed coat and germination begins. A seedling slowly develops shoots, roots, and leaves. The growing plant develops a sturdier stalk from which new tillers emerge. At their tips, panicles and spikelets begin to appear. Roots start to anchor the plant, their lengths defined by soil, moisture, and microbial relations with bacteria and fungi. Just as the last leaf (called the flag leaf) emerges on top, spikelets begin to flower and bloom over a few days, taking up a small window of time, a few hours, for wind- or self-pollination and fertilization. Grains then start to ripen, and mature over the next 15 to 40 days depending on rice variety and surrounding temperature. As the grains fill with starch, they draw on most of the plant's metabolites, so leaf senescence or

aging begins. Grains will only fill with starch because of multiple processes of synthesis and conversion: light energy into carbohydrates, bacteria for nitrogen fixation, carbon dioxide and water into oxygen. Every cycle is different. Every rice seed is a recursion: a carrier of ongoing possibilities when differences come together at the right moment.



Anthropologist Clifford Geertz described an ecosystem as a "patterned interchange of energy" and wet-rice agriculture as "an ingenious device for exploitation of a habitat," for redirection of the energy between diverse living systems into food for human consumption.⁹ Redirections are situated by a logic of anticipatory action, a temporality of pre-emption where a future hunger, war, or pestilence might be deferred.¹⁰ Fields cleared from forests have become the unspectacular and slow-changing silos of national security, the means by which states and subjects feed, reproduce, and foretell themselves as markers of History and Progress. Much is at

⁹ Clifford Geertz, *Agricultural Involution: The Process of Ecological Change in Indonesia* (Berkeley: University of California Press, 1963), 3.

¹⁰ Joseph Masco, "From the Nuclear Borderlands to the Counter-terrorist State," *Social Anthropology/Anthropology Sociale*, 21, 3 (2013): 389-402.

stake in the ability to calculate the right mix at the right time for the right populations — preferably at the right prices and with the right contracts. Modern market economies have been honing these skills for a long time. For example, hedging against price changes might trail back to samurais and the Dojima Rice Exchange in Osaka. Storing grain against weather fluctuations links to the construction of pyramids in Gizeh or grain silos in Persia and Mesopotamia. Trade in high-yielding seeds that grow quickly stretches to first century Champa along the Mekong River, or earlier, to the floodplains of the upper Niger Delta. Technologies of exchange and domestication do not arise from a singular chain of human cause and effect, but from a mingling of multiple processes that amplify and disrupt in indeterminate ways.

Scientists like to claim that modern agriculture has enriched this more-than-human multiplicity, that the domestication of rice into a food-producing machine has led to substantial phenotypic and physiological changes.¹¹ They obscure the nature of these changes, which has not produced greater diversity and endurance, but genetic erosion and obsolescence. Over 75% of rice planted today was bred in research labs.¹² *Oryza sativa*, or Asian rice, dominates rice fields. *Oryza glaberrima*, African rice, the harder but lower-yielding cultivar, is now limited to northern Nigeria and Sierra Leone. And even that is dwindling as labs crossbreed *O. glaberrima* with *O. sativa* to

¹¹ Xun Xu et al., "Resequencing 50 accessions of cultivated and wild rice yields markers for identifying agronomically important genes," *Nature Biotechnology*, 30 (2011): 105-111.

¹² J. L. Maclean et al., *Rice Almanac*, Fourth Edition (Los Baños: International Rice Research Institute, 2013), vii.

create high-yielding NERICA, or "New Rice for Africa", a variation on the miracle rice model. *O. glaberrima* is now increasingly described as a troublesome weed.¹³

IR36



Figure 2. Different varieties of rice are constantly being crossbred and field tested at IRRI (Gan, 2011).

IR36 belongs to the species *Oryza sativa* and is the most widely planted miracle rice. It was engineered for uniformity and resistance, rather than difference. Crossbred from thirteen varieties, IR36 was released in 1972. Earlier models, such as IR8 in 1962 and IR26 in 1969, plus a long record of crop research, had equipped scientists with a list of ideal traits to breed for: white, slender, medium-sized grains; low

¹³ Olga Linares, "African Rice (*Oryza glaberrima*): History and future potential," *Proceedings of the National Academy of Sciences of the United States*, vol. 99 no. 25 (2002): 16360-16365, accessed September 2, 2014, doi:10.1073/pnas.252604599; D. H. Grist, *Rice*. Fourth Edition. (London: Longmans, 1953), 4; J. L. Maclean et al., *Rice Almanac*, Fourth Edition (Los Baños: International Rice Research Institute, 2013), 3.

sensitivity to photoperiods; high sensitivity to fertilizers; and a semi-dwarf architecture which meant shorter, sturdier stalks that can hold up a larger number of panicles as grains got bigger and heavier. IR36 appeared to be supernatural indeed: it yielded up to six times more grain than the average one ton per hectare. Its grains did not shatter when harvested by farmers and machines. Importantly, it could be harvested in 107 days, which was more than two months earlier than the commercial average, and less than half the time of local varieties that could take up to 260 days. Furthermore, it was bred with a resistance to grassy stunt virus, a pathogen carried by brown planthopper or BPH, an insect that had been destroying crops in epidemic proportions throughout Indonesia, the Philippines, Vietnam, Thailand, Malaysia, Sri Lanka, and India.¹⁴

Engineered for uniformity and resistance, the miracle rice varieties could be synchronized with industrialized agriculture: a shift from field to factory, from mingled temporalities of an ecological assemblage to fast Fordist assembly line manufacturing. Modernity gained traction through the image and promise of green, abundant, quick-growing harvests that could keep hunger, disease, and war at bay.¹⁵ A factory schedule came to be inscribed onto rice landscapes, a mechanical clockwork universe ticking through the determinate life cycles of very punctual, highly resistant seeds.

¹⁴ Donald L. Plucknett et al, *Gene Banks and The World's Food* (Princeton: Princeton University Press, 1987).

¹⁵ Nick Cullather, *The Hungry World: America's Cold War Battle Against Poverty in Asia* (Cambridge: Harvard University Press, 2010).

But the shift hinged on consolidation to a dangerously narrow genetic base. Writing about the ecology of rice production in Indonesia, anthropologist James J. Fox offers this stark diagram:

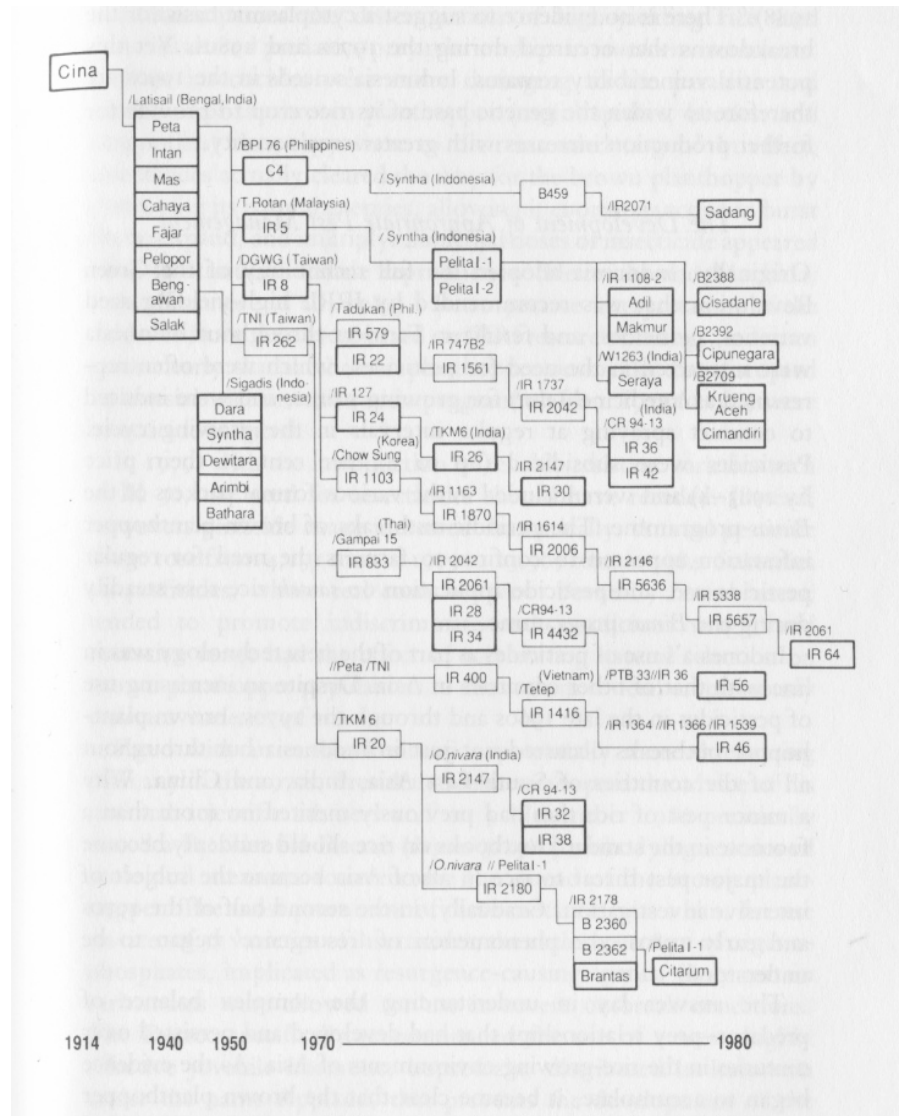


Figure 3. "Consolidated Pedigree of Major Rice Varieties with Cina Cytoplasm Planted in Indonesia since the 1940s", the diagram produced by anthropologist James J. Fox to show how the miracle rice varieties were all related to a single Chinese variety known as Cina (73).

Fox traced the miracle varieties in Indonesia to the same maternal parent, a Chinese variety known as *Cina*, which was introduced in Java in 1914. In the diagram, *Cina* is

represented in the box on the upper left side. Moving towards the right, Fox followed varietal crossings that were made between 1940 to 1980: the crossing of *Cina* with *Latisail*, a Bengali variety, by the Dutch-Indonesian breeding program in 1940 became one of the most far-reaching events in rice history. The crossing produced sturdy-stemmed, quick-growing varieties, one of which was called *Peta*. Twenty years later, *Peta* was crossed with a semi-dwarf Taiwanese variety known as *Dee-geo-woo-gen* or DGWG, to produce IR8, the first miracle rice variety from IRRI.

Fox maps the massive erosion of genetic diversity throughout tropical Asia. He notes that "by 1975, *Cina* was the ultimate maternal parent of 62% of the new (post-IR8) miracle varieties in Bangladesh; 74% in Indonesia; 60% in Korea; 75% in Sri Lanka; and 25% in Thailand." More than half of Philippine rice fields were planted to genetic derivatives of *Cina*. All IR varieties, except one (IR5), and virtually all semi-dwarfs developed in national breeding programs carried the same dwarfing gene from DGWG.¹⁶ By 1981, more than three-quarters of Philippine rice fields were planted to IR varieties. 90% of those fields were sown with a single variety: IR36.¹⁷

Fields of supernatural self-similar seeds required substantial redirections of energy. If rice had become a machine, a Model-T, what fueled its new speed?

¹⁶ James J. Fox, "Managing the Ecology of Rice Production in Indonesia," *Indonesia: Resources, Ecology, and Environment*, ed. Joan Hardjono, (Singapore, Oxford, New York: Oxford University Press, 1991), 64-67.

¹⁷ Plucknett et al., *Gene Banks*, 171-185.

Nitrogen

The green revolution was one of the largest anthropogenic disturbances to the global nitrogen cycle in the modern era.

The rate of application of synthetic nitrogen around the world has increased by at least seven times since the 1960s.¹⁸ A two-fold increase in rice yields depended on a thirty-fold increase in the use of nitrogen fertilizers.¹⁹ Timing is crucial when fertilizing rice; many farmers overapply, not used to miracles that run on a tight schedule. Half to two-thirds of nitrogen fertilizers leach into non-agricultural ecosystems causing widespread contamination and eutrophication, which literally chokes terrestrial and aquatic webs of interdependence. Nutrient-loving harmful algal blooms grow fast and crowd out large vascular plants, as well as cut off the oxygen supply to fish and marine invertebrates. In a 1998 article in the journal *Nature*, ecologist David Tilman noted:

The intensification of agriculture has broken what was once the tight, local recycling of nutrients on local farms. Indeed, the green revolution and the large-scale livestock operations that have come with it are reminiscent of the early stages of the industrial revolution, when inefficient factories polluted

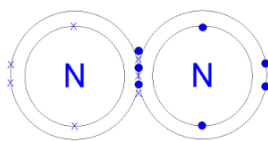
¹⁸ David Tilman, "The Greening of the Green Revolution," *Nature* 396 (19 November 1998): 211-2, accessed September 4, 2014, doi:10.1038/24254.

¹⁹ Zhong-Xian Lu et al., "Effects of nitrogen on the tolerance of brown planthopper, *Nilaparvata lugens*, to adverse environmental factors," *Insect Science* 12 (2005): 121-128.

without restriction... This has created an open nitrogen cycle that is rapidly degrading many other ecosystems.²⁰

There is a double movement at play here. From one perspective — *considering rice* — there has been a rapid consolidation of pedigrees. From another perspective — *considering nitrogen* — there has been an eruption, an overabundance that is suffocating other cycles.

A closer look at nitrogen sociality might be useful. Nitrogen is ubiquitous; it makes up 80% of the earth's atmosphere. Its strong chemical bonds, a triple bond, render it very stable and thus unreactive to most other processes.

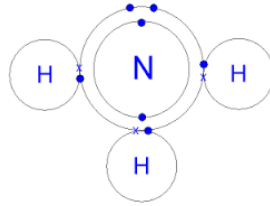


To be useful to living organisms like plants, atmospheric nitrogen must be given a nudge. It must be transformed or fixed. Until the early 20th century, it seemed that only bacteria, lightning, volcanic activity, and fire could spark nitrogen fixation, thus setting an important limiting condition for life. Today, humans produce over half of the world's supply of useable nitrogen.²¹ In 1909, a chemist, Fritz Haber at the

²⁰ Tilman, "Green Revolution," 211.

²¹ Edward D. Melillo, "The First Green Revolution: Debt Peonage and the Making of the Nitrogen Fertilizer Trade, 1840-1930," *American Historical Review* (October 2012): 1034; Michael Pollan, *The Omnivore's Dilemma: A Natural History of Four Meals* (New York: Penguin, 2006), 44-47.

University of Karlsruhe, developed a process for fixing nitrogen artificially by combining it with hydrogen to create ammonia (NH₃).



Later, with another chemist, Carl Bosch, they industrialized the process, fixing nitrogen at significantly larger scales. Ammonia has become the chemical base for fertilizers, pharmaceuticals, refrigerants, explosives, plastics, and cleaning solvents. Large amounts of electricity are required to generate the heat and pressure that can combine nitrogen with hydrogen to make ammonia. Hydrogen itself is derived from fossil fuels: coal, petroleum, and natural gas.

The fertility of soil used to be timed to sunlight, the presence and decomposition of organic matter (such as manure), and the periodicity of bacteria and oxygen.²²

Relations between humans and nonhumans cycled through local fluctuations that unfolded in close proximity. In the 1960s, fertility was rigged to fossil fuels instead — inputs that depended less on maintaining local coordinations and more on transporting energy over vast distances.

It is important to note that the shift from local nutrient cycling to transnational fertilizer trade emerged from earlier encounters. A rise in agricultural productivity,

²² Grist, *Rice*.

resulting from fertilizers imported from elsewhere, existed well before the 1960s. Historians Edward Melillo and Gregory Cushman describe the excavation and export of nitrogen-rich *guano* (dried seabird droppings) from Peru and sodium nitrates from Chile, to distant places such as California, Virginia, Prussia, Great Britain, and France from the middle of the 19th century to the First World War. These processes helped shape the modern Pacific World, and emerged through the introduction of new forms of contract labor or debt peonage,²³ as well as modern technologies of movement, such as the train, steamboat, and the steel-hulled clipper ship.²⁴ But nitrates soon replaced *guano* in the late 1870s; and, ammonia replaced sodium nitrate in the 1930s. In the Second World War, the Haber-Bosch process for synthesizing ammonia was applied to the large-scale manufacturing of explosives and gases used in Hitler's concentration camps. At the end of the war, stockpiles of unused nitrogen intended for explosives factories were repurposed for agriculture, causing a drop in farm fertilizer prices. These different events converged with the development of input-intensive wheat, corn, and the miracle rice varieties in the 1960s.

The sudden abundance of cheap nitrogen fertilizers and a slew of engineered crops structured a new rhythm in the world. Rice was running like Ford's Model-T.

²³ Workers were neither slaves nor wage laborers but entered into arrangements in which they repaid loans with fixed periods of physical labor.

²⁴ Melillo, "The First Green Revolution," 1028-1060.

With this, two other life forms began to stir in rice fields.

Brown Planthopper & Stunt Virus

Vital to every species is the ability to coordinate and respond to a particular environment, to nourish an *umwelt*, as Jakob Von Uexküll called it.²⁵ Rice fields saturated with nitrogen fertilizers became favorable habitats for more than 200 species of insect herbivores.²⁶ Alarming as that might sound, it is not necessarily disastrous: hundreds of species typically inhabit rice fields; no single species tends to dominate because of naturally occurring limits, such as changes in water levels, the presence of alternate plant hosts and predators, farmer practices, weather fluctuations, etc. Several things can break the life cycles of insects and the spread of diseases. But widespread and excessive use of nitrogen inadvertently improved the conditions of possibility for one herbivore in particular. Brown planthopper or BPH, *Nilaparvata lugens*, flourished. It eats only rice and prefers nitrogen-enriched rice crops. It had a field day with the sudden supply of nitrogen across multiple areas, continuous submergence, and closer plantings of genetically similar rice plants. BPH changed from being a fairly ordinary pest in the 1950s to being a major pest by the 1970s.

I was flipping through a 500-page volume on wet-rice cultivation by agricultural economist D.H. Grist. Published in 1953, Grist's work was part of a postwar initiative

²⁵ Jakob Von Uexküll, *A Foray Into The World of Animals and Humans, with a Theory of Meaning*, translated by Joseph D. O'Neil (Minneapolis: University of Minnesota Press, 2010).

²⁶ Zhong-Xian Lu et al., "Effects of nitrogen," 247.

by the United Nations to increase food supply as a way of securing world peace. I was scanning his chapter on pests, looking for BPH. The chapter has 32 pages filled with plant bugs, stem borers, army worms, grasshoppers, locusts, crickets, butterflies, beetles, water weevils, and flies. Grist had noted that the greatest total damage was caused by paddy bugs and the worst individual pest was the stem borer, or moth larvae.²⁷ On page 311, a short paragraph describes *Nilaparvata oryzae* as one of the worst bugs in Formosa, a short-lived Japanese republic in present-day Taiwan. *Nilaparvata lugens*, or BPH, the scourge of rice fields today, warranted little more than this terse description: "*is sometimes damaging in Malaya and Ceylon*".

Nilaparvata oryzae Mats., which is one of the worst bugs in Formosa, attacks the lower part of the plant, nymphs and adults boring into leaf-sheaths. Good results have been obtained by spraying with petroleum oil with or without pyrethrum and by pyrethrum-soap sprays or, if there is no irrigation, by the use of tobacco dust or synthetic insecticides. *N. lugens* Stål. is sometimes damaging in Malaya and Ceylon. *Nisia atrovenosa* Leth. is prevalent in the Far East. It over-winters in the egg state on paddy and grasses and is controlled by flooding, ploughing and grass burning to destroy the hibernating egg masses. Tobacco dust kills the pest.

The first BPH outbreak was in 1968 in Indonesia, following the release of IR8 a few years earlier. By the 1970s, BPH was *the* top pest in South and East Asia. Any increase in nitrogen resulted in a 40-fold increase in BPH density. Nitrogen stimulated their feeding rates and increased their ability to survive, lay more eggs, and live longer.²⁸ Entire IRRI reports are devoted to the study of major outbreaks in

²⁷ Grist, *Rice*, 290.

²⁸ International Rice Research Institute (IRRI), "Rice Grass Stunt Virus," *Rice Fact Sheets* (2010): 1-3.

temperate and tropical regions; its population dynamics in single-, double- or multi-cropped rice paddies; its brownish black and yellowish brown body; its life stages, predators, and parasites; its migration patterns in relation to maturing rice and changing seasons; its habit of taking up residence at the base of crop canopies where shade and humidity are high; its ability to drain the sap of rice plants, affect the rate of photosynthesis, impede the uptake of nutrients from roots, and change the chemical composition of the leaves of rice plants.²⁹

BPH became deadly because of three capacities:

(1) They multiply very fast. They lay many eggs and can produce multiple generations in one season; their speed outpaces rice and its scientists, and other pests. This rate has become increasingly problematic with global warming temperatures in recent years.³⁰

(2) They change. These insects have two wing morphologies that affect their olfactory senses: there are long-winged hoppers (*macropterous*) that can migrate over land and sea, able to fly long distances in search of newly planted, nitrogen-enriched rice fields to eat. And short-winged hoppers (*brachypterous*) that stay put, sensitive to

²⁹ Tomonari Watanabe and Hisashi Kitagawa, "Photosynthesis and Translocation of Assimilates in Rice Plants Following Phloem Feeding by the Planthopper *Nilaparvata lugens* (Homoptera: Delphacidae)," *Journal of Economic Entomology* 93 (4) (2000): 1192-1198; G. Hu et al. "Rice planting systems, global warming and outbreaks of *Nilaparvata lugens* (Stål)," *Bulletin of Entomological Research* 101 (2011): 187–199.

³⁰ Fox, "Ecology of Rice Production in Indonesia"; Hu et al., "*Nilaparvata lugens*"; Grist, *Rice*.

different odors that change their behavior at different life stages.³¹ When food supply dips or overcrowding occurs, short-winged hoppers grow wings. They become long-winged hoppers and migrate.

(3) They are carriers. BPH is a transmission vector for virulent pathogens known as grassy stunt and rice ragged stunt virus, both of which a planthopper can pick up and disperse simply while feeding.³²

You may recall from earlier in this chapter that grassy stunt virus is the virus against which IR36 was bred for resistance. It only infects rice because BPH, its vector, only eats rice. In 1970, it was reported in Taiwan and accompanied BPH outbreaks. In the mid-1980s, viral infections dropped with the introduction of BPH-resistant miracle rice varieties. But, not for long. Planthopper and virus overcame the engineered resistances within a few years. Once BPH overcomes a resistance, crops are easily infected by the virus or new viral strains.³³ Within a decade of release, IR36 was pulled from rice fields, soon to be replaced by an endless chain of lab-bred miracle rice varieties. From 2006 to 2009, hopperburn and severe viral epidemics led to high yield losses in the Mekong Delta, one of the largest rice exporting areas.³⁴

³¹ Shuang-Shuang Zhou et al., "De novo analysis of the *Nilaparvata lugens* (Stål) antenna transcriptome and expression patterns of olfactory genes," *Comparative Biochemistry and Physiology*, Part D9 (2014): 37.

³² Fox, "Ecology of Rice Production in Indonesia".

³³ IRRI, "Rice Grassy Stunt Virus".

³⁴ Hoang-Anh Ta et al., "Molecular diversity of rice grassy stunt virus in Vietnam." *Virus Genes* 46 (2003): 383-386.

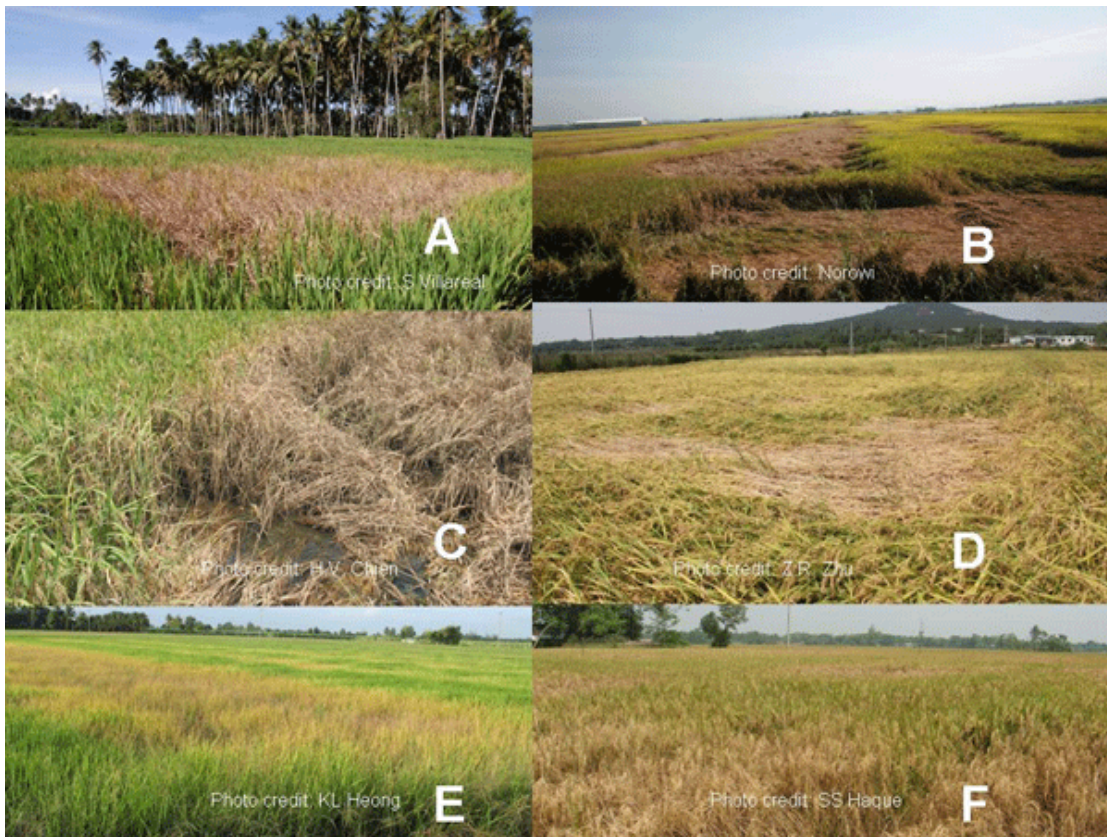


Figure 4. Field photographs show signs of hopperburn in: (A) the Philippines, (B) Malaysia, (C) Vietnam, (D) China, (E) Thailand, and (F) Bangladesh (ricehoppers.net).

A fast, nitrogen-loving bug that transmits pathogens can wipe out entire fields of rice. Rice labs now take 10 to 15 years to develop a new variety that will become obsolete within 4 to 10 years.³⁵ According to a molecular biologist I interviewed at University of California at Davis in 2013, engineered crops generally do not last long in the field. Vegetables that can be planted and harvested for 3 to 4 years are considered successful. Many have argued that this kind of simplifying technology costs a lot more labor and energy than it yields.³⁶

³⁵ Plucknett et al., *Gene Banks*, 19-21.

³⁶ Jack R. Harlan, *Crops and Man*, Second Edition, 1975 (Madison: American

Revolutions perform radical breaks in prevailing relationships and trigger new rhythms. In the 1960s, nitrogen fertilizers produced from fossil fuels powered up and resynchronized the growth rate of miracle rice. This same substance, nitrogen, also boosted the fitness of brown planthoppers, that also happened to be the mode of transmission for virulent viruses. Together, they wiped out harvests. Meanwhile, leaching nitrogen chokes and contaminates multiple ecosystems. Scientists recycle genes for an ever-growing arsenal of resistances. An unintended race, an aleatory muddle of toxic accelerations and novel attunements still unfolds.

II

DOOMSDAY — FROZEN SEEDS — UNDO and FOREVER



Figure 5. Snow and permafrost cover the mountain that encloses the Svalbard Global Seed Vault in March 2015. The entrance to vault is minimalist in style, calling little attention to its existence, history, and function (Gan, 2015).

In 2006, construction of the Svalbard Global Seed Vault (SGSV) began on Spitsbergen, an island in the arctic archipelago of Norway, about 1,300 kilometers from the North Pole. Today, three different agencies — Global Crop Diversity Trust (Crop Trust), Nordic Genetic Resource Center (NordGen), and the Norwegian government — fund and manage the vault, with a mandate to provide a secure backup of the world's plant life by accumulating and freezing its seeds. Built deep into a sandstone mountain insulated by permafrost, the vault is a storage unit for genetic resources, housing over 860,000 seed accessions and able to contain up to four million. It is a curated modern-day Noah's ark: agricultural research institutes in

various places around the world are slowly selecting their most valuable food crops, drying the seeds, sealing them up in pocket-sized foil packets, packing them into bins and boxes, for air shipments destined for SGSV. Upon arrival at the airport in Longyearbyen, Svalbard's main settlement, these containers are screened for foreign matter, logged into databases, loaded onto vans, then unloaded and delivered by hand. Inside the vault, they are stacked onto metal shelves that are arranged in rows, indexed alphanumerically. There the seeds wait, induced into a state of incapacity and invisibility, until human error or environmental catastrophe somehow prompt their return. The promise of being able to revert over and over again to some level of crop diversity, like programming an "undo" command for the world, sparks many passions and critiques. After all, arrows of time that figure historical movement, ecological succession, or landscape change suggest that there is really no such thing as "undo".



Figure 6. A hundred-meter tunnel leads to the entrance to three storage rooms at the vault. Its length is designed to protect the vault from outside attack (Gan, 2015).

SGSV is a curious place — banal and extraordinary at once — a stark underground bunker with multi-layered enclosures that freeze change, a dead end that locks out life and landscape in order to reconfigure their future iterations indefinitely. It is designed to transcend finitude; it makes no attempt to participate in community, including the special economic zone of Svalbard in which it embeds itself. During a visit in March 2015, I wondered how to make sense of the multiple natures and cultures that assemble around this one purportedly global collection of seeds, now dubbed the "Doomsday Seed Vault." I wondered about living forever, about lying still while histories unfold till an end of time.

How do lively seeds mixed up in dynamic, intimate ecologies and co-evolutionary trails come to serve as solitary and remote backups in a global initiative to seal off biodiversity against changing climates?

Depositors



Figure 7. One of three refrigerated storage rooms for seeds collected from various agricultural institutes. The architecture is utilitarian: fluorescent lights, bare concrete walls and floor, a metal gate, and metal shelves that hold boxes of uniform, stackable sizes from multiple institutes.

SGSV does not own the seeds it stores. It invites institutes, called "depositors", to send duplicates of those deemed most valuable, then banks those selections or "inventories" for free. Larger institutes with gene banks, such as the International Rice Research Institute (IRRI Philippines) and *Centro Internacional de Mejoramiento de Maiz y Trigo* (CIMMYT Mexico), ship inventories taken from existing seed files. Smaller ones with limited storage capacities are planting anew in order to multiply stock and harvest the best grains for safekeeping at the vault. These breeding and selection processes could take years. One institute, the International Center for Agricultural Research in the Dry Areas (ICARDA Syria), began loading boxes filled with seeds onto outbound planes as civil war escalated, and has already requested the first withdrawal from SGSV in September 2015.³⁷ The 63 depositor-institutes themselves represent gatherings from many different places. Some follow national boundaries, like PCGRI with varieties from North Korea, AGES from Austria, IITA from Nigeria. Others hold regional or continental collections, like EMBRAPA from Latin America, USDA from North America, WARDA from Africa. The largest depositor, IRRI, holds seeds from over a hundred countries.

Measured and weighted for industrial shelving, the shipping boxes are made of corrugated cardboard, wood, or plastic. The boxes sit unopened, proof that they

³⁷ The ICARDA online press release describes "cereals, legumes, and forages collected from regions in the world where the earliest known crop domestication practices were recorded in civilization, such as the Fertile Crescent in Western Asia, the Abyssinian highlands in Ethiopia and the Nile Valley, and the Central Asia and Caucasus region." Accessed April 1, 2015, <http://www.icarda.org/press-release-world-heritage-seed-collection-makes-its-way-syria-svalbard>.

remain the property of others. I look closely at the exteriors of the boxes, the many walls that separate me from the seeds packed inside. I try to distinguish labels and dents that might tell me where the boxes have come from and how they have traveled. Traces of human labor, industry, and border security are easy to recognize: labels handwritten with magic markers on paper, airline tags in primary colors (yellow Lufthansa, red DHL), rubber stamped instructions, plastic cable ties, digital barcodes, laserjet printouts, unruly packing tape, vegetal logos and boldface fonts. So many histories might be mapped from these all-too familiar material-semiotic traces.



Figure 8. Storage containers from CIMMYT sealed with plastic cable ties and stickered with DHL and Lufthansa shipping labels showing their passage from Mexico to Oslo (Gan, 2015).

But tracking such a profusion is not my task at the vault. I remind myself not to mistake SGSV for the Parisian arcades through which Walter Benjamin discerned a

phantasmagoric modernity, where a fragmented present might blast open many elusive pasts. The willful enclosure and rationalized extermination of many ways of life call for resituating criticality, a search for methods of unpacking the frames of meaning that render the violences of such a seed vault acceptable today. Here, in the twenty-first century, I learn to search and see differently.

SGSV is unmanned except when seed deliveries arrive and must be transported in. Visits like mine are timed to these deliveries and access is limited. Roland von Bothmer, a retired plant geneticist from NordGen in Stockholm, arranges my visit and takes me through the vault's three chambers. He tells me that most visitors are politicians, policymakers, filmmakers, and major media channels like the BBC. Following them, I sign my name and institutional affiliation into a guest book. Likewise, the names and countries of origin of the seed accessions are logged into a NordGen database. Called a "Seed Portal," the database is made available on NordGen's website.³⁸ A screenshot of one of the web pages of the Seed Portal appears in Figure 9 below. The site gives me tallies and breakdowns, classifications and quantitative accounts of crop biodiversity. Almost 5,100 species belong to almost a thousand genera, coming from eight continents. The largest number of accessions comes from Asia (321,547). By country, Mexico leads with 122,806 accessions, followed by India with 69,962, the United States with 37,849, China with 26,125, and

³⁸ NordGen Seed Portal, accessed March 14, 2015, <http://www.nordgen.org/index.php/en/content/view/full/1400>

Ethiopia with 25,719. Curiously, a relatively large proportion, 59,645 are classified as being from an "unknown" origin.

Continent name	Number of accessions	Number of seeds	Details
Africa	131,385	153,706,899	[Details]
Antarctica	2	400	[Details]
Asia	321,547	225,307,202	[Details]
Europe	103,952	45,488,729	[Details]
North America	185,923	66,546,057	[Details]
Oceania	6,030	2,063,378	[Details]
South America	55,485	24,304,206	[Details]
unknown	59,645	37,936,233	[Details]

Figure 9. The online "Seed Portal" database on NordGen's website gives breakdowns of the various kinds of seeds stored at SGSV, and their continents of origin.

The category "unknown" reminds me of old maps that used to distinguish *terra incognita*, or lands unknown yet to be mapped or documented. I email NordGen to find out more, thinking about Ptolemy's eight-volume *Geographia* in which concepts of latitude and longitude were introduced to overcome some of the challenges of representing a spherical earth onto a flat drawing surface. On the Seed Portal, instead of such cartographic conventions, I find plant worlds from various continents flattened out onto a very different kind of surface: a table with rows and columns. Thus, I search a universe of SGSV things not "unknown", of things subjected to the human inclination to identify by name and number.

I download a Microsoft Excel spreadsheet and scroll through the digital inventory. There are domesticated crops, wild plants, medicinals, hallucinogenics. I find varieties of watermelons, chicory, hemp, mahogany, poppy, spruce, pine, pears,

marigolds, numbering in the tens or hundreds. There are way more varieties of oats, rice, wheat, barley, potatoes, pepper, beans, peas, each numbering in the thousands. Deep histories layer behind each entry. Translated into searchable data, things seem to lose their historical connections and complexities. Looking for hints about their relative values, I scroll through the total counts of different varieties. I go by a familiar ordering logic of comparing the very few to the very many. I find that there are two varieties of *Gossypium herbaceum*, or Levant cotton first cultivated in western Sudan, India and Egypt for clothing, and described by Herodotus in the 5th century BC in his accounts of the Persian empire. There are seven varieties of *Mirabilis jalapa*, known as the marvel of Peru, a plant that grows multi-colored flowers (from bright yellows, whites, dark pinks to vibrant purples) that open in late afternoon, produce a sweet-smelling fragrance throughout the night, then close for good in the morning. These color variations, now useful for food coloring and fabric dyes, enabled Carl Correns' study of cytoplasmic inheritance in the early 1900s, a counterexample to Gregor Mendel's laws of genetic heredity.

Among the 148,667 varieties of the genus *Oryza*, or rice, I find that there are little more than a thousand of a wild red rice species, *O. rufipogon*, 5,000 of cultivated African rice, *O. glaberrima* — and a whopping 140,000 varieties of *O. sativa* or cultivated Asian rice, the dominant variety of today's rice industry. If my simple ordering logic of few vs. many may be considered symptomatic of the selection

criteria for seeds worth saving, then we may be in for a future world with little color, limited fluffiness, and a terrible paucity of wildness.

Why make a world in which plants only exist to serve and feed humans?

Temperature

Temperature renders all seeds equal. Dried to 5% of their moisture content, then sealed into foil packets designed to keep moisture and air out, the vault's 860,000 seed deposits are preserved at a uniform temperature of -18 degrees Celsius. While humans are comfortable within a temperature range of 20 to 24 degrees when sedentary, plants can live within a wider range of temperatures. Crop seeds germinate and grow within a range of 4 to 38 degrees (26.7 degrees optimally), depending on variety. At -18 degrees, the metabolic and physiological processes of plant seeds are slowed down significantly. Risks of spoilage or decay due to bacteria, fungi, or insects are reduced. Thermometers, sensors embedded into the walls, vents, and alarm systems stand as wired sentinels for this "frozen Garden of Eden,"³⁹ digital measuring sticks to ensure that life remains suspended within the ice-rimmed walls. And should

³⁹ There are many biblical references in discourses around environmental change and particularly around SGSV. This one is from a documentary titled "Seeds of Time" (2015), directed by Sandy McLeod. Accessed April 1, 2015. <http://www.seedsoftimemovie.com/> Phrases like these may be considered as symptoms of long entangled legacies between science and theology that have been powerfully theorized by scholars such as Donna Haraway, Isabelle Stengers, Susan Harding.

freezing and monitoring technologies fail, the permafrost or cryotic soil of Svalbard provides the next layer of backup.

By tinkering with temperature, then holding it constant every minute of every day, the seed vault creates a time lag, a hermetically sealed delay through which scientific research institutes and industrialized agriculture might perhaps address environmental change. Change that they had previously, perhaps inadvertently, triggered.

Dehydrated and frozen, the seeds seem to linger outside the limits of human time.

They are valuable because they may be harvested for their genes, toolkits of specific traits and resistances that may be useful for crop breeding and agricultural production for a few hundred years in the future. Seeds persist not as kinetic energy generated through bodies in motion, but as potential energy deposited, shelved, put on hold.

Thus, SGSV promises that any unfortunate loss of seeds or destruction of biodiversity may be reversed by a withdrawal; depositors simply request their boxes back. The boxes, then, are a kind of time capsule, sealed containers of timeless seeds, available on demand.

But, can the world be programmed for "undo"?

Technologies of refrigeration have played a key role in the coordination of food supply, medical research, human comfort, as well as the redefinition of life itself.

Refrigeration provides a temporal architecture of stasis: a time machine within which

organic processes might be held at bay. Through stasis, new forms of wealth may be produced. Environmental historian William Cronon points to refrigeration as the primary technological problem that meat packers faced in expanding markets for beef and pork in 19th century Chicago.⁴⁰ Historian of science Simón Reif-Acherman points to its importance in the fermentation processes of beer breweries in Germany and the United States.⁴¹ Science studies scholar Hannah Landecker situates its significance for enabling cell cultures, or the technical means by which cells can survive in laboratories, detached from living bodies.⁴² Frozen bodies become stable and fungible units of property that can circulate through many more sites of production and exchange.

Refrigeration has taken a while to develop. In 1755, William Cullen of University of Edinburgh produced ice in a laboratory by mechanically playing with vacuum pumps and the evaporation rates and boiling points of ether and water. Until then, ice supply fluctuated with seasonal weather conditions as it was harvested from ponds, lakes or rivers and transported from North America (particularly New England) to Central and South America, the West Indies and India, and from Norway and Sweden to England and German ports on the North Sea.⁴³ In the early 1800s, growing needs for more

⁴⁰ William Cronon, *Nature's Metropolis: Chicago and the Great West, 1848-1893*. (New York: W.W. Norton and Company, 1991), 230-235.

⁴¹ Simón Reif-Acherman, "The Early Ice Making Systems in the Nineteenth Century," *International Journal of Refrigeration* 35 (2012): 1224-1252.

⁴² Hannah Landecker, *Culturing Life: How Cells Became Technologies* (Cambridge, MA and London: Harvard University Press, 2007).

⁴³ Reif-Acherman, "Early Ice Making Systems".

reliable supply pushed for temperature control that could run independently of costly weather changes. Experiments into mechanical ice making systems with artificial heat exchange, air compression, and vapor cooling coils, as well as chemical refrigerant agents were undertaken.⁴⁴

In 1906, engineer Willis Carrier of Buffalo NY was granted U.S. Patent No. 808897 for what he described as an "Apparatus for Treating Air", a centralized air conditioning system that could control the air humidity inside a Brooklyn printing plant owned by the Sackett-Wilhelms Lithographing and Publishing Company.⁴⁵ Around the same time, Frigidaire, Kelvinator, and General Electric began releasing the first iceboxes or refrigerators for household use, continuing use of toxic and flammable chemical refrigerants such as ammonia. In the 1920s, Thomas Midgely Jr. and Charles Kettering led a team at Frigidaire, a subsidiary of General Motors, and turned to the synthesis of chlorofluorocarbons (CFCs) as a much less dangerous alternative. By the 1930s, Kinetik Chemicals Inc. (later to become DuPont) registered the trade name Freon, a stable, odorless, nonflammable, and seemingly nontoxic refrigerant made from a compound of CFCs. With the development of Freon, refrigeration and air conditioning became increasingly ubiquitous fixtures of modern domestic and industrial life in the West.

⁴⁴ Reif-Acherman, "Early Ice Making Systems"; George C. Briley, "A History of Refrigeration," *ASHRAE Journal* 46 11 (November 2004): S31-S34.

⁴⁵ Gail Cooper, *Air-conditioning America: Engineers and the Controlled Environment, 1900-1960* (Baltimore: Johns Hopkins University Press, 1998).

For the past 250 years, humans have been working to conserve food and forestall expiration by designing machines that can regulate temperature and weather, thus re-engineering the unforgiving tempo of life and death — one room, meal, and slaughter at a time.

Ozone

Tempos reverberate. In the 1960s, James Lovelock started measuring accumulations of CFCs in the Earth's atmosphere on expeditions in the Arctic and Antarctic, providing initial data that would later feed the work of scientists at University of California at Irvine, Mario Molina and F. Sherwood Rowland. By the early 1970s, scientific research showed that the stability of CFC molecules allows them to linger in our atmosphere for a long time — somewhere between 40 to 150 years — before wind might diffuse the molecules and carry them up towards the stratosphere. There, ultraviolet rays break apart the CFC molecules, freeing one chlorine atom per molecule. This freed chlorine atom in turn splits apart ozone molecules, which form a protective ozone layer against the sun's rays. According to the U.S. Environmental Protection Agency, one chlorine atom can break apart more than a hundred thousand ozone molecules. Once split apart, an ozone molecule (O_3) becomes three oxygen atoms. This is constantly happening: molecules of the ozone layer are constantly binding and splitting apart. However, the accelerated introduction of CFCs due to human technologies such as refrigeration has overwhelmed such processes through which a layer can hold. With a depleted ozone layer, higher levels of the sun's

ultraviolet radiation reach the Earth. Cancers and other mutations result. Humans, animals, plants such as rice that depend on nitrogen-fixing cyanobacteria to enrich root networks, as well as the reproductive cycles of phytoplankton, marine, and amphibian life undergo irreversible damage.

Collaborations between scientists, researchers, environmental activists, and policy makers helped slow down the manufacture of CFCs and other ozone depleting substances (ODS) in the late 1980s. Broad-based international treaties include the Montreal Protocol on Substances that Deplete the Ozone Layer, which phased out use of CFCs when it went into effect in 1989, as well as the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) which has aimed to limit greenhouse gas emissions since its implementation in 2005. But, complexity is tricky: the fact that CFCs can linger in the atmosphere for more than a hundred years suggests that the effects of these novel conjunctures are just beginning to surface. Atmospheric indeterminacies saturate planetary futures.

Paradise Lost

In writing about cultural and ecological survival in Hong Kong, science studies scholar Timothy Choy argues that the politics of endangerment depends on two moves: threat and specification. He writes that "to speak of an endangered species is to speak of a form of life that threatens to become extinct in the near future; it is to raise the stakes in a controversy so that certain actions carry the consequences of

destroying the possibility of life's continued existence."⁴⁶ A threat must be identified. And before that, specification of the object of threat, and its life chances, must be made. Thus, Choy associates endangerment with a temporality of *anticipatory nostalgia*: an urge to protect the past from the present, and the present from the future. He links this to *imperialist nostalgia*, a term offered by anthropologist Renato Rosaldo to describe an affect that could be discerned among Western anthropologists writing about ruination, loss, and transformation in the global South. Choy writes:

What was especially pernicious about this nostalgia, Rosaldo helped make clear, was that through it we might mourn the loss of something while disavowing our own complicity in destroying it. It was imperialist nostalgia, for instance, when colonists lamented the transformations of native lifestyles into colonies. It was equally so when settlers decried the ravaging of a nature that they had helped to decimate...⁴⁷

This is helpful in considering SGSV. Depositor-institutes like IRRI mourn the loss of varieties that they have classified as heritage or wild. They take actions that include embarking on seed collecting expeditions headed for distant communities whose "traditional" ways of life have been endangered by corporations that fund the very same depositor-institutes. A similar situation becomes apparent at Crop Trust, SGSV's main financial partner. Working alongside two other partners, the Norwegian

⁴⁶ Tim Choy, *Ecologies of Comparison: An Ethnography of Endangerment in Hong Kong* (Durham and London: Duke University Press, 2011), 26.

⁴⁷ Choy, *Ecologies of Comparison*, 40.

government and NordGen, Crop Trust is a public-private fundraising organization based in Bonn, Germany. Its supporters include the Bill & Melinda Gates Foundation, the Rockefeller Foundation, World Bank/CGIAR, Syngenta, DuPont, and CropLife International. CropLife is a curious aggregate of multinational corporations in the petrochemical, pharmaceutical, and agricultural industries: BASF Chemicals, Bayer Crop Science, Dow Agrosciences, DuPont, FMC Technologies, Monsanto, Sumitomo Chemicals, and Syngenta.⁴⁸

Echoing depositor-institutes, these multinationals publicly lament the loss of biodiversity and the rise of hunger, while simultaneously privatizing food distribution, patenting seed varieties, and externalizing costs of disease and landscape degradation. The temporality of endangerment that is at work here seems to belie a more complex dialectic: on the one hand, we witness a nostalgia for dying others, imaged through paradise lost. On the other, we hear a promise of unlimited living, of paradise forever.

Forever

On Crop Trust's website, SGSV is described as a "fail safe, last chance backup facility." Even the United Nations calls it "the ultimate backup of global crop

⁴⁸ The CropLife International website also publishes its complete list of partners, a global member network: <https://croplife.org/about/members/>, accessed on March 30, 2015. The configuration of multinationals is changing. As I finalize this dissertation in August 2016, Dow and DuPont are poised for a merger, and U.S. regulators have just approved China National Chemical Corp.'s planned \$43 billion takeover of Syngenta.

diversity."⁴⁹ In Figure 10 below, Crop Trust describes itself on its homepage as "an international organization working to safeguard crop diversity, *forever*."⁵⁰

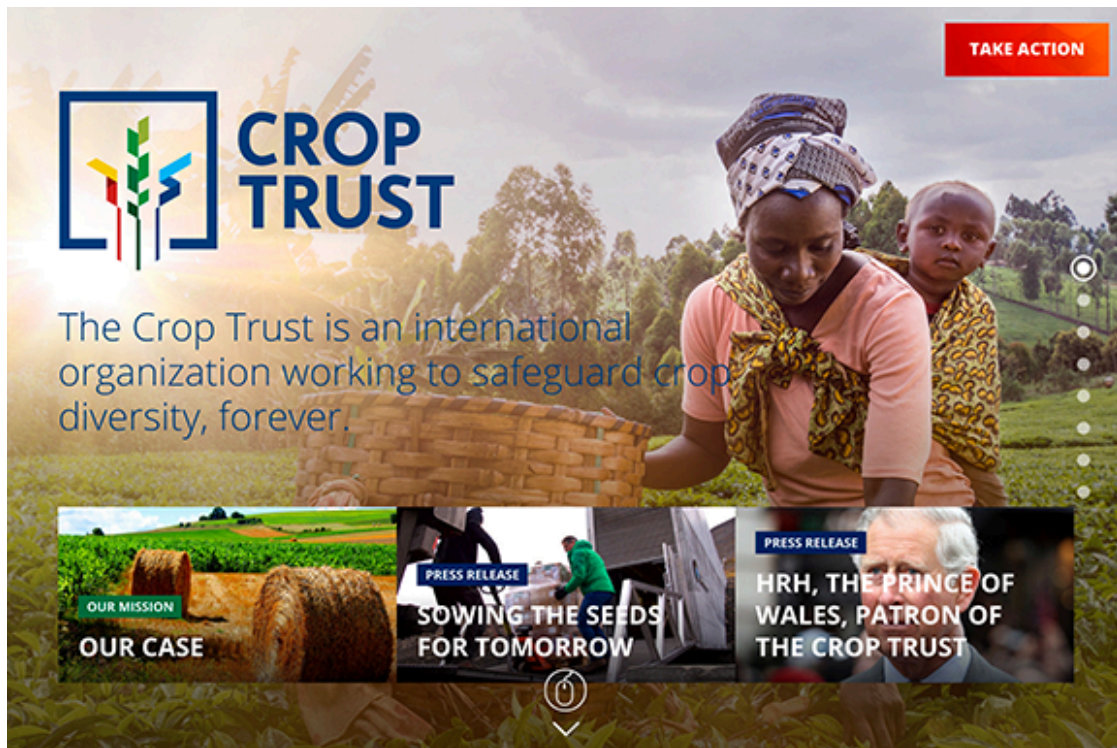


Figure 10. The Crop Trust homepage announces its mission to safeguard crop diversity, forever.

Human beings *are* the endangered species around which a vault of seeds must be organized. Nothing less than human security is at stake — a security that can be controlled through lockdown and achieved through ongoing collection of seeds, forever.

⁴⁹ UN News Service, "Conserving plant genetic diversity crucial for food security," *UN News Centre*, October 26, 2010, accessed September 14, 2015, <http://www.un.org/apps/news/story.asp?NewsID=36564#/h>

⁵⁰ Slogan on the homepage of the Crop Trust website, accessed on March 30, 2015, <https://www.croptrust.org/>.

Like a refrigerator, Crop Trust positions itself as a technology that insulates against entropy or decay, a time machine of enclosure against climate change. But a refrigerator is one kind of time machine: an assemblage of metal, plastic, compressors, pipes, dryers, chemical agents, and electrical circuits that became possible with industrialized manufacturing in the 18th century. A refrigerator mechanically extends intervals of time, rigging longer periods between two events — for example, the time between slaughtering a cow and eating its meat. Crop Trust is another kind of time machine: an assemblage of private and public organizations, patents, policies, territories, and petrochemical-pharmaceutical-food conglomerates. These do not mechanically extend time, but contract to enact new forms of power over life, or what Michel Foucault famously theorized as biopolitics.⁵¹

Science studies scholar Kaushik Sunder Rajan resituates Foucauldian biopolitics as a co-constitutive relation between the biological sciences and capitalist market forces. With the introduction of recombinant DNA technology (RDT) in the late 1970s, Sunder Rajan argues that the life sciences become "technological." The performance of a set of techniques that involves splicing and joining DNA molecules to create cellular or molecular products brings into being new forms of value and modes of accumulation, or biocapital.⁵² Rajan's theorization of the co-production of two

⁵¹ Michel Foucault, *The History of Sexuality: An Introduction*, 1978 (New York: Vintage Books, 1990).

⁵² Kaushik Sunder Rajan, *Biocapital: The Constitution of Postgenomic Life* (Durham and London: Duke University Press, 2006), 5-9.

simultaneous threads — one involved in the production of commodities and the second speculative and technoscientific — is helpful in considering how "forever" becomes meaningful to the operations of the seed vault.

Crop Trust was founded in 2004 to raise funds, two years before SGSV opened its doors. News of unprecedented species extinction and genetic erosion in recent decades have supported its mission to expand the collection of seeds at SGSV, and importantly, to characterize and catalogue the genetic makeup of all seed accessions that have been deposited. In January 2015, it launched *Diversity Seek*, or *DivSeek* for short, a digital initiative to create a comprehensive information system that will translate physical seeds into a digital library of genetics that can then be "mined" by crop breeding programs around the world. Joining the foray into big data solutions for environmental crises, DivSeek aims to accelerate the development of new agricultural products — "climate-ready crops" — as human populations approach the nine-billion mark. A white paper published by Crop Trust claims: "DivSeek will mine the wealth of genetic resources to enhance food and nutritional security."⁵³

Critics quickly responded that big data solutions require computing power and equipment that only wealthier researchers and institutions can access. Rather than democratizing resources, the initiative would extend unfair advantages to corporations, building yet another pipeline for what Marxist geographer David

⁵³ DivSeek, "Harnessing the power of crop diversity to feed the future," accessed August 8, 2015, <http://www.divseek.org/white-paper>.

Harvey has called "accumulation by dispossession."⁵⁴ Debates around whether to translate and quantify publicly available seeds into privately held data are crucial political struggles. Yet, I also want to attend to a larger shift, one that hinges on the promise and products of "securing forever." Research and development for new rice varieties currently take 10 to 15 years. Because of genetic erosion, soil degradation, and species mutations, these varieties can only be planted in fields for an average of 4 years. Agriculture cannot keep up. To maintain current food supply chains and agricultural profits that sustain multinational corporations, an endless track of new product possibilities must be forged. Unlike a refrigerator that becomes empty as its contents are eaten, a digital library may be searched, processed, and remixed constantly to create infinite variations, without deterioration. DivSeek offers new products in the form of data that may be unlocked, accessed, crunched, upgraded, and replicated, without being tethered to the unruly materialities and charged histories of seeds. Data can be mined — forever.

An online press release for DivSeek includes a list of endorsements from rice scientists and gene bank directors. One from a biologist and Cornell University professor took me by surprise. It reads: "To me, DivSeek is like having all the colors of the rainbow at your disposal: you have the essence, now you can mix and match and create almost any color you like."

⁵⁴ David Harvey, *A Brief History of Neoliberalism* (New York and Oxford: Oxford University Press, 2005).

In a frozen, digitized, paint-by-numbers world, undo and forever pretend that there are no limits and no ruins.

III

MONSOON — FLOATING RICE — OSCILLATION⁵⁵



Figure 11. Rain falls during a monsoon storm in the Mekong (David Bibby, 2013).

From April to September, monsoon winds blow southwest across the Indian Ocean, bringing rain to the Mekong, the longest river in Southeast Asia. Rainfall intensifies into tropical storms and typhoons in June and July. From October to March, winds reverse direction; rainfall becomes less frequent and the weather becomes dry. For centuries, the oscillation between wet and dry seasons, the presence or lack of rain, has structured a tempo for many ways of life. From year to year, seasons come and go with a regularity that enables collective practices like the cultivation of rice, as well

⁵⁵ This chapter was presented under the title "Oscillation: Layered Temporalities of the Mekong", as part of *Cultivation: Vegetal Lives, Global Systems, and the Politics of Planting*, a conference organized by Matthew Fuller and Shela Sheikh, Centre for Cultural Studies at Goldsmiths University of London, March 18-19, 2016.

as fluctuations that reconfigure such practices — sometimes to devastating effect. If the first rains come early in April and the river floods gradually, farmers can synchronize rice growth with freshwater and anticipate a good harvest.⁵⁶ If rains arrive late or flooding happens too much or too fast, things proceed differently. In 2008, heavy rainfall exceeded expectations; floods rose to their highest levels in over a century, sweeping away lives, homes, and harvests.

Thus, the monsoon conditions life and landscape, an ecology of interactions and affordances. Histories and habitats are made by the seasonal winds and rains that are themselves shaped by differential circulations of heat and moisture, moving through land and sea. The Mekong crosses six nations: it rises in the Himalayas, in the Chamdo region of the Tibetan Plateau that is described as an "area of perpetual snow." From these steep upper reaches, its waters descend and flow southward through Yunnan in China, between Myanmar, Laos, and Thailand, then through Cambodia, before branching out into multiple channels that course through the floodplains and delta of southern Vietnam. There, it discharges onto the South China Sea. Freshwater from rain and snow meet the tidal pulses of incoming saltwater from the sea.

I have just described the Mekong — a word in Lao that translates into "mother of waters" — as a single flow that extends over 4,000 kilometers (about 2,500 miles) in

⁵⁶ In the early 1900s, poll taxes came due during the harvest period.

length, a watershed that drains more than 795,000 square kilometers (or more than 300,000 square miles) as it makes its long journey from the Himalayas to the South China Sea.⁵⁷ At least forty million people and countless species depend on it. But "it" is not a static place and hardly a single force. It is a "continual state of flux" where timing matters.⁵⁸

That's part of the story. The river is also shaped by trajectories of power and empire, circuits of trade and technology, regimes of taxation and governance that carve out territory. Since the eighteenth century, the southward migrations of the Vietnamese have displaced lowland agroecological complexes of the Khmer and Cham, bringing wet-rice irrigation practices to the delta.⁵⁹ Historians have described the monopoly credit systems of Chinese merchants and Indian *chettys*, and then the ruptures of French colonization, the Indochina wars, American invasions in the nineteenth and twentieth centuries.⁶⁰ These now haunt 21st century mega-dams. The river has been a site of wave after wave of revolutions and massive anthropogenic changes. Today, the

⁵⁷ William Cronon, "Nation-Making in the Mekong Mire", foreword to *Quagmire: Nation-Building and Nature in the Mekong Delta*, by David Biggs (Seattle: University of Washington Press, 2010), xi.

⁵⁸ David Catling, *Rice in Deep Water* (Los Baños: International Rice Research Institute, 1992), 28.

⁵⁹ Richard O'Connor, "Agricultural Change and Ethnic Succession in Southeast Asian States: A Case for Regional Anthropology," *The Journal of Asian Studies*. Vol. 54, No. 4 (November 1995), 968-996.

⁶⁰ David Biggs, *Quagmire: Nation-Building and Nature in the Mekong Delta* (Seattle: University of Washington Press, 2010); Pierre Brocheux, *The Mekong Delta: Ecology, Economy, and Revolution, 1860-1960*. (Madison: University of Wisconsin-Madison, 1995).

Mekong Delta in southern Vietnam is one of the largest rice-producing regions, with a "rice first" government policy that prioritizes economic development through irrigated agriculture over environmental health.⁶¹

While the monsoon shapes life and landscape, it is also jerry-rigged onto resolutely human sociopolitical projects and a technoscientific modernity that metabolizes by churning difference into property and profit.

Through what scales might we understand who makes and unmakes the Mekong? On the one hand, there are the cycles of rain, wind, and floods, as well as their unexpected fluctuations that lead to famine and disease; on the other, forces of human industry, war, and waste. From 1870 to 1914, no less than thirty million people in Southeast Asia died of hunger when the monsoon rains failed, even as the products of their labor were being conscripted into emerging market economies of the British, French, and Dutch.⁶² These cannot be described through the language of linear causes and effects, or of big and small categories for humans and nonhumans occupying timeless environments. Describing them as ever-proliferating multiplicities and processes is not enough either. The key challenge lies in trying to describe how specific configurations bring new worlds into being. How does one thing articulate

⁶¹ In Vietnam, "rice first" translates into the build-up of irrigation infrastructure and concrete dikes for water control, planting of high-yielding commercial seeds that depend on chemical inputs, the shift from one crop harvest to two, and now three per year.

⁶² Mike Davis, *Late Victorian Holocausts: El Niño Famines and the Making of the Third World* (London and New York: Verso, 2002).

another, and in so doing, enact a structural transformation? How might we make sense of articulations that may only come into being through contingent encounters?

Here, I follow four species: floating rice, cultivated by the Khmer people; water hyacinth, an ornamental plant from South America; a snail that hosts a deadly parasite, a blood fluke; and giant catfish, a freshwater mega-species that is becoming extinct. To help me think through the puzzles of articulation, I use the temporal scale of a monsoon. I started with a simple question: what happens when rain falls along the Mekong? The monsoon marks an oscillation between wet and dry seasons. Here, I consider oscillation as a structural tempo that might render visible four species as variations in capacities for change, mobility, and coordination.

Rice (Oryza sativa)

When the Khmer New Year comes in April, weather in the Mekong is hot and dry. Rains bring freshwater and the soil becomes soft — both vital to rice cultivation. And so, the planting season begins with high-intensity, long-duration rainfall. By June, heavy rains overflow riverbanks and lead to floods. The lower Mekong delta is extremely flat; many of its low-lying coastal areas may stay under water for a few months during the wet season. In September or October, water levels can reach up to 5-7 meters. By November, floodwaters recede and fields drain. When the rains end in December or January, harvest begins. A new dry season unfolds.⁶³

⁶³ Philip Taylor, *The Khmer Lands of Vietnam: Environment, Cosmology, and*

Rice is the dominant crop in this landscape. But it is water that determines the mode of cultivation and the kinds of rice cultivated, which may be various mixes of early rice, half-season rice, or full-season rice.⁶⁴ Rice is a semi-aquatic plant: it needs oxygen as much as it needs water. To survive the Mekong floods, it has to either hold its breath — or, find ways to keep breathing. Over millennia, particular varieties, known collectively as deepwater rice, seem to have done just that.

There are deepwater rice varieties that grow in the wild — without human planting — and many that have been cultivated by the Khmer in the lower and central Mekong (*srau laeng tuk* or *srau beng*). Deepwater varieties are adapted to two kinds of floods. Some are able to respond to flash floods by going dormant. They stop growing, save their energy, and can stay submerged, under water, for about 10 to 14 days. When waters recede, they resume growth.⁶⁵ Others, called floating rice, have evolved internal air tubes or *aerenchyma*, "snorkel-like conduits" in the stem internodes, roots, and leaves that allow a steady flow of oxygen to submerged parts.⁶⁶ Floating rice varieties also have a remarkable capacity for extreme elongation, as illustrated in Figure 12 below:

Sovereignty (Honolulu: University of Hawaii Press, 2014), 170.

⁶⁴ Brocheux, *Mekong Delta*, 9-10.

⁶⁵ Yoko Hattori et al., "Rice Growth Adapting to Deepwater." *Current Opinion in Plant Biology*, 14 (2011): 100.

⁶⁶ Hattori et al., "Rice Growth", 102; Takaki Yamauchi et al., "Aerenchyma Formation in Crop Species: A Review." *Field Crops Research*. 152 (2013): 8-16.

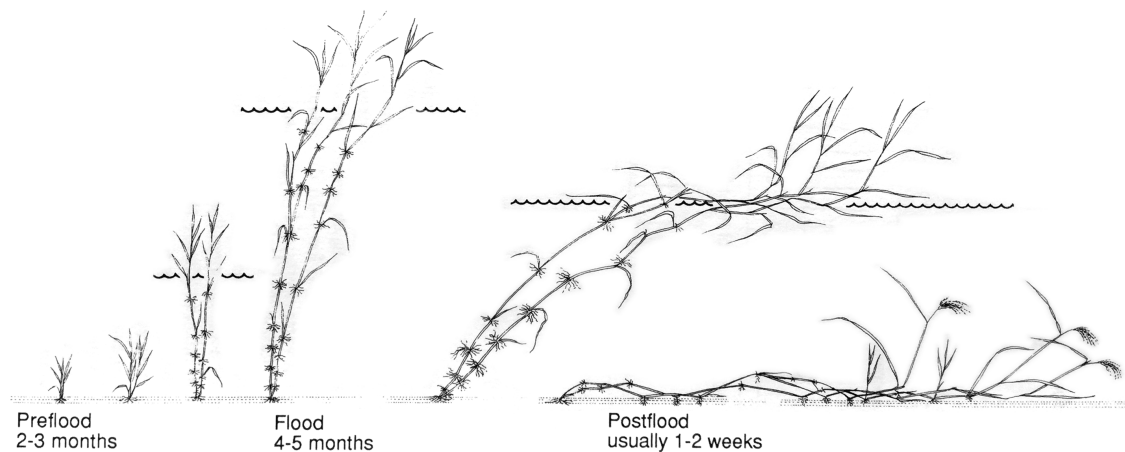


Figure 12. Growth stages of deepwater rice as it responds to flood levels (Catling, 1992).

Flooding can happen very quickly and inundation can last from 4 to 6 months.⁶⁷ Broadcast sown in April or May, floating rice can grow up to 25 cm (or almost ten inches) per day when partially submerged. Internodes on their stems undergo both cell division and cell elongation. Stems can reach an astounding length of 3 to 7 meters (23 feet), in water depths of up to 4 meters (13 feet).⁶⁸ When waters recede in January, the rice is harvested; a sickle is used to hand-cut heads of rice from long stalks lying on dry ground.⁶⁹ While it remains unclear just how the rice plant senses changes in water levels, biologists describe this plasticity as "submergence-induced", meaning that the rate of stem elongation or plant length is driven by environmental conditions. The deeper the water gets, the more stems elongate in relation.⁷⁰

⁶⁷ Taylor, *Khmer Lands*, 162.

⁶⁸ Hans Kende et al., "Deepwater Rice: A Model Plant to Study Stem Elongation," *Plant Physiology*, 118 (1998): 1105-1110.

⁶⁹ Taylor, *Khmer Lands*, 171.

⁷⁰ Catling, *Deepwater Rice*, 9-10, 35.

Second in importance to elongation is photoperiod sensitivity. Rice is a flowering grass. For floating rice varieties, flowering synchronizes with shorter day lengths; growth periods can range from 180 to over 300 days. Photoperiod sensitivity also synchronizes the plant to flooding, enabling it to "escape the adverse effect of low temperature... and usually ensures maturity as soon as the floods have receded."⁷¹ In addition, seeds of floating rice can stay dormant for up to several weeks. Like sensitivity to day lengths and floods, seed dormancy is a means through which rice coordinates — or basically, does not drown — through timing.

Deepwater rice varieties are an important subsistence crop, feeding over a hundred million people in Southeast Asia. When measured by yield and growth period, deepwater varieties may seem like weak producers in comparison to commercial varieties: deepwater varieties yield less than two tons per hectare vs. commercial varieties that yield an average of 6 to 10 tons per hectare. Deepwater varieties allow one crop harvest per year, while commercials grow quickly to yield a second or even third crop. But looking at this measure alone is misleading. Commercial varieties were first introduced in 1968. They were photoperiod insensitive and short-statured, bred for efficiency not plasticity. When floods came, they drowned.

Rice scientists today continue — unsuccessfully — to breed for seeds that will have combined traits of flood tolerance *and* high yield. Unable to have both, they opt for

⁷¹ Catling, *Deepwater Rice*, 10.

high yield; an economic logic of accelerated productivity wins over an ecological logic of multi-temporal relationalities. Rather than cultivating deepwater rice that coordinates with floods, governments have decided to extend, straighten, deepen irrigation canals and waterways. This engineers the annual oscillation of wet and dry seasons — an annual flood surge in which nutrients and contaminants, acidic groundwater, saltwater and freshwater mix and flush out anew — into a perennial system of water management. Rice crops can be planted and harvested all year round.



Figure 13. Aerial view of An Giang province, the largest rice-producing area in the Mekong Delta, where there are three crop harvests per year, and reported yields of up to 22 tons per hectare. Irrigated fields have replaced floating rice areas largely cultivated by the Khmer (Mike Ives, 2013).

Accompanying the distribution of commercial varieties, hydraulic developments along the river intensified in 1975, particularly in Khmer floating rice areas. The river was being remade into a perennial freshwater regime, decoupled from seasonal

oscillations. But by the 1980s, chemical fertilizers and pesticides used for commercial varieties began leaching into the river. By the 1990s, ironically, freshwater had become more available, although increasingly undrinkable for humans.⁷²

This contaminated condition proved beneficial for other species, those better suited for modern human activities.

Water Hyacinth (Eichhornia crassipes)



Figure 14. Water hyacinths form dense mats that crowd out everything else in Tonle Sap Lake (Katie Foote, 2010).

A complex variety of flora lives in the river. But one that has come to dominate is the common water hyacinth, *Eichhornia crassipes*, a floating freshwater weed.

Considered an "ornamental plant" because of its lavender, violet, and pink flowers, it appears in popular gardeners' encyclopedia, as well as agricultural manuals, and is

⁷² Taylor, *Khmer Lands*, 25, 60.

usually described as beautiful and aggressive — a lethal combination. Beautiful beasts have a way of taking over one's life. In the case of the water hyacinth, it has taken over much of the Mekong and many other bodies of water in Mexico and California in the west; Louisiana and Florida in southern United States; Cuba, Bolivia, Guatemala, and Ecuador in South America; Kerala backwaters in India; Lake Victoria in Rwanda; several countries along the Nile and Congo rivers in Africa; and now New Zealand and Australia. The sheer density of water hyacinth mats changes the physical configuration and ecology of the river.

Water hyacinths are perennial aquatic plants that produce thousands of seeds all throughout the year. Germination and growth are influenced by water quality. They can germinate in a few days or remain dormant for 15 to 20 years. They favor nutrient-rich standing water full of nitrogen, phosphorus, and potassium — effects of human-accelerated eutrophication. In the dry season, water hyacinths persist in retracted water bodies. When flooding begins, they simply spread out. Unlike rice and other terrestrial grasses and sedges whose roots are anchored to the soil, water hyacinths float on the surface of the water, making them both impervious to floods and easily carried away by currents and wind. Reproduction is through stolons or long rhizomatic runners, which easily hitch onto boats, rafts, and other vessels. Water hyacinths proliferate very quickly and can create enormous dense mats. They can double their population and spatial spread every 6 to 15 days.⁷³ The mats choke and

⁷³ Catling, *Deepwater Rice*, 79-81.

crowd out everything else, preventing sunlight from reaching other aquatic plants and depleting water of oxygen, thus killing fish and other aquatic fauna.⁷⁴

Native to South America, water hyacinths started appearing in different continents in the late 19th century. It first arrived in North America as a gift at the 1884 World's Fair in Louisiana. It was in Egypt by 1879, Asia by 1888, Australia by 1890. It reached Zimbabwe in 1937, then the Congo, Nile, and Lake Victoria in the 1950s.⁷⁵ Classified as an invasive species, it seems to have no "natural" enemies or predators.⁷⁶ Floating on the surface of water, it also serves as a "natural" habitat for other organisms.

Two of the most devastating carriers of human disease, in fact, live on water hyacinths: first, there are mosquitoes, which are formidable vectors for malaria⁷⁷ and Japanese encephalitis (JE), a zoonotic disease that is spreading through proximate relations between pigs (its amplifying host) and humans in increasingly dense

⁷⁴ Daniel Simberloff, *Invasive Species: What Everyone Needs to Know* (Oxford and New York: Oxford University Press, 2013), 13.

⁷⁵ Myralyn Osey-Agyemang, "Introduced Species Summary Project: Water Hyacinth (*Eichhornia crassipes*)", accessed March 2, 2015, http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/water%252520hyacinth.html.

⁷⁶ Manatees or sea cows are herbivores that can eat up to 10-15% of their body weight. They consume water hyacinths. However, the slow-moving marine mammals are under threat; many are mutilated because of ship strikes.

⁷⁷ Malaria is borne by female *Anopheles* mosquitoes. Environmental historian J. R. McNeill's book, *Mosquito Empires: Ecology and War in the Greater Caribbean, 1620-1914* (2010) unpacks the mosquito's role in the political and economic history of the Greater Caribbean from the 17th to early 20th centuries.

urbanized areas in Vietnam.⁷⁸ Second, there is a species of freshwater snail that hosts a parasite that causes bilharzia.⁷⁹

Of these two carriers, I will make a short turn to the lesser-known species: the snail.

Freshwater Snail (Neotricula aperta)

Rice and fish make up the primary diet of people who live along the river. Farming and fishing entail being in the water for extended periods of time. This is an interval during which the larvae of parasitic flatworms that live in contaminated waters can work their way through human skin, and then go on to lay their eggs in the urinary tracts, intestines, and blood vessels of undoubtedly unwilling human bodies. The trematode parasite, which is a blood fluke, causes bilharzia or snail fever.⁸⁰ Some of its eggs are passed back into the river when humans defecate or urinate in the water. Eggs hatch upon contact with water. Human bodies, thus, are incorporated into the parasite's life cycle.

⁷⁸ Japanese encephalitis is a zoonotic disease that is spreading over large parts of Asia, about 10 million cases over the last 60 years, with 30% case fatality. An important vector is a zoophilic mosquito, *Culex tritaeniorhynchus*, which breeds in rural, irrigated rice fields.

⁷⁹ Lindahl, Johanna F., Karl Ståhl, Jan Chirico, Sofia Boqvist, Ho Thi Viet Thu, Ulf Magnusson. 2013. "Circulation of Japanese Encephalitis Virus in Pigs and Mosquito Vectors within Can Tho City, Vietnam" *PLOS Neglected Tropical Diseases*. April 2013. Vol. 7 Issue 4, pp. 1-8.

⁸⁰ Bilharzia or *schistosomiasis* currently afflicts over 200 million people in as many as 78 countries. It is caused by five blood fluke species of the genus *Schistosoma*: *S. mansoni*, *S. japonicum*, *S. mekongi*, *S. intercalatum*, *S. haematobium*. These are discussed further in David U. Olveda et al., "Bilharzia in the Philippines: past, present, and future." *International Journal of Infectious Diseases*. 18 (2014): 52-56.



Figure 15. Freshwater snails, *Neotricula aperta*, live on stones in riverbanks of Laos.

But, what happens during the dry season when there is no water? A parasite cannot live without a host. These ordinary freshwater snails, *Neotricula aperta*, endemic to the rocky banks of the Mekong are the sole intermediate hosts for blood flukes, *Schistosoma mekongi*.⁸¹ The snails thrive on water hyacinths and in small crevices in partially submerged rocks. They feed on algae, repopulating every year.⁸² Inside the snails, fluke larvae can incubate and reproduce over 32 weeks. Transmission follows the snails' seasonality, occurring in the dry period: March through June in Laos; February through April in Cambodia. Upon contact with water, free-swimming larvae release from the snail and can survive for up to 72 hours before it must attach to a

⁸¹ Different species of *Schistosoma* pick different types of snails: *Biomphalaria* for *S. mansoni*, *Oncomelania* for *S. japonicum*, *Neotricula aperta* for *S. mekongi*, *Bulinus* for *S. haematobium* and *S. intercalatum*.

⁸² S. W. Attwood and E. S. Upatham. "Observations on *Neotricula aperta* (*Gastropoda: Pomatiopsidae*) population densities in Thailand and Central Laos: Implications for the spread of Mekong schistosomiasis". *Parasites & Vectors* 5 (2012): 126. doi:10.1186/1756-3305-5-126.

host, which might be human, dog, or pig. As water hyacinths spread, this seasonality may also change. A question that arises of course is: does transmission become perennial as well?

The fluke, *S. mekongi*, was first reported in 1957 in Laos and in 1968 in Cambodia—a few years after postcolonial land reforms and water control policies began. These added new disturbances to landscapes that had been transformed by French colonizers since the 19th century who failed to understand river hydraulics. From 1880 to the 1930s in particular, the rapid intensification of rice monoculture and a technological reliance on dredges and associated colonial machines (e.g., water pumps, sluice gates, milling equipment) remade patterns of coordination. Fields planted to rice doubled and rice exports (mostly headed for China) nearly tripled.⁸³ Irrigation and drainage infrastructures layered over older trade routes and meeting points set up by Chinese and Indian merchants.⁸⁴ In the Mekong delta, canals were laid out geometrically: a rational, modernist grid with little relation to natural drainage channels and low backswamp areas.⁸⁵ David Biggs writes:

Colonial statistics suggest rapid agricultural growth and environmental change during this period. From 1880-1930, the total volume of earth dredged in the

⁸³ Eric Wolf, *Europe and the People Without History* (Berkeley: University of California Press, 1982), 320-321.

⁸⁴ David Biggs, "Water Power: Machines, Modernizers, and Meta-Commoditization on the Mekong River" in *Taking Southeast Asia to Market: Commodification in a Neoliberal Age*, edited by Joseph Nevins and Nancy Lee Peluso (Ithaca: Cornell University Press, 2008), 108-123.

⁸⁵ Catling, *Deepwater Rice*, 340.

Mekong Delta totaled 165 million cubic meters; this compares to 210 million for the Panama Canal and 260 million for the Suez... Cultivated land area rose from 200,000 hectares in 1879 to 2.4 million in 1929. This represented an increase from roughly 5 per cent to 60 per cent of the total surface area in the Vietnamese portion of the Mekong Delta.⁸⁶

While Biggs writes of the dredging and hydraulic engineering of French Cochinchina, historian Pierre Brocheux writes of the buildup of infrastructure. Brocheux writes:

Transportation was given a higher priority than flood control... Public works designed by the French actually aggravated the ill effects of the different hydrographic regimes. In the zone of floating rice, roads built perpendicular to the flow of floodwaters toward the Gulf of Siam blocked the waters' escape. In the intermediate zone, canals dug parallel to the Mekong impeded drainage. In certain places, the water became stagnant and toxic. In others, or during certain years, floods were catastrophic. In the tidal zone, newly constructed waterways leading to the sea induced the rapid desiccation of the soil following the wet season, which in turn caused alum to rise to the surface.⁸⁷

Twenty years after these massive changes, bilharzia appeared in Laos.

⁸⁶ David Biggs, "Problematic Progress: Reading Environmental and Social Change in the Mekong Delta," *Journal of Southeast Asian Studies*, Vol. 34, No. 1 (2003), 79.

⁸⁷ Brocheux, *Mekong Delta*, 52-54.

As the parasite burrowed its way into human bodies, government officials under Mao Zedong in China were becoming fascinated with flood control. Dreams of economic modernization for a new People's Republic were yoked onto monumental machines of hydropower — a new infrastructure of mega-dams. In 1986, China under Deng Xiaopeng began building the first structure of a "Mekong Cascade", a series of eight massive dams along the upper Mekong, to harness electricity and wean itself off coal and oil. China, after all, controls the Mekong's headwaters, high up in the snowy slopes of Tibet. In response, four countries of the lower Mekong — Thailand, Laos, Cambodia, and Vietnam — formed the Mekong River Commission in 1995 to begin a study for twelve of their own hydropower stations.

Like the water hyacinth, whose dense, proliferating mats are repaving the physical and ecological infrastructure of the waterways, hydraulic engineering has become an invasive and harnessing force in a very short period of time.

So now, we turn to the fourth species, the giant catfish.

Giant Catfish (*Pangasianodon gigas*)

Fish diversity in the Mekong is surpassed only by the Amazon and Congo. It is home to nearly twelve hundred fish species, as well as the largest freshwater mega-fish known today: *Pangasianodon gigas*, a giant catfish. Many of the Mekong fish species

are migratory.⁸⁸ During the flood season every year, these large-bodied fish travel through inland waters with about 15 other species. Each migrates over varying distances between Laos, Thailand, Cambodia, and Vietnam, and returns at the end of the monsoon.⁸⁹ Since 1986, seven hydropower dams have blocked their way. Many more dams are coming.

The environmental effects are alarming: habitat loss and fragmentation, altered migration patterns, starvation, extinction. There has been a significant drop in the numbers of fish caught — called the "harvest" or "capture of wild stocks"— in the past three decades. The drop, called a "fisheries crisis," has a direct impact on poor rural communities for whom fishing is most likely to be the primary source of protein and income.⁹⁰ This is a massive structural transformation, a disaster that Rob Nixon describes as "slow moving and long in the making... anonymous and starring nobody... attritional and of indifferent interest to the sensation-driven technologies of our image-world." A "long emergency of slow violence."⁹¹ In severing the flows of

⁸⁸ One researcher, Eric Baran of WorldFish (CGIAR research program), notes that as high as 87% of known species are migratory, about 50% of fish catch are long distance migrants. The percentages are difficult to verify because so little is known about fish migration, but worth citing to highlight that different scales of analysis are needed to study these mobilities.

⁸⁹ Catling, *Deepwater Rice*, 93, 325; J. David Allan et al., "Overfishing of Inland Waters," *Bioscience*, Vol. 55 No. 12 (December 2005): 1046.

⁹⁰ In the lower Mekong, yearly consumption of fish averages about 56-71 kg per capita, considerably higher than the global average of 16 kg per capita per year. More in Allan et al., *Overfishing*, 1041.

⁹¹ Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA and London: Harvard University Press, 2011), 3.

fish, we disperse the everyday practices of gathering food that do not work through capitalist networks. We also stir up more-than-human ecologies in indeterminate ways. These are dangerous.



Figure 16. Attempting to save the Mekong giant catfish in Chiang Rai, Thailand (Chiang Rai Bulletin).

There may only be a few hundred left of the giant catfish. As the largest bodies in the water, their presence — and disappearance — makes a difference to the order of things, to the composition of habitat and ecological assemblage, as well as the bioturbation of soil and sediments, the cycling of nutrients such as nitrogen and phosphorous. Yet, very little is known about this highly migratory, seasonally attuned species, and more generally, about "big fish in big rivers," as a marine biologist described in a recent conversation.⁹² Big rivers such as the Mekong play such an

⁹² Conversation with Professor Eric Palkovacs, Department of Ecology and

integral role in human civilization that the distinction between "natural" and "cultural" mechanisms is almost impossible to study. Big fish have been so overfished that they have become very hard to track. We need other ways of following what is happening.

Giant catfish can grow up to three meters (10 feet) and weigh up to 300 kilograms (660 pounds). As toothless herbivores, they feed mostly on algae. Like the freshwater snail I pointed out earlier, giant catfish feed actively in the dry season and fast during the wet season — a seasonal rhythm synchronized to the growth of algae.⁹³ This long fasting season makes them vulnerable to environmental changes and habitat fragmentation. Researchers have recently found that they live out part of their lives at sea, much like the more well-studied salmon. Highly migratory, they travel over 1,000 km (600 miles), swimming inland from the South China Sea and upstream to spawn in Thailand. As floodwaters surge, they head upstream, catching river flows and fasting as they migrate. Sensitive to water temperature and flow, they move quickly so that they can spawn when oxygen and food supply are optimal. This takes place during an interval between first rains and maximum flood levels.

Evolutionary Biology, University of California, Santa Cruz. Meeting on February 24, 2016, Long Marine Lab.

⁹³ Koki Ikeya and Manabu Kume, "Seasonal Feeding Rhythm Associated with Fasting Period of *Pangasianodon Gigas*: Long-Term Monitoring in an Aquarium," *Zoological Science*, 28(8) (2011): 548.

Giant catfish grow primarily in Tonle Sap Lake in Cambodia. Called the Great Lake, it is the largest inland lake in Southeast Asia, and feeds into the Tonle Sap River, that then meets the Mekong River. Hundreds of species of fish, birds, reptiles, and amphibians live in Tonle Sap Lake. It is here that giant catfish feed and mature. In the dry season, the lake covers 2,500 square kilometers. At the height of the rainy season, the lake expands fourfold and water depths increase from 4 meters to 10. The temporary wetlands serve as "rainy season nurseries" for young catfish and many other species. When the rainy season ends, its outflow into the Mekong River reverses direction from north to south, carrying millions of fish. Fishers anticipate this phenomenal downstream flow and, in seasonal synchrony with the Tonle Sap River, set all kinds of fishing traps and nets.⁹⁴ These indiscriminately capture many young catfish before they grow into their reproductive stage. Over the years, fish populations have dwindled. With less to catch, fishery efforts escalate. As large-bodied fish disappear, fisheries turn to smaller and smaller species, using more finely meshed nets. Ecologists write:

The numbers of fishers in Tonle Sap River basin has increased from 360,000 in the 1940s to an estimated 1.2 million in 1995... Although large and medium-sized fish dominated the 1940s catch, by 1996 the catch was heavily dominated by small fish, largely because of increased fishing pressure and assemblage overfishing. Small cyprinids now make up more than 40% of the

⁹⁴ Researcher Eric Baran reports that during peak migrations in the Tonle Sap River, 34 tonnes of fish (about 3 million individual fish) are caught *every hour*. Baran contrasts this with the Columbia River where 2 million salmon are caught *every year*.

total catch of the Tonle Sap system, and populations of large migratory catfish and carps have declined.⁹⁵



Figure 17. Small fish make up much of the daily catch at Mekong fisheries.

Cyprinids include common carps, goldfish, and minnows (bait fish or aquarium fish). Some of these small species feed on freshwater snails, which you might recall, are hosts for bilharzia. This is a classic trophic cascade: in the absence of their fish predators, snails will multiply. In time, more-than-human ecologies will shift.

Change

In the multispecies story that I have just told, the giant catfish and its migratory companions become extinct. What is left of Khmer floating rice will be replaced by high-yield, quick-growing commercial rice, which will drown under rising sea levels exacerbated by methane gas emissions from industrialized agriculture. Small

⁹⁵ Allan et al., *Overfishing*, 1046.

cyprinids will be overfished. Water hyacinths and snails hosting parasitic blood flukes will begin to occupy a sclerotic, global future powered by mega-dams. I have not mentioned forests at all, which will be long-forgotten spirits. Without forests, riverbanks erode and landslides become more devastating. The monsoon rains will fail.

Through oscillation, I have attempted to show the breakdowns and transformations wrought by the construction of dams, irrigation networks, overfishing, and the takeover of commercial high-yield rice agriculture. I have also shown that humans are significant but not the only drivers. By following the capacities of floating rice, water hyacinth, a freshwater snail, and a giant catfish as seasons shift from wet to dry, perhaps we might consider that the river is not a single body of water that can be chopped up by nation-states, technoscientific regimes, or divisions between human and nonhuman. Drawing out specific capacities — attending to how they arise through layered and mingled temporalities — might point us towards a different set of ontologies, an articulation of a different kind of politics that enables the voices of historical attunements, contingent encounters, and oscillating interdependencies.

IV

1980 — GENETICALLY ENGINEERED RICE — CONTRACT



Figure 18. Test varieties of genetically modified rice in refrigerated cases at IRRI Genetic Resources Center (Wanda Acosta, 2010).

In 1980, three legal cases made bold contributions to a new world: (1) the U.S. Supreme Court ruled in favor of patenting a genetically modified bacterium that breaks down petroleum, effectively naming a human as the legal inventor of an organism (Diamond v. Chakrabarty); (2) the Bayh-Dole Act was passed, decoupling federally funded research from government ownership and allowing it to be commercialized; and (3) the U.S. Patent & Trademark Office awarded the first patent for a technique of gene splicing to Stanford University and University of California at

San Francisco.⁹⁶ The three cases index a conjuncture, an entry into a new world of complex alliances and shifting boundaries in genetic engineering. In this world, life as *bios* is a tool to be licensed and programmed. To speak of divisions between nature and culture is to describe a seemingly archaic epoch, where different species still live, pollinate, and die. The new world is contracted through data, structured by techniques of bioprospecting, digital computation and molecular recombination, and logics of rapid-fire innovation.

The question of how to live with this polarizes many. Genetic engineering brings both promise and peril. It is seductive in its brilliance and simplicity, as well as frightening in its totality, precision, and speed. I begin this chapter from neither side. Rice is being expressed genetically, mathematically, and financially, as never before. Rice is no longer planted solely in the modern agricultural grid, subject to state control, but in a postmodern double helix of recombined DNA, subject to mixed property regimes. Instead of arguing from an ethical standpoint that this is a sign of a coming utopia or apocalypse, here, I ask: what kinds of time are being introduced and omitted? What rhythms, cycles, and metabolisms are being altered in the rush to break down organic life forms into useful traits, data sets, and financial instruments? Importantly, upon what machinic materialities is the unquestioned pursuit of a long, healthy, and beautiful life — for humans — coming to depend?

⁹⁶ Cori Hayden, *When Nature Goes Public: The Making and Unmaking of Bioprospecting in Mexico* (Princeton and Oxford: Princeton University Press), 26-28.

Rice as genome, rice as data, rice as property and patent. Here, I offer the term *contract* with its multiple meanings to analyze genetically engineered rice: a contract is a written or oral agreement that legally binds multiple parties; to contract is to squeeze or tense up, as in to contract one's muscles, as well as to become infected or to be drawn together; and finally, a contraction of uterine muscles, or labor pains, at periodic intervals before birthing a new being. These meanings may be considered as temporal shifts and markers. I use the term in various ways here as I consider genetically engineered rice as media that rewrites, squeezes, and synthesizes new kinds of time.

The Order of Genes

Genes are the basic unit of heredity for organisms and they are made of DNA. In 1953, Francis Crick and James Watson of Cambridge University visualized DNA as a three-dimensional structure, a double helix that looks like a twisted ladder: the vertical uprights consist of alternating molecules of sugar and phosphate, and the horizontal rungs consist of base pairs of nitrogen, or adenine (A) paired with thymine (T), guanine (G) paired with cytosine (C). These organize into chromosomes, long strands found in the nucleus of a cell. The order or DNA sequence is key. Nearly every cell in an organism's body has the same DNA, and DNA can replicate, able to make copies of its base pair sequence. The complete genetic makeup of an organism is called its genome and every organism's genome is unique. Mapping a genome involves methods to identify sequences, distances between base pairs, and frequencies

of repeats. Mapping a genome that might be representative of a "species" involves sequencing, annotating, and comparing multiple, changing variations. Thus, these are ongoing, open-ended processes that generate massive amounts of data. In recent decades, these have been made available in online databases, with an increasingly sophisticated range of browser-based tools.⁹⁷

To get there, labs began sequencing DNA and RNA molecules of simple organisms in the early seventies.⁹⁸ In 1976, the first full DNA-based genome to be sequenced was *PhiX174*, a virus that attacks bacteria.⁹⁹ It has 5,386 base pairs and a single chromosome. Over the past forty years, labs have progressed to increasingly complex organisms, sequencing *Haemophilus influenza*, a bacteria that causes meningitis; *Saccharomyces cerevisiae* or Baker's yeast, the first fungi; a nematode worm, *Caenorhabditis elegans*, the first animal; and a small flowering plant *Arabidopsis thaliana*, the first model organism for plants. In 2003, a complete draft of the human genome was published by an international group of researchers. *Homo sapiens* have 3.2 billion base pairs and 23 chromosomes. It took 13 years of sequencing, at a cost of US\$3 billion.

⁹⁷ The rice genome can be accessed on at least three public online databases: OryzaBase (<http://shigen.nig.ac.jp/rice/oryzabase/>), Plant GDB (<http://www.plantgdb.org/>), and Gramene (<http://www.gramene.org/>).

⁹⁸ James M. Heather and Benjamin Chain, "The Sequence of Sequencers: The History of Sequencing DNA," *Genomics*, 107 (2015): 2-3.

⁹⁹ PhiX is still considered the "positive control genome" in many sequencing labs today. The technique used is considered the real start of first generation DNA sequencing and led to the most common technology used today, known simply as Sanger sequencing or the dideoxy chain-termination method.

Rice, *Oryza sativa*, was the first of the cereals to be mapped because of its relative simplicity. It has 430 million base pairs and 12 chromosomes, compared to wheat, *Triticum aestivum*, which has a whopping *17 billion* base pairs. Synteny among some cereals makes rice a valuable model organism because it aids gene discovery in more complex crops.¹⁰⁰ Efforts to map the rice genome began in the 1980s in Japan and eventually expanded into a ten-nation consortium, the International Rice Genome Sequencing Project (IRGSP). The 12 chromosomes of rice were assigned to different labs: Japan took on chromosomes #1, 6, 7, 8; U.S. researchers sequenced #3, 10, 11; U.K. #2, China #4; Taiwan #5; Thailand and Canada #9; France and Brazil #12.¹⁰¹ Members agreed to make all data public and IRGSP published its draft sequence of the twelve chromosomes in the journal *Nature* by 2005.

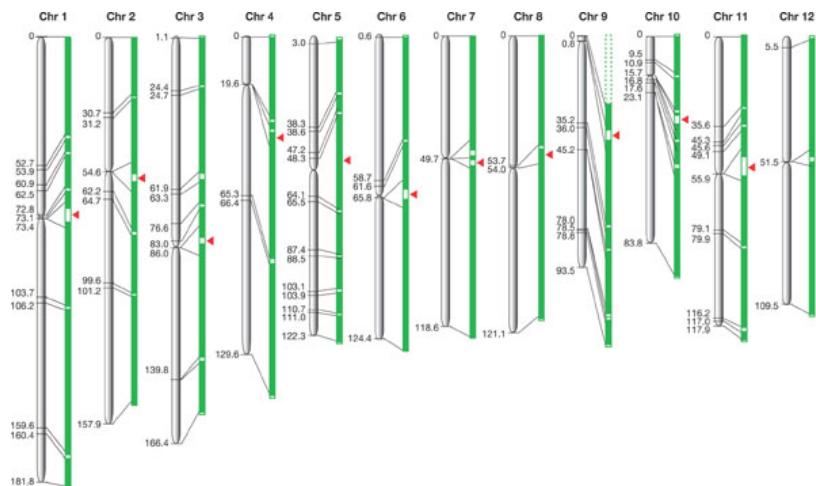


Figure 19. Twelve chromosomes of rice, as published in *Nature*. For each chromosome, the left bar represents the genetic map, the right bar in green shows overlapping sequences used to read the DNA fragments. The red arrows are chromosomal positions.
<http://www.nature.com/nature/journal/v436/n7052/full/nature03895.html>

¹⁰⁰ Synteny means having the same repeating genetic sequences.

¹⁰¹ Nancy A. Eckhart, "Sequencing the Rice Genome," *The Plant Cell* 12 (11) (November 2000): 2011-8.

Meanwhile, three other groups embarked on their own rice mapping efforts: Beijing Genomics Institute (BGI) in Shenzhen, China and two multinational corporations, U.S.-based Monsanto and Swiss-based Syngenta. Various techniques for mapping were used on different subspecies; each was driven by different technoscientific imaginaries, nationalist sentiments, financial models, and protocols for intellectual property and material transfer.¹⁰² Rules for how or whether the findings are published differ. Sequencing at BGI/China was the fastest. It mapped the rice subspecies *indica*, or long grain rice, and published results in the journal *Science* in 2002, three years ahead of IRGSP. Like IRGSP, Monsanto and Syngenta mapped the subspecies *japonica*, short grain rice. As private corporations, they could claim their sequences as trade secrets and choose not to disclose their results.¹⁰³

¹⁰² Elta Smith, "Rice Genomes: Making Hybrid Properties," in *Lively Capital*, edited by Kaushik Sunder Rajan (Durham and London: Duke University Press, 2012): 184-210; Nancy N. Chen, "Feeding the Nation: Chinese Biotechnology and Genetically Modified Foods," in *Asian Biotech: Ethics and Communities of Fate*, edited by Aihwa Ong and Nancy Chen (Durham and London: Duke University Press, 2010), 81-92.

¹⁰³ Monsanto eventually transferred raw data to IRGSP but in exchange, required that the corporation be granted first right to license if use of its sequences led to any patents (Sasaki, 149-50). Syngenta published its genome map in *Science*, but kept the raw data as trade secrets. Held to a different set of rules from academic researchers, Syngenta was exempt from depositing its sequences in public online databases. In her 2012 essay, "Rice Genomes," Smith explains Syngenta's decision with the following analogy: "...publishing sequencing results but not depositing the information in a database is like producing a telephone directory that tells the reader how many instances there are of each last name and what regions of the city they live in, but does not provide specific names, telephone numbers, addresses, and so forth. Thus, by not placing the information in a database, Syngenta effectively held onto what is considered the most important part of the information necessary for use, namely, the equivalent of the connection between specific names and specific addresses" (204).

Automated Sequencer

What used to take 13 to 15 *years* to map can now be completed within 13 *days*.¹⁰⁴ But apparently, even that is old news: a Microsoft ad running on the New York Times online on June 20, 2016 boasted that what used to be done in two weeks could be done within *hours*. New machines speed up work. The effect is not just compression, but qualitative changes in methods of research. There is both contraction and opening up of critical imaginaries and fields of study. The inventions of automated DNA sequencing machines and microchips were crucial to this quickened tempo and creative shift in genomic science.

In the seventies, early techniques were borrowed from analytical chemistry; methods of enzymatic sequencing were laboriously slow. But as more and more were undertaken in the late 1970s, machines were developed that could perform simultaneous sequencing of larger samples and longer DNA strands, tackling increasingly complex species. In the 1980s, a group led by Leroy Hood at California Institute of Technology and Applied Biosystems Inc. began assembling commercial sequencers that used fluorescent color dyes and laser beams to make DNA arrays machine-readable. In nearby Palo Alto, Affymetrix Inc., then a small startup, began manufacturing quartz microchips for DNA microarrays.¹⁰⁵ The two came together with backing from Microsoft co-founders Paul Allen and Bill Gates. A decade later,

¹⁰⁴ Based on a conversation with anthropologist Nancy Chen, from her interviews with genome scientists in China.

¹⁰⁵ Affymetrix Inc.'s first product was a GeneChip for HIV diagnostics, released in 1994.

Gates gifted US\$12 million to the University of Washington to recruit Hood to build a department of molecular biology. The new department brought computer scientists and geneticists working together on basic research.¹⁰⁶ It also signaled a new mix of state, private, and philanthropic funding. These combinations would later play key roles in the Human Genome Project, as well as the Rice Genome Project.

Improvements in microfabrication and high-resolution imaging brought big changes. The very small became visible, fast. Life could be read in terms of patterns of base pairs, as machine-readable code. Second-generation machines began running massively parallel techniques, greatly increasing the amount of DNA sequenced on a micrometer scale, in a single run. "The capabilities of DNA sequencers have grown at a rate even faster than that seen in the computing revolution described by Moore's law: the complexity of microchips (measured by number of transistors per unit cost) doubles approximately every two years, while sequencing capabilities between 2004 and 2010 doubled every five months."¹⁰⁷ Third-generation sequencers are now moving towards what has been called "nanopore technology." The first to offer it, Oxford Nanopore Technologies, will release sequencers that are compact, mobile phone sized USB devices, aiming to make possible near real-time sequencing in the field, as well as decentralize who gets to sequence.

¹⁰⁶ Donna Haraway, *Modest_Witness@Second_Millennium.FemaleMan_Meets_OncoMouse: Feminism and Technoscience* (New York and London: Routledge, 1997), 59.

¹⁰⁷ Heather and Chain, "Sequencers," 5.

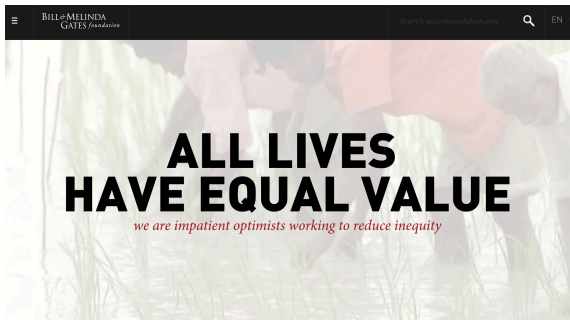
The efficiency of the commercial sequencer is replacing the truthfulness of Dziga Vertov's *kino-eye*. Machine-readable microassemblages contract and capture life into a different temporality. Perhaps it is not all speed, but a timeless time of indifference, a world made to be always and already on.

Data Set

In 2014, the 3,000 Rice Genomes Project or 3K RGP published the genome sequences of 3,000 strains of rice from 89 countries.¹⁰⁸ Funded by the Bill & Melinda Gates Foundation and the Chinese Ministry of Science and Technology, the project is a collaborative transnational endeavor between BGI/China, International Rice Research Institute (IRRI), and the Chinese Academy of Agricultural Sciences (CAAS). 82% of the samples came from IRRI and 18% from CAAS. According to an IRRI press release, the effort produced a "massive data set of 120 terabytes, with millions of genomic sequences... that, when combined with phenotyping observations, gene expression, and other information, provides an important step in establishing gene-trait associations, building predictive models, and applying these models to breeding."¹⁰⁹ Agricultural and biological data will become publicly accessible via the cloud, always on at Amazon Web Services. Data does not sleep; it can always be placed under contract.

¹⁰⁸ Felix Cheung, "The search for the rice of the future," *Nature*, Vol. 514 (October 2014): S60-S61.

¹⁰⁹ The press release on IRRI's website can be found at <http://irri.org/news/media-releases/big-data-on-3-000-rice-genomes-available-on-the-aws-cloud> (accessed May 25, 2016).



The Bill & Melinda Gates Foundation is the largest funder of agricultural research today. As state funding for research shrinks, it plays an increasingly powerful and central role in the future of food systems. It is one of two major funders of 3K RGP, as well as CGIAR, a transnational consortium for agriculture. <http://www.gatesfoundation.org/>

The 3K RGP project is one tip of a massive iceberg moving towards precision breeding and technoscientific fixes. Mapping and sequencing are instruments that assume bodies and lives function equally, and can be scripted like computer programs. How organisms live can be decoded and improved upon by honing in on specific traits and beneficial functions.

Now, it seems that life ways can be rewritten through CRISPR/CAS9 technology, with its capacity for targeted precision in genome editing, which has taken over technoscientific imaginations in the past four years. All kinds of cancers and scleroses, resistances and enhancements are sequences that are subject to cut-and-paste editing. Neither heredity nor environment matter. Freed from bodies and ecological relations, genes can be upgraded outside of evolutionary time. What matters is commensurability: genes can be selected, replaced, traded, inscribed with modern values, and deployed like so many mercenaries. There is climate-friendly rice that emits zero methane; flood-tolerant rice; salt-tolerant rice; insect- and herbicide-resistant rice, and of course, the high-yield, quick-growth varieties of Green

Revolution fame. Genetic engineering has contracted a new ecology and economy of supercharged and instrumental hybrids.

At what scale do genetically engineered crops circulate? The 3K RGP project is an example of how relationships among state-sponsored, market-driven, and university-based groups have become porous and transnational. While rice has functioned as currency and binding social contract for centuries, rice as data circulates and assembles relations differently. Working with rice genome scientists at BGI/China, anthropologist Nancy Chen writes of "ongoing compromises between the ideal of open-source information and private capital that funds highly collaborative work on a global scale. Genetic resources are open-access until certain sequences to be patented can be privatized."¹¹⁰ This suggests that one way to study the iceberg is by looking at the temporality of patents and license agreements — powerful contracts that can generate wealth for a limited period of time.

Patent

Techniques for working with genetic sequences and genome editing — for remixing life forms otherwise not found in nature — can legally be considered "inventions." As such, they can be patented as intellectual private property. The term of a patent is twenty years. In 2004, the U.S. Department of Energy cited "the number of genome-

¹¹⁰ Nancy Chen, "Feeding the Nation," 88.

related patents filed at more than three million. Seventy four percent of agriculture patents are held by private companies, forty percent of which are concentrated in just five companies."¹¹¹ A closer look at one genetically engineered variety, Golden Rice, is helpful in considering what happens within the term of patents.

Golden Rice has yellowish grains, and genes that include two from daffodils and one from a bacterium. The genetic recombination apparently supercharges it with higher levels of beta-carotene than regular white rice, making it a potential solution for vitamin-A deficiency and blindness, which afflicts millions of the world's poor. Plant biologist Ingo Potrykus at ETH Zurich in Switzerland and geneticist Peter Beyer at University of Freiburg in Germany began testing vitamin-enriched rice in 1992. Their timing coincided with a push into food crops, a category that was becoming the liveliest area of transgenic research worldwide.¹¹² Support for Golden Rice from the Rockefeller Foundation and IRRI was an early indicator of a wider shift in agrochemical research. While higher yield was the primary concern of postwar agronomists, the next generation moved towards better nutrition and consumer health. Golden Rice peaked many interests, from public research institutions to large multinationals.

¹¹¹ Smith, "Rice Genomes," 196.

¹¹² Elta Smith, "Corporate Imaginaries of Biotechnology and Global Governance: Syngenta, Golden Rice, and Corporate Social Responsibility," in *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, edited by Sheila Jasanoff and Sang-Hyun Kim (Chicago and London: University of Chicago Press): 254-276; Haraway, "Modest Witness."



Figure 20. Golden Rice is planted and harvested at IRRI test fields in Los Baños, Philippines. To prevent accidental gene transfer or other windy effects, the test fields are bordered on all sides by tall stalks of corn. While the Philippine government has not approved genetically modified rice, some locals say that Golden Rice is already being planted in fields outside of IRRI. There is not enough information at this time of writing to say who owns those rice fields. (Acosta, 2010).

In making Golden Rice, the scientists had signed multiple agreements that, paradoxically, imposed legal barriers to its existence. Unbeknownst to them, Golden Rice was attached to more than 70 patents on intellectual property rights, plus another 15 material transfer agreements on technical property. These belonged to no less than 31 institutions and companies with deep pockets for litigation, including Amoco, Calgene, Certus, DuPont, Hoffman-La-Roche, Monsanto, ICI Ltd., and Novartis and Zeneca.¹¹³ Moreover, patents did not apply uniformly across countries or regions: some held for the U.S. and Europe, others only for Japan, and a few only for either

¹¹³ Novartis and Zeneca would merge in 2000 to become Syngenta.

China, Brazil, Vietnam, and the Ivory Coast.¹¹⁴ Navigating permissions and fees for getting Golden Rice from labs to test fields to target beneficiaries was a daunting task. Eventually, the scientists ceded IPRs to Syngenta; in exchange, they received "humanitarian licenses" allowing license-free use, with set conditions.¹¹⁵

Patents for Humanity

Humanitarian licenses demonstrate corporate goodwill and public/environmental stewardship, but they have limits that privilege the patent holders' rights to profit. With Golden Rice, farmers in developing countries are permitted to plant seeds license-free — *until* a farmer's individual earnings reach US\$10,000. "License-free until" safeguards corporate well-being and its ability to adapt to future uncertainties. They are cast like fishing nets into dispossessed waters, able to pull in profits if and when they begin to surge.

RAND Corporation researcher Elta Smith locates the humanitarian license, or what she calls a biotechnology donation, along two historical trajectories: (1) They are products of corporate social responsibility (CSR) programs, that were themselves direct responses to growing activist movements spurred by Rachel Carson, and highly publicized court cases against multinationals like Philip Morris and Nike in the

¹¹⁴ Smith, "Corporate Imaginaries," 258-9, 266.

¹¹⁵ These are based on RAND researcher Elta Smith's interviews with Gary Toeniessen, Director of Food Security at the Rockefeller Foundation in 2005 and Adrian Dubock, Head of Public-Private Partnerships at Syngenta in 2006 (Smith 2015: 258-9).

1990s. (2) Importantly, they are products of agribusiness cycles. An economic bust in the late 1990s pushed companies to either merge or split their pharmaceutical and agricultural businesses, as well as scale back fairly recent forays into biotech food crops. Both Syngenta and Monsanto dropped rice from their main crop lineups, choosing to focus instead on maize, soybean, sugar beet, and sunflower and rapeseed oils. Put simply, Golden Rice suddenly became unprofitable. It made better business sense to give it away in developing countries where the potential for profit was still low or, at least not enough to warrant policing for patent compliance.¹¹⁶

Golden Rice has, indeed, become the poster child for biotech benevolence. In 2015, the U.S. Patent and Trademark Office named Golden Rice as one of seven top "Patents for Humanity," a cohort that includes drugs against malaria and tuberculosis, nutrient kits, toilets, solar-powered lanterns, and wheelchairs.¹¹⁷ It is the only one that is a machine-organism, capable of being alive. Considered through the twenty-year

¹¹⁶ In contrast, in developed countries like the U.S., Canada, Australia, where potential earnings are high and plants are highly policed, seeds would not be released license-free.

¹¹⁷ "Patents for Humanity" is an initiative started by President Barack Obama in 2012. Many activists reject Golden Rice. Vandana Shiva in India, perhaps the most outspoken anti-GM advocate today, argues that Golden Rice is a dangerous prototype, a "Trojan horse" that enlists farmers as test users with neither compensation nor legal recourse. Working against GM canola with Canadian farmers, political anthropologist Birgit Müller also argues in her essay, "Fool's Gold on the Prairies" (2015) that GM seeds are "carriers of intellectual property rights and systems of oppression and control. Humans and seeds become alienated from the natural world when industrial seeds carry an instrumental rationality and control into the field of the farmers" (61).

term of patents and the broader history of agribusiness schemes, this humanitarian move makes a different kind of sense.

That is the upside of things. The absence of profit does not always lead to contractual giveaways. More often, there are downsides. The insatiable pursuit of profit and growth sets off speculative high frequency trading — the creation of wealth by crunching numbers — which can lead to market anomalies.

Price

Is it Paul Virilio, the theorist of speed, who said that when we invented the car, we also invented the car wreck, and with the ship, the ship wreck, the train, the train wreck, and so forth? Every innovation disrupts a world, and thus also enters into contract with the possibility of exceeding or destroying itself. While rice agriculture brings with it specific organizational demands, environmental constraints, and multispecies coordinations, genetically engineered rice is more closely tied to financial cycles. It is bound to booms and busts, the prices and supplies of commodity crops such as genetically modified soy, corn, and cotton, as well as fossil fuels, chemical fertilizers and insect/herbicides, transportation systems, computer networks, and power grids upon which it depends. This type of input-intensive rice comes with a particular kind of wreck: a market crisis.

In 2007-8, the prices of food commodities skyrocketed within a matter of months: rice was the hardest hit, reaching ten-year highs. Other industrialized crops such as wheat, corn, and soybeans rose too. Food riots ensued. Drought in Asia and Cyclone Nargis in Burma, which reduced yield, were cited as contributing factors. However, others report that there were ample stockpiles; the weather-driven drop in grain supply had nothing to do with the abrupt and unexpected price spike. The spike was caused by other factors: rice was connected to global markets in which crop prices were tied to fertilizer prices which were tied to energy and oil prices (petroleum and natural gas). A spike in oil corresponded with fluctuations in other commodities. Furthermore, rice was affected by speculative trading in futures markets, particularly long-options trading in wheat by Wall Street investment firm Goldman Sachs.

The 2007-8 price spike won't be the last. There was a renewed surge, for example, in 2010.¹¹⁸ Attempting to manage new volatilities, the Food and Agricultural Organization (FAO) of the United Nations established indices to keep a check on worldwide fluctuations: a monthly Food Price Index, an Agricultural Market Information System, and a biannual Food Outlook. But, who benefits from these early warning systems? Who and what become articulated into these pre-emptive data-driven tools that are intended to calibrate and manage global market emergencies —

¹¹⁸ There have also been flash crashes — deep, rapid drops in security prices — since then. On May 6, 2010, a trillion-dollar U.S. stock market crash, and then its correction, occurred over 36 minutes. Another occurred on April 23, 2013. A third, in October 2013, wiped out billions in market capitalization on the Singapore stock exchange. And so on.

perhaps triggered by the very same tools in the first place? Genetically engineered rice solicits a new technoscientific assemblage, with its unintended malfunctions.¹¹⁹ We know all too well who gets squeezed; hunger and dispossession are never immaterial calculations.

Engineered Times

In this chapter, I have attempted to tease out different kinds of time that have been foregrounded or altered by the genetic engineering of rice: machine times of automated sequencers that have sped up genome mapping, and of speculative high-frequency trading cycles that have enabled market anomalies and violent dispossessions; the timeless, always-on time of public data sets and their enclosure into intellectual property through twenty-year patents to agribusiness; the philanthropic time of humanitarian licenses and endowment funds; the ecological-evolutionary time of living organisms, including asymmetrical population growth of humans; the time of nation-states, war machines built on promises of wealth, food security, and health; and finally, the queer and unruly time of cancers, disorders, mutations, and differences that are now being rewritten in university and corporate R&D labs. Genetically engineered times — for better and worse.

¹¹⁹ Future research might seek to understand how these malfunctions are themselves generating novel financial contracts or derivatives. Science studies scholar Melinda Cooper has written about how "turbulent worlds" — market or environmental crises — become new sources of neoliberal value. Contingency, a variable relation, can be priced and financialized.

CENTURY — IRRIGATED RICE — TELOS



Figure 21. The cover of the 44th *Annual Report to California Rice Growers* includes this photo of a modern agricultural grid: rice plots with numbered test varieties, irrigation and drainage channels, combine harvesters, steel plows, rice hay, black adobe soil, grain silos, solar panels, warehouses. Two new concerns were included in 2012: a "new race of blast fungus" and a "substantial spring flight" of a pest, the water weevil.¹²⁰

It was August 18, 2013, a hot Wednesday with sunny blue skies: the 101st Annual Field Day at the Rice Experiment Station in Biggs, CA. The day before, I had taken a three-and-a-half hour, 330-kilometer drive from Santa Cruz. My gasoline-powered Volkswagen Jetta station wagon — whose diesel-powered counterpart would, two years later, be caught with software programmed to misreport lower-than-actual

¹²⁰ California Rice Research Board. 44th *Annual Report: A Summary of Research from 2012 to the California Rice Growers*. (Yuba City: California Rice Research Board, 2012), 3.

emissions of nitrogen oxide — consumed ten gallons, or US\$35 worth, of gas.

You might say that I arrived a year late for the big field celebration that marked the 100-year anniversary of rice breeding in California. Or, you might say that bracketing a century through a chronology of dates, a timeline that runs from year 1 to 100, or 1912 to 2012, is too simple. Marking anniversaries or recounting a sequence of events is not my main preoccupation here. Today, California is the "most powerful agricultural region in the planet — the home base for what has become an international agribusiness empire."¹²¹ How did this come to be? I am interested in what defined this particular century. Environmental historians and science/media studies scholars have unpacked how relationships between humans, machines, and water — particularly large-scale irrigation — brought into being a new form of imperialism. They describe an American century shaped by technological dominance and expertise.¹²² Industry spread out as a visible exoskeleton of steel, concrete, carbon, and cable. And with it, new forms of social engineering, the constitution of bodies with no histories and no claims to land.¹²³ These could not have been foretold.

¹²¹ Donald Worster, "Hydraulic Society in California: An Ecological Interpretation". *Agricultural History*, Vol. 56 No. 3 (July 1982): 507.

¹²² Michael Adas, *Dominance by Design: Technological Imperatives and America's Civilizing Mission* (Cambridge, MA and London: Belknap Press, 2006).

¹²³ Donald Worster, *Rivers of Empire: Water, Aridity & the Growth of the American West* (New York: Pantheon Books, 1985); Preston, William, "Serpent in the Garden: Environmental Change in Colonial California" in *Contested Eden: California Before the Gold Rush*, eds. Ramon A. Gutierrez and Richard J. Orsi (Berkeley, Los Angeles, London: University of California Press, 1998): 260-298.

In this chapter, I describe the century by following trajectories, specifically migrations, displacements, and landscape changes that were unprecedented, irreversible, and durational. A century of California rice appears through a tangle that emerged when humans and nonhumans were displaced *en masse*, and then began to reshape soil and water, private property, and agricultural practices. The trajectories are forward-moving and purposeful, yet discontinuous and not quite synchronized with one another. For simplicity, I refer to them as *telos*, a heterogeneity of processes that co-occur, and then somehow begin to coordinate and advance new conditions.

Many scholars will recognize *telos* as the Greek word for a self-defining purpose or the fulfillment of a final goal. *Telos* connotes a time of developmental progress, of future-oriented and intentional action. For Aristotle, *telos* is central to biological existence. All beings possess *telos*. Existence is articulated through a study of an organism's purpose or functions, intentions, causes and aims. For Hegel, history is dialectical: simultaneously linear and teleological. Hegelian *telos* is the actualization of human reason, an arrow shooting towards a universal and rational synthesis. In both these frameworks, *telos* is embodied in the six-lane highway that brought me north of Sacramento on that hot August field day. Its existence hinges on a single purpose: it takes me from origin to destination, both mappable as points. In teleological time as such, the future is synthesized as a finite point that can be reached. It has already happened. Time ahead appears as a projection of what is

already known, a function defined by a time that has passed. This erases the vitalities and possibilities of difference.

I take up telos in this chapter not to critique it, but to render its quality of linear irreversibility — the possibility of transformation — more fully. Telos is one among many kinds of temporalities through which differences come to situate and remake history and habitat. Here, I expand the notion of purposeful and irreversible action, of forward-moving time. I shift the focus from telos as the unitary fulfillment of human mastery, a future that appears as a single point, to telos as an assemblage of trajectories that emerges from multiple incorporations and purposeful (yet conflicting) practices of ordinary living.

Telos is the making and unmaking of unruly difference that transforms more-than-human bodies and landscapes. An expanded notion of telos helps me ask, not only where the multi-lane highway is headed, but more critically: Who has telos? What counts as voice and bodily presence? Who has a right to grow and fulfill a goal, reach a destination? Whose trajectories do we inherit — or erase — by articulating teleological time?

Three scenes attempt to unpack these questions: practices of weeding in an organic rice field in Richvale; the buildup of irrigation in the nineteenth century that radically engineered California ecologies; and aliens of different kinds that shaped the industry

today. With the trio, I offer a view into an unruly telos that situates the first century of rice in California.

Rice Farm



Figure 22. A rice field planted with sushi rice varieties awaits harvest at Lundberg Family Farms in Richvale, CA (Nicole Crane and Joanie Simon, 2015).

"Do you know what goes into making a grain of rice look exactly the same as every other?" This was one of the first questions Lance Benson asked me when we met at Lundberg Family Farms, the leading organic farming operation in America. I admit that I had never considered it until he held up a single short grain of organic, almost pearlescent rice that had been tested, seeded, transplanted, grown, harvested, threshed, dried, milled, and finally packaged along with countless others just like it, within the facilities of Lundberg. Quality is enacted at every stage of the production process as each grain grows to become like all other grains. Every package of over twenty varieties of Lundberg rice embodies this. At the lobby of Lundberg's headquarters in Richvale, California, where I had met up with Benson, there was a

display of Lundberg's freshest line: Burgundy Red, Black, White, Brown, Mahogany Black, Jasmine, Sushi, Countrywild, Basmati, Long Grain, Japonica, Heirloom, Wehani, Jubilee, and so the designer rice packages read. No, I definitely did not know how a typically unassuming flowering grass could be turned into grains so highly polished and uniform.

Benson is the Growing Services Manager and coordinates about forty other farms, each independently owned and under contract to plant and harvest specific varieties and quantities of Lundberg grain across 20,000 acres.¹²⁴ For over two decades, it has been Benson's job to make sure that these farms can fulfill all rice orders and deliver freshly milled Lundberg packages to stores nationwide, on schedule. He has to plan out who can plant which variety, when, and where so that he can anticipate deliveries way before the first rice seed is set into the ground. He knows his yields a year ahead.¹²⁵ What makes Benson very good at predicting yields is his persistent watchfulness, a keen sense of a complex of more-than-human signs, rainfall and frost, neighborly rhythms, and species synchronies that unfold year after year. Benson is a walking farmer's almanac, closely attuned to his rice — and how he might push

¹²⁴ Five billion pounds of rice are produced every year in California. 95% is grown across 550,000 acres in the Central Valley. At 20,000 acres, organic rice farming still constitutes a very tiny portion of total rice production in the valley.

¹²⁵ While one might jump to critique this by likening it to a Fordist assembly line model of production, it is important to note that organic farmers do not use synthetic fertilizers, herbicides or pesticides, the key ingredients that supercharge rice growth and yields. Without chemical inputs, coordinating with ecological dynamics is crucial.

certain capacities and thresholds in order to harvest target yields. This involves being able to sense the differences between what is and what ought to be, what is weedy and what is pure.

No Dirty Fields

Driving along rice fields in his pickup truck, Benson points out "dirty fields," those in which weeds have overtaken rice plants. Weeds grow taller and faster, a difference in height that can easily be seen from afar (and while driving). Too many weeds sticking out above the heads of rice plants is seen as disorderly or dirty; it signals that a farmer had not been vigilant enough, and as a result, will face a more challenging, if not altogether lost, harvest ahead. There is nothing that can be done, other than to let a dirty field grow out. This is strikingly different from floating rice fields in the Chao Phraya Delta where the appearance of weedy disorderliness may invite the excited curiosity of rice farmers, a possible signal for the "fortune of finding a new useful variety."¹²⁶

Weeds, here, ought to be eradicated. Preserving the "purity of rice lines", the uniformity of designer grains, is the top priority. This is a persistent challenge for farmers. As highly adaptable grasses, rice plants tend to hybridize while their more opportunistic companion weeds spread rapidly, outpacing other plants on disturbed

¹²⁶ Atsuro Morita, "Multispecies Infrastructure: Infrastructural Inversion and Involuntary Entanglements in the Chao Phraya Delta, Thailand," *Ethnos Journal of Anthropology* (2016): 1-20. doi: 10.1080/00141844.2015.1119175

ground. Ensuring pure lines requires constant observation and cultivation.¹²⁷ Unlike regular farming that uses herbicides to get rid of weeds, Lundberg farmers control their water and learn to manage the difference in growth rates between rice and weeds. Once seeds are sown into the ground in April, the fields are flooded gradually with about 4 to 5 inches of water. This immediately triggers germination and growth for both rice plants and their companion weeds. Competition begins over which can hold their breath longer: weeds must break through the surface of the water within twenty days, while rice plants can survive under water for a few days longer. Thus, farmers must hold the water level just long enough to drown out weeds and enable rice plants time to grow with less competition. The fields are then drained to dry out any remaining weeds that might have survived along with the rice. The fields are flooded a second time and over the summer, when temperatures can reach over 100°F (38°C), the rice plants grow to reach a rather uniform three feet (one meter) in height. Fields are drained again when they begin to flower in the fall, hopefully before the much cooler nights bring frost to the valley in late October. If frost arrives before the grains ripen, there will be no harvest.

Varieties are selected both for their quick germination and early growth spurts, as well as for their ability to flower late in September. From the fields, grains are

¹²⁷ David Biggs, "Promiscuous Transmission and Encapsulated Knowledge: A Material-Semiotic Approach to Modern Rice in the Mekong Delta" in *Rice: Global Networks and New Histories*, eds. Francesca Bray, Peter A. Coclanis, Edda L. Fields-Black, Dagmar Schafer (New York: Cambridge University Press, 2015), 118-137.

threshed, dried, and stored in grain silos that will hold the year's inventory. These giant mechanized containers are airtight and moisture-controlled to keep out unwanted insects and microbes. Grains are milled, polished, and packaged as orders are filled, ensuring quality and maximum freshness. You will know that Benson has his harvests well underway when you begin to see Lundberg rice go on sale in supermarkets throughout California every fall. Stores are making room, in time for the new year's top grains. Grains arrive in designer packages: uniform seeds, pure lines, zero weeds.

Black Dust

The Lundberg logo that appears on all products includes the tagline: "Family Farms since 1937". Prior to 1937 is a story of forced migration from the Dust Bowl, also known as the Dirty Thirties: Albert and Frances Lundberg, wheat and corn farmers with sons Eldon, Wendell, Harlan, and Homer, fled Nebraska as severe droughts and black dust blizzards hit the Great Plains hard, marking one of the worst human-induced environmental crises of the twentieth century. In the 1920s, favorable rainfall, farming conditions, and growing demand had made wheat cultivation profitable. Farmers in the Great Plains began introducing new steam-powered tractors and combine harvesters into their fields. Mechanization allowed faster and deeper plowing, and broke apart heavy dry rock into finer particles, which could be easily carried by strong high winds. Farmers tore up native tallgrasses — plants that had constituted the prairie grasslands and had deep roots that could hold in place thin

layers of topsoil and moisture. Such roots lent some degree of resilience against past changes in weather.

By the late 1920s, in place of native grasslands stood newly farmed rows of commercial corn and wheat, or crops planted for speedy profit. Such rapid transformations set up conditions for large-scale erosion and ecological catastrophe when unprecedented drought and powerful high winds packed with dust and loosened soil swept across the Great Plains from 1930 to 1940. The Lundbergs were among 3.5 million people who abandoned their homes within this ten-year period, part of the largest mass migration¹²⁸ in American history.¹²⁹ They arrived in Richvale, a county north of Sacramento that real estate developers had renamed in 1908 to suggest rich, fertile soil. Its previous name was Selby Switch, an unremarkable railroad siding where trains switched tracks along the Southern Pacific Railroad.¹³⁰

¹²⁸ The magnitude of environmental migration or forced displacements of climate refugees today is atrocious. The Wikipedia entry for environmental migrants predicts 150 to 250 million by 2050. To understand those figures roughly, imagine the populations of the top five megacities: Tokyo (39 million), Shanghai (36 million), Jakarta (32 million), Seoul (26 million), Beijing (26 million). That totals about 159 million people, or the lower end of the estimate. To get to 250 million, add the populations of the next four megacities: Guangzhou (25 million), Karachi (25 million), New York City (24 million), and Mexico City (23 million). Now, disperse that onto the rest of the world. But that is, in fact, too easy. Perhaps more realistically — because many borders are already shut down — imagine that mass of people displaced into liminal zones, refugee camps, squatter settlements without state protection, without telos.

¹²⁹ Donald Worster, *Dust Bowl: The Southern Plains in the 1930s* (Oxford and New York: Oxford University Press, 2004), 49-50.

¹³⁰ David L. Durham, *California's Geographic Names: A Gazetteer of Historic and Modern Names of the State* (Clovis, CA: Word Dancer Press, 1998), 300.

The promise of fertility came true, it turns out, for no commercial crop but rice — a grass with shallow roots. What turned an arid ecology with a mix of Old and New World plants, into vast stretches of industrial farmlands sown to rice, one of the most water-intensive crops? Two things, mainly: soil and irrigation. First, Richvale's soil is heavy black adobe, a type of fine-grained clay, fertile and plastic when combined with water. When dried or fired, clay makes great bowls or water tanks, which is essentially what wet-rice pond fields are. Second is the construction of irrigation networks, coupled with the right to access water flow. While humans could not increase the amount of rainfall from the sky, the technology of dams and reservoirs seemed to bring the next best thing to divine intervention: the ability to manipulate the timing of rainfall, to hold and modulate flows and floods, the powerful energy of rivers.

Irrigation

When the Lundbergs arrived in 1937, California was already being remade into a landscape of rectilinear farmlands. Over 90% of its wetlands had been destroyed, converted into a "gridded landscape.... a patchwork of private, state, and federal lands."¹³¹ California was no longer the cultivated garden that Spanish colonial settlers had misread as "pristine wilderness" in 1492, and wrested from native American Indians who had "skillfully learned to prune, till, coppice, transport and burn

¹³¹ Robert M. Wilson, *Seeking Refuge: Birds and Landscapes of the Pacific Flyway* (Seattle and London: University of Washington Press, 2010), 7.

California's vegetation in order to encourage a greater abundance of plant and animal foods and materials" since the end of the Ice Age.¹³² Neither was it the land of the 1848 Gold Rush, which saw a massive surge of people from China, Europe, and South America within a brief span of two years. These two enormous upheavals of people, flora, fauna, pathogens, and machines remade what came to be known as the state of California. A third — irrigation — remade the timing of rain, and changed the modern world.

Environmental historian Donald Worster described irrigation in California as "a key formative element, an underlying infrastructure out of which social relations grew." The rivers of California, particularly those flowing from snowmelt of the Sierra Nevadas down the Central Valley, were major sources of energy. Irrigation was a "distinctive emergent" that structured a modern hydraulic society, a "social order founded on the intensive management of water."¹³³ Worster points to the connections and collisions between material relationships with the land, democratic ideals, and the rise of technological expertise.¹³⁴ Conquest of nature, or intensive reclamation of the desert, was legitimated through a promise of greater wealth, which presumably would lead to equality.

¹³² Preston, "Serpent in the Garden," 264-5.

¹³³ Worster, "Hydraulic Society," 504.

¹³⁴ Worster points to the work of cultural ecologist Julian Steward and Marxist scholar Karl Wittfogel in developing the concept of a modern hydraulic society in California.

In 1878, John Wesley Powell proposed reconfiguring Western lands through irrigation, which would improve conditions for human settlement, especially if organized into self-managed watershed-defined communities. However unsubstantiated, irrigation was equated with happiness, prosperity, and democracy. By 1886, advocates for appropriation rights were declaring that "the more land that was irrigated, the more wealth it produced, the nearer the state would come to realizing democratic ideals."¹³⁵

In July 1902, Francis Newlands, Congressional Representative of Nevada, introduced the National Reclamation Act and in 1907, the Bureau of Reclamation was established. It opened up federal funding for irrigation projects in twenty Western states including California. But it did not work directly with individual farmers, Powell's dream agent of democracy. Instead, the bureau encouraged the formation of local irrigation districts, or what the agency referred to as "public corporations."¹³⁶

Over the next two decades, the development of large-scale, federalized projects increasingly called for scientific methods, i.e., more "businesslike farming", "modern organization men", and the expertise of an "elite cadre of technocrats" that could bring higher yields and profits from ever-more distant markets.¹³⁷

¹³⁵ Worster, *Rivers of Empire*, 106.

¹³⁶ Worster, *Rivers of Empire*, 106.

¹³⁷ Worster, *Rivers of Empire*, 114-5, 142.



Figure 23. An aerial photograph of Oroville Dam, the tallest earthen dam in the U.S. and located east of the Sacramento valley. Snowmelt from the Sierra Nevadas and rainfall drain into a manmade reservoir, Lake Oroville (left). Water is released via a spillway (center) into the Feather River (right), a main tributary of the Sacramento River. The dam has significantly reduced the river's annual discharge, splitting it between agriculture in Northern California and hydroelectricity for Central and Southern California, and endangering the cycles of ecological niche constructors like beavers and steelhead salmon (Jason Halley, Chico-Enterprise Record, 2011).

The modern hydraulic society bred new kinds of farmers, crops, engineers and experts, institutions and cooperatives. While the seasons could not be changed, rain and rivers could be contained, diverted, and rescheduled through these emerging bodies. Masculine and mechanized, California became the leading agricultural center of the world. By the 1920s, California had one-fifth of the nation's irrigated acreage and by far, the largest amount of capital invested in highly organized farm water systems. With water coming from the Sierras and a rich diversity of ecological zones, farms in California were able to harvest more than 200 commercial crops — an impossible feat without irrigated water. Rice became the leading irrigation crop,

growing along with "peaches, lemons, plums, prunes, potatoes, beans, walnuts, cotton, sugar beets, barley, apricots, spring and winter wheat, other small grains cut for hay, kaffir, milo, cantaloupes and melons, apples, tomatoes, flower and vegetable seeds."¹³⁸

The engineering and commodification of vegetal life required the constitution of other kinds of bodies. Instead of a more egalitarian society, irrigation centralized power, rewarded corruption, and turned whiteness into a prerequisite for land ownership. Declared "alien" in a series of land laws passed from 1913 to 1940 and hence excluded from permanent titles to land, groups considered non-white — Chinese, Japanese, Indian, Filipino, Korean, and Mexican farmers — were rendered subservient to crop schedules. Aliens endangered the orders of democracy. As subhuman, aliens were deemed socially valuable as temporary work hands, detached from ongoing life cycles and the telos of generations, and made present only for the harvest of a cornucopia of new commodity crops.

Aliens

While water could be contained and redirected, other forces could not. In the early 1900s, experimental plot plantings of long grain varieties failed repeatedly. The growing season was too short. Temperature and day lengths could not be manipulated. In 1909-10, the USDA Office of Cereal Investigations had rice trials

¹³⁸ Worster, *Rivers of Empire*, 213-214.

underway, with over 300 varieties planted in separate areas. A shift was made from long to short grain varieties, more suitable to climate. A year later, 45 imported varieties finally produced promising yields.

In 1912, the first year that commercial production of rice reached a thousand acres, the U. S. Department of Agriculture established the Rice Experiment Station at Biggs. The leading variety was *Wataribune*, a short grain variety from Japan that could be grown in 150 days.¹³⁹ A Japanese farmer from Texas had brought it in; little else is known before it charts a different course for California agriculture. Its impact on the rice industry is noted in a report from a meeting in March 1951 between the Board of Directors of the Sacramento Valley Grain Association and the Superintendent of the Rice Experiment Station:

In order to fully evaluate rice research in California, two things should be kept in mind. First, traditionally, our climate would not be judged to be suitable for rice production. Second, and to a considerable extent the consequence of the first, only a few of the thousands of varieties of rice which exist in the world today will thrive in California. Fortunately, the *Wataribune* type on which our industry was founded was one of these few. This was of Japanese origin. Repeated introductions of many hundreds of varieties from that country and elsewhere have failed to uncover any germplasm superior to this stock. Of further significance is the fact that in using mass production methods, we have been able to obtain average yields almost equal to those of Japan where the most intensive farming conceivable is practiced.¹⁴⁰

A few years before those notes were written, from 1942 to 1946, over a hundred thousand Japanese Americans were evicted from their homes in California, relocated,

¹³⁹ Jack H. Willson, ed. *Rice in California* (Richvale: Butte County Rice Growers Association, 1979).

¹⁴⁰ Willson, *Rice in California*, 55.

and detained without due process in military internment camps. To fill the labor shortage, from August 1942 until 1964, the *bracero* program, a series of U.S. labor agreements with Mexico brought in farm workers from Mexico on temporary employment contracts to fill labor shortages. When contracts expired, those who stayed on became new kinds of aliens: undocumented migrant workers.

In 1948, a new variety of rice was introduced to California farmers. It was named *Calrose*, a medium grain, homegrown at the Rice Experiment Station in Biggs. It has replaced Wataribune's place in California rice history, sustained by the "most elaborate hydraulic system in world history."¹⁴¹

¹⁴¹ Worster, "Hydraulic Society," 506-507.

HINTAWON — IFUGAO RICE — RECURSION

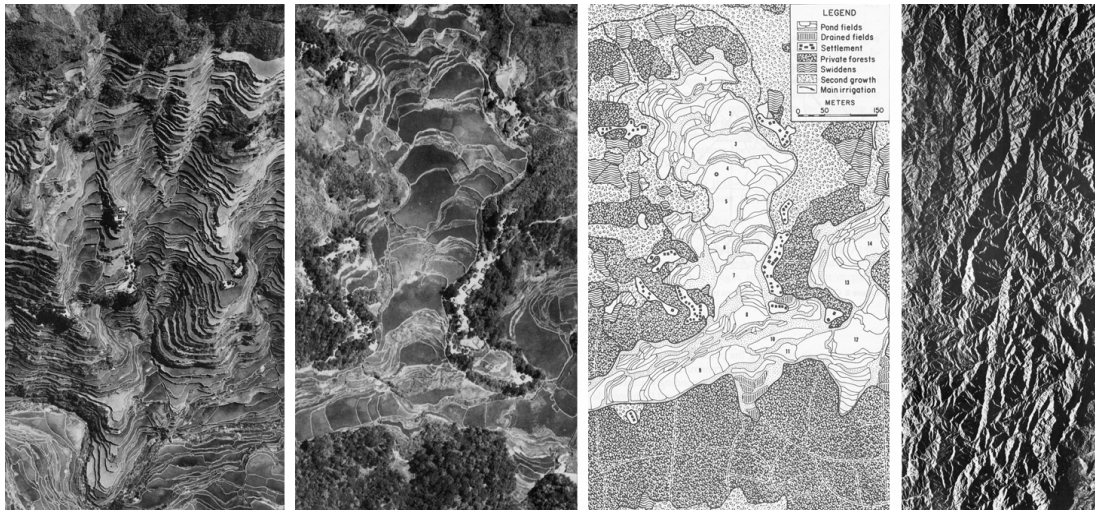


Figure 24. Conklin experimented with a range of imaging techniques to represent highly variable landscapes. From left: (1) aerial photo of Banaue terraces; (2) aerial photo of Bayninan terraces; (3) map of Bayninan, with planimetric data derived from aerial photogrammetry; (4) airborne radar imagery (SLAR) of Ifugao Cordillera and adjacent Mountain Province, Benguet, and Nueva Vizcaya.

The Ifugao rice terraces of the Philippine cordilleras are breathtaking — prized for the formal majesty of the landscape, as well as vilified for its seemingly pre-modern agricultural ways. Among the many scholars and explorers who have gathered around the Ifugao, perhaps the best known is anthropologist, Harold Conklin. From his first field visit in 1961, to the publication of his grand *Ethnographic Atlas of Ifugao* in 1980, to his sketch of irrigation gates in a notebook in 2014, Conklin’s engagement with Ifugao cultural ecology spanned more than fifty years. His work provides a critical lens into an irrigated upland region that is not at all timeless and unplanned;

rather, it is presented as an assemblage of tightly coordinated hydraulic engineering and shifting cultivation practices. There is only one of its kind, and its singularity is composed from an ecology of differences. Multiple natures and cultures are articulated through interlocking rhythms of continuity and change, life and death. Unlike researchers before him, Conklin addressed the challenges of representing Ifugao life across more than 900 sq. km. of highly variable terrain by experimenting with an extraordinary range of observational techniques and media. These included aerial photography, ethnographic mapping, historical cartography, map plates, diagrams, nested calendars, wind and rain charts, etc. Little was available on land use and local ecology when he began, so Conklin set out to collect and record his own, mixing ethnography with recent postwar advances in aerial imaging and mapping, in long term collaborations with indigenous Ifugao researchers.

It is a curious and splendid atlas — one of the finest models for an interdisciplinary art and science project — filled with bird's eye views and meticulous representations of complex land forms and land use patterns, as well as diagrammatic illustrations of interrelated cycles through which vegetal and animal life, rituals and cultural practices, rock and rainfall come together.¹⁴² Conklin's main puzzle did not lie in why

¹⁴² Conklin's contribution to the Ifugao is substantial. It is a valuable art and science project that does not find its final home on display in a museum vitrine or locked in a university library or fee-based academic journal. When I visited the Ifugao governor's office in Lagawe in 2010, the cultural officer Renato Patacsil pulled out Conklin's atlas to show me the distribution of terraces across the region. It was an unexpected revelation for me: the atlas contains the primary, and perhaps only, full set of maps for the Ifugao provinces even today, thirty years after it was first published. Online

things changed; he wondered instead about how forms developed into their own particularities, how things could hang together and endure for centuries. If change or ecological succession was nature's way of being, then what underlying patterns and processes could maintain an agricultural system at such vast scales of time and space? How did the system work and what were its long-term effects?¹⁴³ The Ifugao posed a puzzle of resilience — stability adapted to change.

Conklin's atlas is a methodological experiment in ethnoecology and cognitive mapping, an attempt to present the many human-plant interactions through which environments are made. Over twenty years of study, an Ifugao world informed by and perceived through vegetal multiplicities became apparent. The significance of Conklin's long term engagement is its temporal congruence with Ifugao cultivation cycles which range from 200 days to 10 to 15 years, as well as its multiscale approach which covered a single pond field to all the mountain provinces of Northern Luzon. Extended engagement immersed Conklin in patterns of different kinds and variable durations that were incoherent otherwise.¹⁴⁴ Conklin concluded that patterns

maps, while useful in industrialized countries with seemingly ubiquitous internet access, are of little use in the region. Mr. Patacsil met with me during a power outage or blackout — a more or less daily occurrence in the provinces.

¹⁴³ Harold C. Conklin, *Ethnographic Atlas of Ifugao: A Study of Environment, Culture, and Society in Northern Luzon* (New Haven: Yale University Press, 1980).

¹⁴⁴ In an essay titled "Kinds of Fields," Michael Dove writes that Conklin's work on Hanunóo shifting cultivation in Mindoro, for example, showed a highly productive agricultural system where rice was just one among a larger field of relations. This was contrary to common perceptions of shifting cultivation, or *kaingin*, slash-and-burn agriculture, which was considered destructive and made illegal (413).

are maintained through sophisticated cultivation of multiple kinds of fields, crop rotations over many years, and relentless negotiations of difference.¹⁴⁵ Ifugao time reckoning is shaped by well-seasoned coordinations, which recur in habitual and ritual cycles, contingently. It takes constant attention and adaptation to keep things going, to select companions that matter, and make place for their presence or future reappearance. Without coordination, stone walls crumble into disrepair, soil fertility is exhausted, species die, others move in. Entropy reorders irreversibly.

Here, I consider Conklin's description of the Ifugao agricultural cycle, *hintawon*, as a temporal relation between plant growth, land use, and land form. The best place to begin is Conklin's atlas, where *hintawon* is a cycle of activities in which rice harvest is the primary goal. Harvest, '*ahitulu*', is the shortest but most intense period of the cycle. It sets the rhythms that enable Ifugao being and belonging. Critically, Conklin situates *hintawon* through different kinds of fields: the prized pond field terrace and its two complementary forms, swidden and woodlot.

Through the atlas, history and landscape are made and remade, not through spectacular innovation or heroic deeds that enact structural transformation, but through many seasonal and daily practices that enable recursion. Persistent, careful negotiations across difference are embodied in grains that are planted and harvested.

¹⁴⁵ Michael R. Dove, "Kinds of Fields" in *Fine Description*, ed. Michael R. Dove (New Haven: Yale University Press, 2008), 411-427.

It is those picked, bundled, and stored by seed selectors — before harvest — that enable the next cycle. The past contains a bit of the future, the future a bit of the past. Recursion works quietly, through the inheritance and repeated planting of grain that keep the ordinary rhythms of collective life going over generations. Conklin's methodological experiment unpacks recursion as a valuable tool. Differential timing across radical incommensurability (e.g., between grass and rain) materializes into a resilient multiplicity of human-plant interactions and land forms.

I end in the present time, writing this chapter in the summer of 2016, just a few months after Conklin's death and as *hintawon* seems unable to find its repetitions. The terraces have been on the UNESCO list of endangered cultural heritage sites since 2001. How does a recursion that has inscribed lives and landscapes over centuries become endangered? Why has it become a landscape in ruins? Rather than pointing out who are to blame or engaging in an ungrounded critique of climate change, I ask here: what, in fact, ought to be "saved"? This question requires some commitment to particular kinds of futures. To struggle over which kinds of futures — and for whom — is to engage in the political. What happens, then, when we begin to think about the political in terms of more-than-human temporalities, or recursions made through biotic and abiotic forces assembled over millennia? This changes how the political may be configured.

A closer look at how the agricultural cycle works offers a critical point of departure.

Hintawon, An Agricultural Cycle

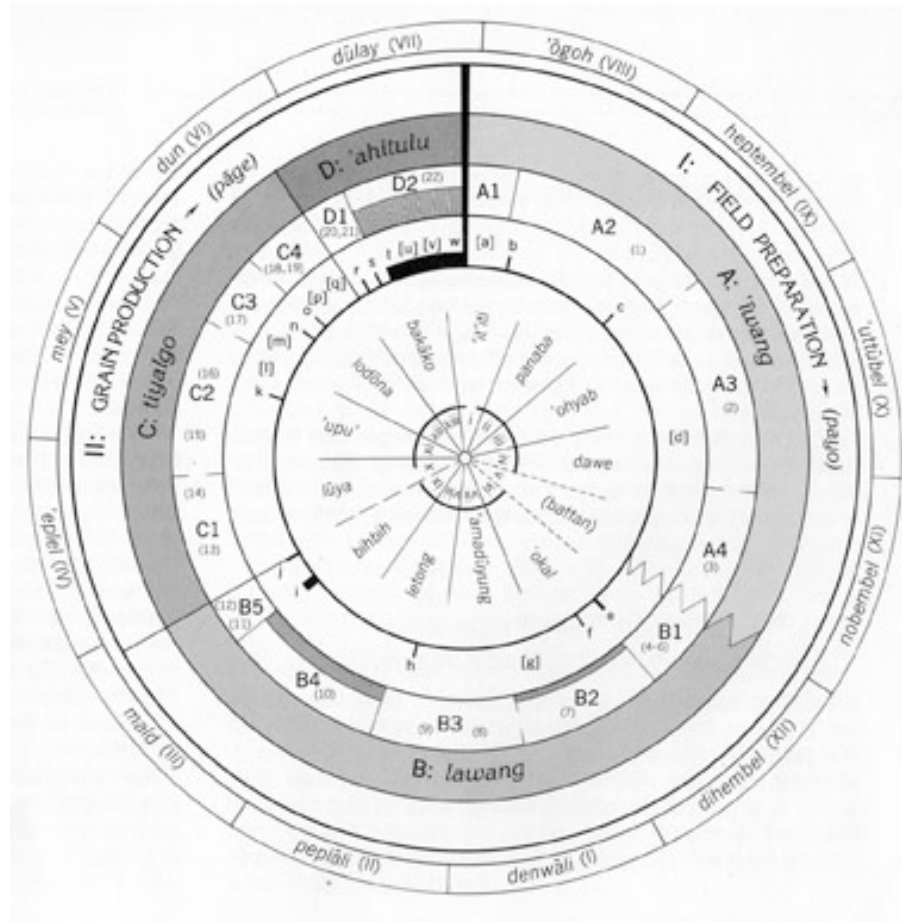


Figure 25. Diagram of the Ifugao agricultural cycle from Harold Conklin's *Ethnographic Atlas of Ifugao* (1980).

Conklin represented *hintawon* through a series of concentric rings. Celestial time is represented in the outer- and innermost rings. The outer is a Gregorian calendar with 12 solar months of equal durations, marked *denwali* (I) through *dihembel* (XII); the inner is the Ifugao lunar cycle with 13 named months, beginning with *'it'iti* (i) in August and running through *bakāko* (xiii) in July of the following year. Every third year, an intercalary month named *battan* (v) which means "position in between", is

added based on observation of environmental conditions. It is added during the least predictable season, the beginning of *lawang*.

Nested between the outer/solar and inner/lunar are four activity rings. The rings represent co-occurring sequences of seasonal tasks and rituals, divided most broadly in two: field preparation and the production of grain. Rice is the primary crop, in terms of cultural significance, not subsistence. *Pāge* is the Ifugao word for pond field rice — not a rice seed but a rice bundle. *Tawon* is the word for year; *hintawon* is a yearly cycle; *pāge tinawon* means rice made yearly. It is the primary rice crop, also called dry season rice, of subspecies *javanica* or *bulus*, and requires 7 to 9 months for weeding, planting, growth, and harvest; higher elevations take longer.

Rice cultivation begins when rice bundles are taken from storage, rituals are performed, chickens are sacrificed, and panicles are laid out. Three to five types (including one for rice beer) are laid out, grouped by type, per nursery. Growth is timed to occur in the driest months of April and May, allowing the plants to take in the greatest amount of sunlight and the warmest temperatures. During this season, there is great concern over pests: the growing rice plants are protected from being eaten by rats, ducks, and other animals and insects. Harvest, '*ahitulu*', comes a month after the onset of heavy rains in July; it is immovable. There is a second rice crop, *pinidwa*, which is the rainy season or summer rice, of subspecies *indica*. While these take less time and can be planted twice per year, they are less significant and can only

be planted at lower elevations (lower than 500 meters above sea level). *Pinidwa* does not figure in Conklin's Ifugao calendar. 80% of the varieties are *tinawon*; they are most demanding of Ifugao labor and attention and they drive the yearly cycle. Upkeep of elaborate waterworks and highly differentiated fields are not accomplished through centralized planning or hierarchical administration, but through coordination around the annual harvest of *tinawon*.

For both *tinawon* and *pinidwa*, there is not a single variety, but hundreds.¹⁴⁶ The constant breeding and selection of desirable varieties reflect the cultural focus on rice. A family plants anywhere between 8 to 40 varieties per year, spread across its pond fields.¹⁴⁷ They are classified as two types: non-glutinous *qipugo* and glutinous *dayaqqot* or *malagkit*. The latter, *dayaqqot*, are planted for use in rituals, some are favorite family tastes, some are for rice wine or beer.¹⁴⁸ Harvest is accompanied by feasts, rituals, and sacrificial killings of pigs and chickens.

¹⁴⁶ Rice is a highly adaptable grass, readily cultivated into different varieties. The homogeneous commercial rice, with all grains exactly alike, that most of us purchase at stores is the anomaly. At IRRI alone, there may well be over 565 varieties of rice from the Ifugao provinces (Nozawa et al., "Evolving Culture," 73).

¹⁴⁷ This is based on conversations with Ifugao folks: Banaue landowner Lily Beyer (also granddaughter of American anthropologist H. Otley Beyer), government agriculturalist Raymond Bahatan, and Amganad resident Aurora Amayaw.

¹⁴⁸ In conversation, Beyer listed the varieties she had been planting. *Tinawon* varieties were mostly aromatic, including *imbuukan*, *hinglu*, *inawi*, *minangan*, *donar*, *ingalotgot*, *ayuhip*, *lamuhan*. She had recently added some new varieties: *binuggun*, *California*, and *oklan*. She always reserved a special section for glutinous *malagkit* varieties, including *imabti* (which pops when put on a fire), *ingumarlingon* ("juicy" and preferred), *balikwadang* (pinkish), and *lipo* (violet).

Ifugao expect variation; *hintawon* is an attempt to manage it, to enable successive harvests through an abundance of difference. The sequence of activities can shift earlier or later by days or weeks, but the sequence itself stays the same as it corresponds to the seeding and growth of the flowering rice plant, and consequent *'ahitulu*, rice harvest. While it is the shortest period in the cycle, harvest is the most intensively worked and celebrated. It is the event that ends all farming activities for the year, and commences a new cycle. No two harvests are the same. And no two districts follow exactly the same schedule. Conklin writes:

...because precise dating by some external system such as the Gregorian calendar receives little attention, successive years rarely have the same number of days. The precise termination of each local Ifugao year is determined not by celestial phenomena but by the conclusion of harvest rites; activity for a particular calendric date is specified in terms of an intercalibration of various phenological fluctuations and local cultural activities.¹⁴⁹

Much of it depends on the timing of

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..
.. *Udan*

While rice is the primary player, its conditions are set by *udan*, rain. The Ifugao say

¹⁴⁹ Conklin, "Ifugao Atlas," 13.

ahiudanan, the time of rain. There are at least fifteen other words to describe various intensities, frequencies, and sounds — from *hamiy'ok* for light monsoon showers and noisy *lagetlet* for heavy downpours, to *lomlom* and *tapeek* for rains that continue for two or more weeks, and solemn *uyung* for rains that come after someone is killed.¹⁵⁰

Rain is abundant, exceeding 3,000 millimeters (118 inches) per year.¹⁵¹ Rain falls on more than 190 days out of the year, making conditions generally wet or moist. Dense forests cover the steepest inclines which can reach up to 1,500 - 1,600 meters above sea level; irrigated terraces (inundated all year) and woodlots are built into gentler hillside slopes; settlements are located in flatter valleys. Managing the amount of rainfall and the variable distribution of water across these multiple elevations and sites is key to cultivation of grains, sweet potatoes, and fruit trees, as well as for transporting heavy stone and soil to build and repair terraces, drainage canals, embankments, and other structures. Knowing when to open irrigation gates across hillside terraces, in time for the arrival of rain, is crucial.

Hintawon may be seen as sophisticated adaptations to climate — particularly the abundance of rainfall and water flow — and complex coordinations taking place within highly irregular land formations.

¹⁵⁰ Based on a *Tuwali Ifugao Dictionary*, compiled by missionaries who lived in the Ifugao province of Kiangnan from 1981-1991. < <http://tuwali-ifugao.webonary.org/> >

¹⁵¹ In contrast: annual rainfall in Sacramento, CA averages less than 500 millimeters or 19 inches; the Mekong Delta in southern Vietnam averages 1,300 millimeters or 51 inches per year.

Terrace, Swidden, Woodlot

The terraced fields of Ifugao dominate the Central Cordillera Highlands of Northern Philippines. They are bounded by the Mountain Province on the north, the Magat River on the east, Nueva Vizcaya province on the south, and Benguet province in the west. The Ifugao province has eleven municipalities: Kiangang, Lagawe, Hengyon, Banaue, Mayayao, Aguinardo, Alfonso, Lista, Lamut, Hungduan, Tinog, and Asipulo.¹⁵² There are 20,000 km of irrigated terraces, 7,000 of which are built of stone, dating back at least 400 years.¹⁵³ Ranging from 2 - 3 square meters to more than ten thousand square meters (one hectare), none of the hundreds of thousands of fields are the same.¹⁵⁴ The terrace is one form in a complex ecology that consists of hundreds of other forms. Each is a different combination of rock, river stones, soil, water, vegetation, and mode of cultivation and ownership.

Conklin categorized the many combinations into eight basic land forms and ranked them according to increasing agricultural intensity. Of the eight land forms, three are of prime importance and I have underlined the terms to distinguish them: *mapulun* or untitled grassland; *'inalāhan* or public forest; *mabilāu* or caneland; *pinūgu* or private

¹⁵² Stephen B. Acabado, *Archaeology of the Ifugao Agricultural Terraces: Antiquity and Social Organization*, Diss. University of Hawaii, 2010, 35.

¹⁵³ Michael R. Dove, "Ethnographic Atlas of Ifugao: Implications for Theories of Agricultural Evolution in Southeast Asia," *Current Anthropology*, Vol. 24, No. 4 (August - October 1983), 516.

¹⁵⁴ Harold C. Conklin, "Ethnographic Research in Ifugao" in *Fine Description*, ed. Michael R. Dove, 1974 (New Haven: Yale University Press, 2007), 435-436.

woodlot; *hābal* or dry swidden; *latāngan* or house terrace; *na'ilid* or drained field; and *payo* or pond field terrace.¹⁵⁵

Importantly, the three land forms do not run independently, but are coordinated with *hintawon*. In Figure 26 on the right,

Conklin represents the seasonal interrelationship between Ifugao land forms through three concentric rings: the innermost and central ring is the pond field terrace, driven by *hintawon*; the middle is swidden or *kaingin* for farming of subsistence root crops, primarily sweet potato or *kamote*; the

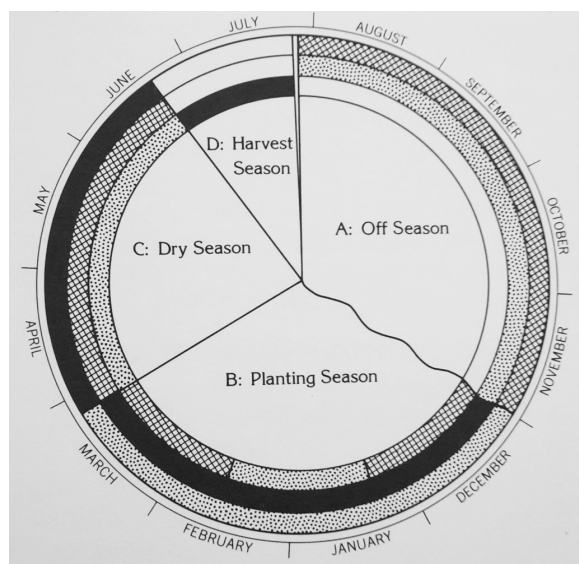


Figure 26. Conklin's diagram of interrelated activities between three land forms.

outer ring is woodlot for timber and fruit trees. Conklin filled in solid black areas to represent harvest; crosshatching represents planting periods; and stippling or solid white areas for off-season activities. Visible here is the rotation of activities from one land form to the next.

Coordination between the cycles does not mean they are of equal duration. While rice harvest is annual, the cycles for swidden and the cultivated woodlot extend over much longer periods. The pond field itself is a multipurpose, multispecies habitat, used also

¹⁵⁵ Anything above 18° slope is owned by the state. Thus, Ifugao forests are all state-owned.

for taro, other crops, as well as mudfish, aquatic snails, and other food supply.

Swidden burn, farming, and fallows may extend over 8 to 15 years¹⁵⁶ and are a crucial part of Ifugao shifting cultivation.¹⁵⁷ While rice may be the prestigious crop, sweet potatoes planted in swidden are the main food staple for most of the year.

Conklin writes:

the most important aspect of Ifugao shifting cultivation is the relative ease with which swiddens can be made and extended when there are signs that the rice crop will be poor. Without this flexible and additional form of land use, the population in most valleys would be sharply reduced. Swiddens furnish the bulk of the food consumed by most families except the wealthy and they provide insurance against times of economic stress.¹⁵⁸

The third form, woodlots, are sources of timber for firewood used in cooking and heating throughout the year, as well as house construction and carving material. Well-managed lots can have more than 200 floral types, ranging from hardwoods and softwoods to fruit trees and medicinal herbs. The woodlots are highly variable and

¹⁵⁶ Harold C. Conklin, "An Ethnoecological Approach to Shifting Agriculture" in *Environmental Anthropology*, eds. Michael R. Dove and Carol Carpenter, 1954 (Malden, MA, Oxford, Victoria: Blackwell Publishing, 2008), 241-248. Reprinted from *Transactions of the New York Academy of Sciences*. 17(2): 133-142. New York: Columbia University, 1954.

¹⁵⁷ In an essay descriptively titled, "The Study of Shifting Cultivation," published in *Current Anthropology* in 1961, Conklin defined shifting cultivation as any "continuing agricultural system in which impermanent clearings are cropped for shorter periods in years than they are fallowed." Shifting cultivation has been practiced since the Neolithic.

¹⁵⁸ Conklin, "Ifugao Atlas," 25.

hold multiple vegetal temporalities. Their ability to maintain great diversity makes them second to pond fields in importance.

These land forms are not static and uncontrolled, but undergo multiple transitions and recursions through well-defined Ifugao practices over years. The Ifugao engage and manage what Conklin calls "patterns of succession from one differential stage of land usage to another" and "recursive loops indicating 'internal' cyclic progressions."¹⁵⁹

The atlas includes a diagram shown in Figure 27 below, articulating the most common transitions among five land forms:

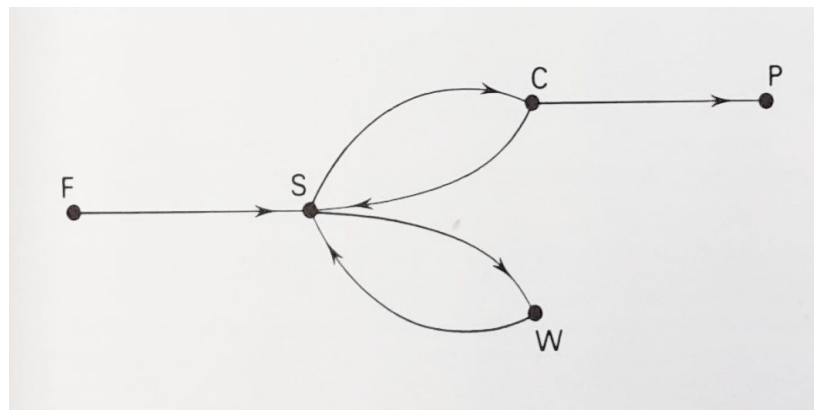


Figure 27. Diagram of patterns of succession between five different land forms.

The initial state, an uncultivated forest (F) might be transitioned to swidden (S). S might then be converted to either of two forms: canelot (C) — and eventually pond field (P) or back to swidden — or, woodlot (W) which can also cycle back to swidden. Directional arrows indicate that the transformations operate in a specific order, whether it is succession from one form to another (F to S), or a cycling back

¹⁵⁹ Conklin, "Ethnographic Research in Ifugao," 445-451.

and forth between two land forms (S to/from C), or a combination of succession and cycling (S to/from C, C to P). Some forms are more desirable than others, calling for greater attention and more intensive labor. Techniques differ from one area to another, and with changing conditions.¹⁶⁰ Nevertheless, each plays its part, for the time being, in conjunction with all others.

Re-pairing

Conklin describes multiple actants that work the *hintawon* cycle:

For centuries, and with only the simplest of hand tools, the Ifugao have farmed the steep slopes and valleys of their mountainous territory. This firmly established, integral, and continuing agricultural pattern depends on many factors: the availability of water for irrigation and soil transport; suitable earth or stone for construction and repair of embankments; a variety of vegetational habitats as sources of fuel, fencing, and other constructional materials; a large number of protected and cultivated plant types, including rice, sweet potatoes, legumes, and fruits; domesticated pigs, chickens, and ducks; the presence of mudfish, snails, and other aquatic fauna; sufficient labor to keep up the annual round of repairs, cultivation tasks, and associated rituals; and most important, the knowledge of how these and many other economic factors are interrelated and may be profitably utilized.¹⁶¹

Ecological systems never stand still. They are constituted through a large number of dynamic assemblages interacting in complex ways. They are open to change and subject to occasional external shocks or traumas. Resilient systems can withstand these changes or develop adaptations but not indefinitely. Effects accumulate and reach a critical threshold, beyond which there is considerable, cascading

¹⁶⁰ Conklin, "An Ethnoecological Approach to Shifting Agriculture," 246.

¹⁶¹ Conklin, "Ethnographic Research in Ifugao," 438.

transformation. A change or disappearance of one fragment can reverberate negatively throughout.¹⁶²

In recent decades, things have been changing significantly, pushing Ifugao cycles and systems that have endured for centuries. According to Lily Beyer, a longtime Banaue resident, 70% of stone walls were in disrepair as of 2010. Younger generations have been abandoning the fields and moving to larger towns or cities in search of other kinds of livelihoods. The weather is drier. With not as much rainfall, landslides occur more frequently. Heavy monsoon rains in 2011 resulted in massive erosion, causing major damage to infrastructure such as roads, irrigation and drainage channels, and terrace walls.

Pests described in Conklin's atlas have become bigger threats: common rats (*Rattus tanezumi*) and small weaverbirds (*Lonchura spp.*) eat growing rice, while large earthworms (*Pheretima elongata*), usually a vital ally for aerating the soil, burrow into and weaken or crack dikes, bunds, and terrace walls. Since the 1970s, giant earthworms, more troublesome and unwieldy at 25 to 50 cm in length, have become dominant,¹⁶³ problematically breaking apart terrace walls as they burrow through the

¹⁶² C. S. Holling and M.A. Goldberg, "Ecology and Planning," *Journal of the American Institute of Planners*. 37 (4) (1974): 221-230.
doi: 10.1080/01944367108977962

¹⁶³ Central Cordillera Agricultural Programme (CECAP) and Philippine Rice Research Institute (PhilRice), *Highland Rice Production in the Philippine Cordillera* (CECAP, Banaue, Ifugao and PhilRice, Maligaya, Muñoz, Nueva Ecija, 2000), 143-144.

stones or mud.¹⁶⁴ Furthermore, several species have been introduced in recent years. Before the second World War, species in pond fields included mudfish and shellfish, and in streams, eels, frogs, crabs. After the war, *dojo* or Japanese loach (*Miagurnus anguillicaudatus*), a hardy bottom feeder, began appearing. In the early 1970s, tilapia (*Oreochromis niloticus*) and the common carp (*Cyprinus carpio*) were introduced. In the 1980s, *golden kuhol*, or golden apple snails (*Pomacea caniculata*) were imported by the provincial government as alternate sources of protein, but have since become invasive, crowding out native snails species and destroying rice plants at their roots.¹⁶⁵ This snail also happens to be a host for a parasitic nematode, *Angiostrongylus cantonensis*.

For better or worse, a "friendly rat", seemingly with an appetite for golden kuhol and giant earthworms, has been enlisted: the striped shrew-rat (*Chrotomys whiteheadi*), a native of Luzon montane regions, is now part of the changing mix.¹⁶⁶ Thus, a new trophic cascade assembles. Rats, earthworms, and snails: a re-pairing of species unfolds in pond fields — and, with new pairings come new cycles.

¹⁶⁴ It is unclear whether the giant earthworms belong to the same *Pheretima elongata* species, as identified in Conklin's research. The source of the giant earthworms remains a mystery. However, one reporter Carlos D. Marquez writes that locals believe that they are connected to the rise of illegal logging in the region.

¹⁶⁵ CECAP, *Highland Rice Production*, 72-73, 155-7.

¹⁶⁶ Carlos D. Marquez, "Ridding Philippine rice terraces of rats and worms." *Scidev.net*, accessed July 1, 2016, August 23, 2005, <http://www.scidev.net/global/biotechnology/feature/ridding-philippine-rice-terraces-of-rats-and-worms.html>

In October 2010, the Ifugao Provincial Governor Eugene M. Balitang, submitted a written proposal to the Secretary of the Department of Tourism Alberto A. Lim, titled "Conservation Program for the Ifugao Rice Terraces World Heritage Sites." It was a three-part conservation plan involving the districts of Kiangan, Banaue, Hungduan and Mayayao: (1) repair of 3,000 cubic meters of deteriorating and abandoned rice terraces; (2) rehabilitation of a communal irrigation system; and (3) management of forest and watershed resources. It made a case for the scientific, aesthetic, and educational value of the region as a UNESCO World Cultural Heritage Site, and requested a budget of PHP 5 million (approximately USD 100,000). Since then, local newspapers have reported that at least PHP 35 million (approximately USD 745,000) have been committed to repair of the terraces (the first of the three initiatives), with funds coming from different departments and programs. Volunteers and students are pitching in. An agriculturalist, Raymond Bahatan, was quoted in local papers noting that over half of the Banaue terraces have been repaired.

While valuable and commendable, these conservation efforts are not enough. They reduce the rice terraces to physical infrastructure — broken and now subject to reassembly like a pile of bricks or Lego blocks. Considering Conklin's work, the construction of terrace walls is hardly just that. The terraces are one land form entangled with a larger, historically constituted ecology of multiple land forms, of natures and cultures, humans and nonhumans. Also considering the emerging species mix, the terraces are increasingly vulnerable to the workings of giant earthworms,

promiscuous snails, and hungry rats. It seems crucial to consider conservation that more broadly re-engages the temporalities of multispecies/microbial growth, land use, land formations, and weather patterns that have become increasingly indeterminate.

To focus exclusively on saving terrace walls, perhaps because those repairs are easily made measurable and visible to international organizations, is to prop up another million-dollar ruin. Or, to develop a theme-based amusement park for tourists. What then of the Ifugao? For whom are such efforts undertaken if they are detached from the complex agricultural system, the recursions of rice harvest worked through hundreds of land forms that are at the heart of Ifugao being and belonging?

Meanwhile

Over three hundred and fifty Ifugao rice varieties are stored at the seed bank of the International Rice Research Institute in Los Baños, with backups at Svalbard Global Seed Vault in Norway. This is *ex situ* conservation, the conservation of biological/genetic diversity outside their natural habitats. I first encountered the sample collections of Ifugao seeds at IRRI in 2010 and somehow learned that there was a copy of a master index archived at the IRRI library. The master index explains the Ifugao polynomial naming system (each begins with either *tinawon* or *pinidwa*), cropping cycles, and characteristics. It was typewritten on three pages and signed by hand, on the upper left corner: "*Harold Conklin, August 10, 1982*".

In this chapter, I have relied on Conklin's ethnobotanical work with the Ifugao to consider a working agricultural cycle as a recursion that is made through an assemblage of differences: the timing of rice, sweet potatoes, rain, mountains, pond fields, swidden, burns, wood lots, forests, rivers, and a slew of animal, vegetal, microbial, and human generations. Rice harvest recurs through many worlds. These now encounter and overlap with the timing of drought, landslides, giants and invasive species, tourists, government agencies, research institutes, and charitable NGOs. Times are changing. The best of times and the worst of times are mingling — disrupting, amplifying, and settling into each.

A previously unimaginable geological epoch, named the Anthropocene in 2009 by earth systems scientists, bears the telling scars of overwhelming and extinguishing forces of industrialized technoscience on every way of life. Ifugao life and landscape are unique, but are hardly the only ones affected by industrial disturbances. What might Conklin and Ifugao *hintawon* teach us about deeply situated and more-than-human cultivation, and the differential temporalities through which complex systems can build or rebuild dynamic resiliences and recursions over centuries — perhaps until now?

I want to believe that the Anthropocene is not a marker for a world that is ending, but a different kind of carrier for many more-than-human rhythms, land forms, seeds, and practices. Other worlds are here.

Udan, rain, recurs . . . ¹⁶⁷

¹⁶⁷ This chapter, presented as the last of six, is in fact the first place where I began my research on rice in 2010. It is through Conklin's work that I began thinking about multispecies temporalities and historicities. I would not have met Conklin, or learned about shifting cultivation, or the Ifugao atlas, or so many details about rice — without first, the generosity of a gift from Anna Tsing, a student of Conklin.

PART TWO:

TIME MACHINES

TIME MACHINES

What A Machine Is

A machine is an apparatus that produces a capacity. It is a composite of distinct parts that, when assembled, enables material effects that would otherwise be impossible. Everything can become an instrument of, can be incorporated into, a machine. A machine is an apparatus with material-semiotic parts that come together for no single reason, with no prescribed function or preconceived product. It can, but need not, be constructed from human designs. A machine is made and unmade historically and contingently, through encounters of humans and nonhumans, biotic and abiotic forces. A machine is composed through more-than-human socialities; it has no existence prior to the coming together of various parts. It has no consciousness and yet it is creative; it produces a capacity, without intending to do so.

Multiple kinds of machines — in many shapes and sizes — appear in Part One. Among the most familiar kinds perhaps are the human inventions. I describe mechanical ones such as refrigerators and air conditioners, which allow larger machines to work, such as a temperature-controlled seedvault in Svalbard, or a vehicle driving on a highway in northern California on a hot summer day. They extend the length of time during which things might otherwise expire or become unwieldy. I describe chemical inventions such as synthetic fertilizers and toxic

pesticides applied through Southeast Asia, produced by postwar industries fueled by petroleum. They accelerate the growth of organisms and favored crops like rice, and eradicate unwanted pests and weeds. I also describe massive infrastructures and technical feats of engineering and terraformation, such as hydropower dams in the Upper Mekong and in Sacramento, as well as terraced, irrigated fields in the Ifugao cordilleras. They redirect and store the energy of sunlight and flows of water, easing demands on labor. Furthermore, I describe software-driven machines, such as automated sequencers, computer archives, and genome databases that are all producing novel ways of ordering and re-membering life. They not only alter the life cycles and traits of multiple species, but also mediate what qualifies as life and, who qualifies as human. This is just a small list of particular kinds of machines, namely human inventions, that appear in Part One.

Saying that human inventions are one among many kinds of machines is not meant to minimize the effects of anthropogenic disturbance, but to recognize that other species play critical parts in inventiveness, the ability to create and evolve conditions of possibility. In addition, to invoke machines is not to flatten out complex and dynamic relations into a Newtonian world that is a finite totality structured by mechanical gears that produce repeating and lawful motion. I use the figure of machines in considering rice to conjure and articulate various carriers, transformers, converters of energy that are powered by relations of radical differences and irreducible capacities. In this sense, I build on Gilles Deleuze & Félix Guattari's use of the machinic as a

conceptual figuration of productive forces that interrupt a world of fluid flows and enact rhizomatic relations.¹⁶⁸ Writing in the late 1970s, Deleuze & Guattari focused on the machinic capacity for complexity, exteriority, and deterritorialization — a critical stance against power, capitalism, and State philosophy. My study of rice is situated fifty years later, in another historical moment, one marked by a heightened awareness of anthropogenic interruptions to earth systems at multiple scales. From this standpoint, my study pushes for a closer focus on the machinic capacity for coordination: creativities that make and unmake conditions of habitability. I focus less on philosophical inquiry, and instead move toward interdisciplinary ways of articulating capacities that exist and enact in common, in relation — without human-imposed hierarchies that privilege purposeful action, communicative signals, or coherent networks.

Describing articulations through rice begins with expanding modernist notions of temporality, whose various figurations I attempt to draw out in Part One. In attending

¹⁶⁸ Responding to the student-worker revolts of May 1968 in France, Deleuze & Guattari aimed to rethink the role of the intellectual in society, and the order of society itself. They theorized the machinic in a two-part volume: *Anti-Oedipus* (1972) and *A Thousand Plateaus* (1980), with the joint subtitle *Capitalism and Schizophrenia*. They posited multiple kinds of machines that could be material, symbolic or imaginary: desiring-machines (creative, affective capacities that overturn Freud's grounding of subjectivity on lack and Marx's grounding of production in the factory); capitalist machines; abstract machines (codes and milieus or semiotic-pragmatic systems that overturn Foucault's *dispositif*, an apparatus that configures and orients power relations over ongoing historical change); nomadic war machines (anarchic and itinerant presences that resist a colonizing State); machinic assemblages that are distinct from assemblages of enunciation. Deleuze & Guattari's machines operate through a plane of immanence, a field of ongoing differentiation, nomad thought, and deterritorialization.

to how relationality is made and unmade in concrete historical conjunctures, more-than-human counter-modernist patterns and logics start to become visible and perhaps, then, mappable along alternate coordinates.

Why Machines Now?

Before moving on to other kinds of machines, I should point out more clearly what is at stake in considering the machinic today. In 2000, atmospheric chemist Paul Crutzen, in collaboration with marine scientist Eugene Stoermer, proposed the term *Anthropocene*, to identify the current geological epoch with what seems to have become the most powerful force that drives global and historical ecology: *anthropos*, the Greek word for human. Building on research from various scientific communities from the 1950s onwards, the new term brings into view a Human age in which globalized capital and industrialized civilization have outsized and outpaced planetary cycles.¹⁶⁹ From the industrial revolution in eighteenth century Europe, world wars and colonial agroecology, to the explosive growth of cities, nuclear power, and transnational neoliberalism, humanmade machines have had huge impacts on

¹⁶⁹ The definition and demarcation of the onset of the Anthropocene has been the topic of a growing number of articles and books. These have been particularly useful: Paul J. Crutzen, "Geology of Mankind," *Nature* 415, 23 (3 January 2002), doi: 10.1038/415023a; Will Steffen, Paul J. Crutzen, John R. McNeill, "The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?", *Ambio*, Vol. 36 No. 8 (December 2007): 614-621; Bruce D. Smith and Melinda A. Zeder, "The Onset of the Anthropocene," *Anthropocene*, 4 (2013): 8-13; J. Zalasiewicz et al., "The Anthropocene: a new epoch of geological time?" *Philosophical Transactions of the Royal Society A*, 369 (31 January 2011), doi: 10.1098/rsta.2010.0339.

reconfiguring biogeochemical rhythms and formations. Many of the ecological assemblages and environmental-climatic patterns upon which contemporary life has come to depend are changing, irreversibly. At present, acid rain, eutrophication, deforestation, monocrop plantations, the extraction of fossil fuels, the mass extinction of particular species like amphibians and migratory fish, the uncontrollable spread of diseases like rice blast, are just a few examples of human-induced catastrophes that, in many different ways, are altering conditions for the persistence of multiple, interdependent forms of life.

And yet, human inventions have not led to degradation alone. They constitute media ecologies in themselves: steam engines, electricity, clocks, radio, airplanes, typewriters, film are some examples of world- and life-changing innovations. More recent apparatuses include high-resolution microscopes, scanners, computers, satellites, space stations. They are part of weapons of war and dispossession, but also extend human senses and rewrite capacities for synchrony, settlement, and mobility.¹⁷⁰ (Without these tools, the very notion of global climate change or genetic erosion may have been inconceivable.) They have also induced feral ecologies and unintended connections: weedy and cosmopolitan invasives like water hyacinths and plant hoppers, virulent microbes, as well as unseasonal droughts, more turbulent storms and floods. These anomalous mixes are producing new ontoepistemologies

¹⁷⁰ Historians of science and technology, sociologists, and media theorists have pointed out that new material and discursive practices arise from the introduction of new media technologies. Key among these are Harold Innis (1950), Marshall McLuhan (1964), Frederick Kittler (1999), and Peter Galison (2003).

and alternate historical structurations — regardless of whether we choose to notice, or know how to narrativize and politicize, their prodigious emergences.

New pluralities co-exist and intra-act: irreversible degradation and collapse; unprecedented extension and connectivity; indeterminate ferality; alongside rhythms and cycles of ordinary everyday life. We face humans in machines, machines in organisms and landscapes, organisms in humans. Nature and culture, machines and organisms are difficult to disentangle, and yet cannot be studied as a singularity. Addressing the Anthropocene as a universal and simultaneous state of ecological breakdown, as a singular product of capitalist systems of extraction, is inadequate to what appears to exist. So is addressing it as a proliferating multiplicity of abstractions and concrete details, for which ever-finer distinctions, significations, and antagonisms must be manufactured endlessly.

The Anthropocene presents a deeper and more profound paradox. By calling out *anthropos* as human exceptionalism, the Anthropocene marks its necessary end — and with it, humanist distinctions between nature and culture, worlds and words.¹⁷¹ It places the "human" under erasure: a form of life to be critically demolished and made

¹⁷¹ Postcolonial historian Dipesh Chakrabarty's important essay, "The Climate of History: Four Theses," published in *Critical Inquiry* (2009) points out that the Anthropocene calls for a "negative universal history:" a shared sense of catastrophic climate change collapses the humanist distinctions that have kept natural history and human history as separate fields of knowledge. He asks an essential question: "How does the crisis of climate change appeal to our sense of human universals while challenging at the same time our capacity for historical understanding?" (201).

anew. Decentering, deconstructing the "human" comes with a violent breakdown of hard-won signifying chains and age-old humanist methods: where might historicity, language, and agency be located without the "human" as their coordinating structure, their locus of meaning? It leaves a bewildering muddle of mutations and ruptures whose analyses call for experimental methods from the arts, humanities, and sciences.¹⁷² As I see it, the puzzle that the Anthropocene poses is: *which constitutive relations matter, when and for whom?* Addressing this puzzle calls for new tools.

I turn to the figure of the machinic to, first, recognize *anthropos* as always and already a relation of ongoing differentiation. Here, *anthropos* is not the Cartesian subject whose human existence depends on individual consciousness, and not the Foucauldian subject that is socially constructed by disciplinary apparatuses and biopolitics. It is sympoiesis and autopoiesis, simultaneously material and symbolic: the making of self and other that is also the unmaking of self and other. I turn to the machinic, secondly, to analyze how relations of forces work together — beyond human consciousness and action — and become sym/autopoietically creative coordinations in different conjunctures. Different forces matter, in different forms, at different times. To conceive of relations of force as creative coordinations of timing is

¹⁷² In this sense, I follow Fredric Jameson's famous call for an "aesthetic of cognitive mapping — a pedagogical political culture which seeks to endow the individual subject with some new heightened sense of its place in the global system." At the conclusion of his essay, "Postmodernism, or the Cultural Logic of Late Capitalism" (1983), he calls for a "new political art" that holds true to the "world space of multinational capital" while simultaneously pushing towards critical modes of representation through which new political capacities might arise.

to argue that history and language are not the exclusive domains of purposeful human action, but are made with significant others.¹⁷³ The machinic proposes a way of situating historicity, agency, and language in *anthropos* of a different kind.

Three challenges arise: How are we to unpack contemporaneous events that emerge from variable histories and geographies, without asserting human reason and discourse as the dominant framework, synchronized progress as the universal ethic, and global capitalism as the all-encompassing logic? How might multiple processes be studied, not only as ever-proliferating heterogeneities or fragmentations, but as meaningful coordinations? Lastly, how might we push past a binary logic that insists on privileging particular methods of study: either reasoning from concrete details to the general and metaphoric (an inductive and descriptive approach), or theorizing abstract principles and verifying through the concrete (a deductive and philosophical approach)? To take seriously the materialities of rice and its companions is to search for new ways of addressing these challenges.

What A Time Machine Does

While a machine is composed of distinct parts that produce a capacity, a *time machine* is a set of machines that produces a capacity for creative coordination among

¹⁷³ Fernand Braudel's *The Mediterranean* (1949) and Alfred Crosby's *Ecological Imperialism* (1986) are groundbreaking examples of histories that conceived of human events and sociopolitical transformations as interwoven with environment and ecology. My inquiry pushes this further by asking, what happens to notions of history, agency, and language when considered through a different ontoepistemology.

significant others. A time machine is defined by its capacity to produce significant effects across radical incommensurability. Read independently, each of the six types of rice in Part One are examples of machines. I describe how each type has a specific capacity to grow and interact. I also describe how each lives in a unique conjuncture, articulated differently from the others. Read as interrelated parts of ecological assemblages and as contemporaneous events, the six types of rice belong to special kinds of machines, which I call *time machines*. Considered together, the six time machines articulate various sympoietic¹⁷⁴ and autopoietic processes occurring in specific landscapes through which an unprecedented field of forces comes into being. Each time machine draws from and configures a contemporary formation, a livable and habitable present made possible through various histories and articulations; not one subordinates or synthesizes the others.

A time machine is like a sentence that is composed of a set of distinct words that — together and in sequence — express an idea or produce meaning that exceeds any particular word. Through a grammatical ordering of words expressed in, and made coherent through, a specific social context or discursive formation, a sentence becomes a unit of communication, a speech act, that has a performative effect on the world. Because words and worlds interact recursively, the next utterance of the same sentence might have a different meaning after the initial utterance.

¹⁷⁴ I borrow the term "sympoiesis" from Donna Haraway's important work on multispecies "becoming-with".

Instead of words that form a sentence, a time machine is composed of historical effects that produce a capacity for coordination — a co-ordering that brings about something unprecedented. Meaning or significance is not conveyed by human language or power relations, but by a creative and differential capacity to play with timing and effect change. Human language is just one mode of coordination. By historical effects, I mean material-semiotic entities that have come to be identified and classified by proper nouns or names of different species or land forms, human or nonhuman. In a time machine, these names do not represent fixed identities or positionalities, but stand in for capacities that only exist in a particular way, and are consequential for a particular interval. By coordination, I mean a contingent and emergent capacity to live time otherwise, not a mechanical activity prescribed by human management. Coordination is made and unmade through a sequence of historically specific relationalities, even as it makes and unmakes emergent conditions. It is a more-than-human language of timing that effects change across dynamic conjunctures.

In each of the six time machines, a conjuncture is not a static set of relations but an emergent polyphony that changes existing coordinations, and then begins to change the conditions of the conjuncture itself. Like a sentence whose meaning depends on, and can also change, a particular social context, a time machine produces coordinations that are inscribed in, as well as constitutive of, a historical conjuncture.

Multiple capacities for coordinations appear in different time machines throughout Part One. None are presented as intrinsically good or bad. Whether they are productive or destructive depends on the specificities of the conjuncture. Thus, they can shift from being productive to being destructive. And they can break down or disappear. I point out the most significant ones that I encountered in working with rice, although my list is by no means exhaustive or complete. I also offer examples to point to particular sections in Part One that illustrate how the coordinations drive structural changes. To effectively address the puzzle of the Anthropocene is to embark on an ongoing project of pointing out and analyzing other significant modes of coordination. The following, then, is an initial and necessarily partial list:

Attuning is a mode of coordination in which the rhythms of two or more entities are open and responsive to each other. It takes a while for attunement to evolve and take hold across difference. An attunement leads to the persistence and proliferation of different entities; no one is reduced or rendered subordinate to another. A change in attunement can have significant effects.

For example, in *Time Machine III*, the giant catfish is attuned to the monsoon flood surges of the Mekong river, and the banks of the river are shaped, in part, by the movements and migration patterns of the catfish. This attunement creates habitable conditions for other species, including humans. Without the flood surges, the giant catfish loses its capacity for attunement and becomes endangered. Its extinction, in

turn, reconfigures patterns of human subsistence. Meanwhile, in the same *Time Machine III*, we might also consider that the water hyacinth is better attuned to eutrophication and proliferation of motorized boats along the river. This capacity has enabled the water hyacinth to spread throughout bodies of water worldwide, even as the catfish disappears.

Accelerating is a mode of coordination in which the rhythm or growth cycle of one entity speeds up, altering or abolishing its timing with other species. Modernity tends to imagine itself through speed or rapid growth, which has become synonymous with social progress. But, the spread of invasive species, the frequency of landslides, and even the movement of molecules also perform accelerations that reconfigure life and landscape.

The miracle rice varieties in *Time Machine I* are a clear example of an intensification or speeding up of the life cycle of rice, to have faster and more harvests. However, anthropogenic disturbances have also heightened the responsiveness of other species who thrive on and speed up with increasing levels of environmental degradation. In the story of miracle rice, for example, the introduction of massive amounts of nitrogen fertilizers in rice fields improved growing conditions for brown planthoppers and stunt viruses which destroy harvests at great speeds. These species now move faster than the ability of farmers and scientists to keep developing resistant rice varieties.

Arresting is a mode of coordination in which the life ways or mobilities of one entity are suddenly seized, suspended or stopped by another. The spread of a pathogen or the life ways and possibilities of an organism may be arrested. In *Time Machine II*, arrest is enacted by literally freezing almost a million seed accessions in a seed vault, conserving them *ex situ*. There are more complex and interrelated forms of arrest which accompany capitalist extraction and dispossession. For example, in *Time Machine IV*, the mapping of rice genomes and their translation into proprietary data and patents is a form of enclosure and exclusion, an apparatus of biopolitics. In *Time Machine III*, the buildup of colonial infrastructure (e.g., roads and irrigation networks) and present-day megadams arrest terrestrial and aquatic ecologies.

Seizures cause delays and syncopations, or off-beat arrhythmias, with indeterminate consequences. Forced arrest, like a car crash, can also cause whiplash, the effects of which might render irreversible damage and slow, structural violence.

Incorporating is a mode of coordination in which an entity or practice becomes part of or a carrier for another's body. The parts remain distinct but the incorporated entity is in a relation of dependence on the incorporating entity.

In *Time Machine VI*, *hintawon* is an important example of Ifugao attunement across time and space, between plant growth, land use, land forms, and social practice. The annual cycles of human activities and feasts are incorporated into the cycle of rice

growth in terraced pond fields, which are incorporated into the patterns of multiple land forms and the longer cycles of shifting cultivation, which are themselves incorporated into astronomical and lunar cycles. Another example may be found in *Time Machine III*. Blood flukes are parasitic worms that become incorporated into different hosts: snails, humans, and other animals whose lives are also incorporated into agricultural and seasonal cycles along the Mekong river.

Sedimenting is a mode of coordination in which moving entities settle and come to rest in an unplanned, but not random order. It is a sequential layering of various events, settled one with or on top of another, that begin to form an aleatory strata, a habitable ground that bears material and semiotic traces of more-than-human activity.

The clay soil in Richvale, California in *Time Machine V* and the vast cordilleras of northern Philippines in *Time Machine VI* are more familiar examples of geological sedimentations that materialize as different landscapes. The excessive application of nitrogen fertilizers in *Time Machine I*, which changes the composition of soil and water, is another example. Seemingly counter-intuitive, but useful to consider through sedimentation are atmospheric formations. Examples are the accumulation of chlorofluorocarbons in *Time Machine II*, and excessive methane and carbon emissions from commercial agricultural fields since the Green Revolution in *Time Machine I*. These sedimentations matter a great deal; they situate and constrain life as we know it.

Again, these modes of coordination represent a partial list based on my research on rice. Time machines offer an experimental analytic for seeing their characteristics, interrelations, and effects more clearly.

How A Time Machine Appears

Articulating a time machine calls for a formal inventiveness: a critical-creative form of reading and writing. Historical effects do not necessarily unfold within the same chronological sequence, transition in a single step, or manifest completely within a time span that is congruent to research and analysis. To follow the specificities of each type of rice is to wander through a complex and contingent tangle of life ways, histories, and geographies. Each time machine appears here through an experimental piece of narrative prose that attempts to model a plurality of historical effects/entities and the coordinations that ensue. I make the entities distinct for analytical clarity; it enables me to disentangle different kinds of timing, and describe how they become meaningful and eventful as they relate across multiple scales.

I use a formalism to make these distinctions and articulations: each time machine begins with a type of rice and then proceeds to identify specific entities whose varied kinds of timing contribute to and co-order a conjuncture, for better or worse. For example, in *Time Machine I* on miracle rice, the entities are introduced one at a time, gradually showing how they co-constitute: I begin with grass, then the breeding of IR36, the production of synthetic nitrogen, and the unintended flourishing of plant

hopper and virus. Other time machines are constituted similarly, with sections devoted to their significant entities. I do not impose a hierarchy on the entities, their scales, or their effects. The molecular and local is always and already global. Existence is always and already historical and emergent, an entanglement of possibilities. I focus on clarifying the characteristics of each and showing how the conjuncture is enacted.

The formalism I use is not a list of entities or a chronicle of dates. I develop an experimental narrative through two analytical lenses: I offer (1) discrepant but interrelated historical intervals, and posit which forces play decisive roles in how a conjuncture is made and unmade, when seen through (2) temporal figures.

Historical Intervals

The articulation of intervals experiments with an alternate approach to historical periodization and time reckoning which are primarily delineated by human activities or technological developments that are arranged chronologically. I follow six different types of rice that live in six different landscapes to understand a contemporary condition. All six exist today; they co-constitute a dynamic presencing. To situate them relationally, I use intervals that offer multiple points of entry and conceptual frames of reference that follow the social dynamics, rather than indexical markers of calendar dates that impose a single chronological order onto incommensurable and incongruent practices.

The intervals appear as the first term in the title of each time machine. I summarize them below and italicize the name of the interval. They are analytical lenses that grow out of following more-than-human entanglements:

— *a green revolution* becomes visible through a conjuncture of miracle rice, nitrogen fertilizers, brown plant hoppers, grassy stunt virus, rice research institutes, in Southeast Asia

— *an imagined Doomsday* through a conjuncture of frozen seeds, refrigeration, heroism, transnational institutes, corporations, in Svalbard, Norway

— *the annual monsoon* through a conjuncture of floating rice, rainfall, rivers, giant catfish, water hyacinth, snails, blood flukes, colonial infrastructure, megadams, along the Mekong River

— *1980* as a conjuncture of rice genome mapping, automated sequencers, software, agribusiness patents, humanitarian licenses, databases, corporate philanthropy, in multinational capitalist formations

— *a century* as a conjuncture of irrigated rice, organic farmers, earthen dams, federal bureaus, aliens, weeds, migrant workers, in California

— *hintawon*, an agricultural cycle as a conjuncture of Ifugao rice, ethnobotanical studies, pond fields, swidden woodlots, earthworms, in the Philippine cordilleras

Temporal Figures

In my preface, I ask: what might the world look like if we read and reread its workings through specificities of rice *as* socialities between various companion

species? Learning how to recognize rice as many modes of coordination renders a very different world. It changes who we regard as "we" and how "we" becomes thinkable and workable. It involves re-imagining and remaking our understanding of history, agency, and language.

While a historical interval attempts to trace the contours of a time machine, a corresponding temporal figure attempts to diagram its structuring logic. The temporal figure functions as an analytical lens for specifying which ensemble or configuration of capacities drives change and become significant, when.

In the time machines, I define six temporal figures: an unintended race, logics of undo and forever, oscillation, contraction, telos, and recursion. They appear as the third term in the title of each time machine and are defined in greater depth throughout Part One. Considered together, they offer units of analysis for rendering visible a contingent and emergent "we" from entities that are generally studied separately or through different lenses. They widen a view from human action to multispecies coordinations, while attempting to establish how species and landscapes implicate each other through their situated and incommensurable capacities, and thus structure a dynamic contemporary field. "We" are composed through an emergent polyphony of historical trajectories and differential capacities to relate through timing. "We" are not only composed through human inventions.

Temporal figures reconsider how a more-than-human commons is coordinated, layered, and transformed. In narrative terms, they rewrite the possible cast of characters and open up multiple plots to divergent speakers, actors, and sensible movements. In machinic terms, they reconfigure the relations between historical effects and open up critical understandings of their emergent capacities to articulate continuity and change, life and death, settlement and mobility.

Toward Machinic Ends

I opened this work by describing it as a story told through the cultivation of rice. The manifest story, or what happens in each chapter, situates us in rather dismal anthropogenic catastrophes. For centuries, agriculture has entangled biological, chemical, and geological forces, converting sunlight into energy, making and unmaking multiple ways of life. Since the mid-twentieth century, the cultivation of rice has been industrialized and commodified to such an extent that most of its energies now sustain half of the world's human population, at great cost to all others. Today, multinational consortiums and technoscientific research programs support the production of commercial rice in over 130 countries. Ecological relations tied to the earth are increasingly alienated and subsumed by economic valuations and logics tied to profit and the privileges of a few. Rice seems to have become an industrial machine whose sole purpose is to deliver the greatest number of calories for human subsistence and national security. Rice fields are sites articulated by great violence and overwhelming creativities, with many unintended effects. Irreversible and

uncontrollable transformations at almost every scale tell us that attending to the complex puzzles of who and what, in fact, makes and unmakes *anthropos* is no longer optional.

One scholarly task of a machinist (the one that I undertake with this dissertation) lies in finding significant modes of coordination within these material-semiotic practices, and articulating the more-than-human capacities that structure and effect how they work, break down, or emerge relentlessly. But, toward what ends should such a task be pursued? What makes the conception of time machines grounded by rice agroecologies worthwhile, for whom, within this present moment named the Anthropocene?

There is an urgent political task in defining the relations between words and worlds; in introducing new figures and inventing alternate approaches to describe historical materialities as ways of being and belonging that decenter the human; and, in demonstrating the profound violence of equating temporality with the exclusive and forward march toward a homogeneous modernity. Whether time machines, in practice, contribute to rendering an alternate commons, a world radically otherwise, remains to be seen.

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LIST OF SUPPLEMENTAL FILES

Considering Rice (Ifugao Terraces), 2010
<http://elainegan.com/riceRaw.html>

Rice Child (Stirrings), 2011 / 2014
<http://elainegan.com/riceDarc.html>

Time Machines, 2016
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