THE FOUR HORSEMEN OF THE ECOPOCALYPSE: THE AGRICULTURAL ECOLOGY OF CHINA'S GREAT LEAP FORWARD

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Abstract: China's Great Leap Forward of 1958-60, an attempt to increase agricultural production through increased labor inputs, resulted in the greatest famine in world history from 1959-1961. Most histories emphasize the political mistakes of this period, which were disastrous. But to understand how the political mistakes led to the famine, here I concentrate on the ecosystem mismanagement that led to drastic drops in food production. To explain these effects, I invoke the "Four Horsemen of the Ecopocalypse": Over-emphasis on single variables, cross-scale mismatches, top-down panaceas, and ignorance of system feedbacks, all of which eliminated the resilience of agro-ecosystems to both internal contradictions and external disturbances.

Keywords: China, Great Leap Forward, Mismanagement, Feedbacks, Famine.

History has passed on, but the profound lessons and experiences it has left us deserve to be etched into our memory.

Li Chunfeng, "Prelude to the 'Great Leap Forward'"

In summer 1957, Mao Zedong grew impatient. His call for open discussion of policy, expressed in the slogan "A hundred flowers bloom together; a hundred philosophies compete for fame" had resulted in criticism far more vehement than he had been prepared for (MacFarquhar 1974: 261-317), and his plans for national development through revolution were stalling. In food

production, as in many areas, China had made modest progress since Mao had founded the People's Republic in 1949 (Nongye Bu 2009: 14), but the population was expanding rapidly (Bannister 1987: 79-82), and gains in food production could barely keep up, let alone provide the surplus needed for industrialization following the Stalinist model. Mao thus gave his enthusiastic support to a series of grand transformations of the ecological system that led to the most destructive famine in world history, resulting in between 20 and 40 million deaths.

Much has been written about the politics and the human tragedy of the Great Leap Forward, as these attempts at grand transformations became known (Becker 1996; Smil 1999; Yang 2007; Dikötter 2010), but less about the ecological effects of this developmental strategy. Ecologically, the Great Leap continued and intensified many of the same strategies that had previously been moderately successful in the early and mid '50s: they had increased both the productivity and the resilience of most Chinese agro-ecosystems. But beginning in late 1957 Mao and his fellow Chinese Communist Party (CCP) leaders made four kinds of crucial mistakes, the “four horsemen” that resulted in ecosystem collapse.¹ First, they took the previously successful strategy of maximizing labor input in agriculture to such an extreme that short term gains in productivity were accompanied by drastic declines in resilience [Figure 1]. Second, they created cross-scale mismatches, applying policies and programs at inappropriate scales, causing waste, inefficiency, and futile expenditures of labor. Third, they imposed panacea solutions on local problems, resulting in ineffective and counterproductive measures. Finally, they eliminated the crucial information feedback mechanisms that would have allowed them to recognize their mistakes and adjust their policies. They thus made possible the disastrous collapse, the “ecopocalypse,” that was the Great Famine. I briefly introduce these four system effects below, before turning to a narrative of how they were responsible for ecosystem collapse and subsequent famine.²

The Four Horsemen

¹ Ben Fitzhugh reminds me that I am not the first to use the “four horsemen” motif to describe ecosystem disasters; William Ruddiman (2005) uses this figure to describe the role of the original biblical horsemen—war, pestilence, famine, and death—in the probable decline of greenhouse gas emissions worldwide in the early Middle Ages.

² The present article deals only with “China Proper,” the area mostly in the east and south of the People's Republic, inhabited mostly by Han Chinese and possessing a millennia-long history of intensive agrarian cultivation centered around cereal grains. The Great Leap also affected the ecologies of pastoral areas in China's north and northwest and of upland extensive agro-silvio-pastoralism in the southwest and south, but they are outside the scope of this analysis.

The First Horseman: Maximization of a single variable. If we define resilience as the ability of a social-ecological system to withstand disturbances or shocks (Holling and Gunderson 2002: 27), in agro-ecosystems at low levels of intensification, building infrastructure and adopting technologies that increase productivity can also increase resilience of a system. As an example, replacing steeply sloping fields with terraces, if implemented correctly, can both increase production and buffer against erosion (Cohen 2016:148, Muscalino 2019: 156). However, when people manage an ecosystem to maximize one variable (in this case, grain output) at the expense of all others, the system loses resilience to both outside disturbances and increasing strains within the system (Walker and Salt 2006: 5-7).

Figure 1: The curvilinear relationship between resilience and intensification of a single variable, in this case labor input.

As Marxists of a certain stripe, Mao and his followers believed that material progress was dependent on changes in the mode of production that would liberate the potential of human labor, previously fettered by exploitative elites (Kung, Wu, and Wu 2012: 483). At the same time, leaders were committed to Stalin's model of development through giving priority to heavy industry, dedicating almost all available capital to factories and industrial infrastructure (Naughton 2007: 55-59). Since they still needed to boost food production, meaning primarily staple grains, liberating the potential of labor became an even more important consideration.

The strategy of increasing labor inputs and efficiency had worked reasonably well earlier, when it was undertaken in moderation. Land reform in the early '50s and collectivization in the middle of the decade had redistributed human and animal labor and may have made them more efficient—they certainly enabled two major changes in the application of agricultural technology: constructing waterworks in the North and increasing the double-cropped area in the South (Perkins 1974: 56). At the same time, most of these changes also increased local ecosystem resilience to certain disturbances. Reservoirs, when properly constructed, allowed farmers to allocate water more efficiently, storing it when there was too much to use or when it would otherwise have flooded fields, and using stored water when they needed extra. Resilience thus increased to both too much rain and too little. Canals had similar effects, transporting water away from where it was excessive and bringing water to places that lacked it. Double cropping spread the risk from weather disturbances between early and late crops. Collectivization spread risk among households.

Despite these improvements, the modest gains they achieved fell far short of solving China's developmental problems or its food problems. *Per capita* staple crop production had increased modestly, from 288 kg in 1952 to 308 kg in 1957 (Nongye Bu 2009: 14), but output was barely staying ahead of population growth, and population was not going to slow down in the absence of a major disaster. There was hardly any of the surplus agricultural product that the leadership had hoped to use to pay for the industrialization that would, in turn, allow agriculture to really modernize. And more importantly, any gains from collectivizing household agriculture, constructing small irrigation projects, and double-cropping seemed to have been exhausted. Still reluctant to invest capital in agriculture, the regime intensified labor reallocation and increased the number and scale of major infrastructure projects. Thus the Great Leap Forward.

The Great Leap Forward was thus born of the conviction that more of the same was better. Collectivization and mobilization in the early years were but forerunners of much greater things to come; higher-scale collectivization and mobilization would enable accelerated increases in labor productivity and thus in agricultural output. Great Leap Forward slogans like *ren you duoda dan, di you duoda chan* (As big as people's courage is, so big will be the product of the land) reflect this faith in the boundless possibilities of human labor. And in fact, it worked at first. Further intensification of labor inputs created record harvests in 1958 (Dikötter 2010: 132), but exhausted soil, water, and human energy, and also made agricultural production dependent

on shoddy infrastructure and impossible-to-maintain labor inputs. This led to rapidly declining harvests in 1959 and 1960, until there was little left to eat (ibid.).

The Second Horseman: Cross-scale mismatches: It is a basic principle of environmental management and ecosystem science generally that things do not work the same at all scales (Levin 1992), and that management at an inappropriate scale can lead to “cross-scale mismatches,” which “occur when the scale of environmental variation and the scale of the social organization responsible for management are aligned in such a way that one or more functions of the social-ecological system are disrupted, inefficiencies occur, and/or important components of the system are lost” (Cumming, Cumming, and Redman. 2006: 3). Two prominent instances of management at inappropriate scales helped lead to the collapses of the Great Leap. First, at more local scales, collectivizing farm labor and redistributing income among a few tens of households, as the CCP did between 1953 and 1957, resulted in greater efficiencies and increased production, as set out above. Beginning in late 1957 and especially after summer 1958, however, production, consumption, and management were collectivized at a scale of thousands of households, resulting in waste, inefficiency, and loss of an important ideational component of the system, namely the incentive to conserve. Second, at grander scales, techniques of production that might have worked in a single village in North China, for example, were unsuited to the South—a policy that might have been ecologically appropriate at a local scale was mismatched with the national scale at which the regime insisted people apply it.

The Third Horseman: Top-down management and panacea solutions. Panacea solutions are closely related to scale mismatches. Top down, or command-and-control environmental management leads to “unforeseen consequences for both natural ecosystems and human welfare in the form of collapsing resources, social and economic strife, and losses of biological diversity” (Holling and Meffe 1996: 328). Modernizing regimes (Scott 2018), such as the CCP’s, are particularly prone to impose panaceas.³ Such management often leads to the “panacea problem,”

³ The Great Leap, however, involved more than just a “high modernist” ambition to control and regulate the natural environment. The Chinese Communists, to be sure, had this sort of ambition, but they pursued it from the beginning of their regime in 1949 and continue to pursue it today. The Great Leap involved a paradoxical combination of this high modernist scientific control agenda with extreme voluntarism and reliance on folk wisdom, combined with extreme political radicalism. Mere high modernism was literally not the half of it—more like a third.

in which “a government may fail by homogenizing the diversity of contexts to which it applies its policies and management practices” (Ostrom and Cox 2010: 2).

In prescribing and imposing the programs of labor mobilization that characterized the Great Leap Forward, the CCP leadership took on the role of ecosystem managers, dictating just how farmers and rural laborers were to treat the agro-ecosystems they worked in, including both cropland itself and the waterworks that supplied and drained it. They did so based on the aforementioned set of principles involving human labor’s inexhaustibility (in two senses—both infinite potential and insusceptibility to fatigue), and imposed solutions without regard to local conditions, in the words of Holling and Meffe, “becom[ing] isolated from the managed systems and inflexible in structure” (1996: 328). Programs that might have worked at another time, or that would work in one place, or worked as long as they did not emphasize one variable to the exclusion of all others, were imposed at all times, in all places, and to maximal degrees. When farmers were required to use agricultural equipment designed for broad arid lands in Soviet Central Asia rather than for the small, muddy rice fields of South China, those rice farmers became victims of a panacea solution (Jin 2011).

The Fourth Horseman: Disruption of feedbacks. As complex adaptive systems, social-ecological systems depend for their regulation on balancing feedbacks⁴ (Meadows 2008: 27-34) of information, which travel through both biophysical and social paths within a system. If something goes awry, this information should lead managers to implement a corrective or balancing reaction. However, during the Great Leap, top-down management and its propensity to impose panaceas led to two mechanisms that blocked the possibility of balancing feedback about how well or poorly the logics of “more is better” and “no limits to the productivity of liberated labor” were actually working on (or in) the ground. Sometimes information about problems never traveled to the central managers, because lower level leaders were eager to ingratiate themselves with higher levels or afraid of being accused of counterrevolutionary tendencies if they doubted the effectiveness of Leap programs (Shapiro 2001: 79; Bramall 2011). When

⁴ Systems theorists have conventionally called these “negative feedback” in the sense that a stimulus provokes a response in the opposite (negative) direction from the original stimulus. However, “negative feedback” in our popular discourse has come to mean “adverse criticism,” so the term “balancing feedback” is more intuitive, and I adopt it here. Similarly, the systems term “positive feedback” does not mean “praise,” but rather a response in the same (positive) direction of the stimulus, leading to a vicious (or sometimes “virtuous”) circle. So again I adopt Meadows’s corresponding term, “reinforcing feedback” [Meadows 2008: 27-34].

information did reach the center, leaders often interpreted it not as a warning about things going wrong, but rather as an indication that things had not gone far enough. Hence the opportunity to correct adverse results of Leap policies was stymied, and the center often instructed local leaders to “double down” on the destructive policies, thus bringing about recurring cycles of reinforcing feedback, intensifying the measures that were driving ecosystem degradation and collapse at the local level.

Prelude: Water projects in fall and winter of 1957-58

The Great Leap Forward did not start suddenly. In addition to being an extension of the early- and mid-‘50s campaigns for collectivization and waterworks construction, it was an element of a general “left turn” in CCP policy that took place after the failure of Mao’s relatively liberal policies in 1956-57. As Mao turned against his liberal critics in the Anti-Rightist Campaign and began to take a more militant line in foreign policy, intensification of agricultural labor was also beginning.

In 1957, harvests were poor: despite the efforts of the Socialist High Tide in 1954-55, irrigated area had only expanded by about 11%, and the area sown to staples had actually diminished from 1956 to 1957. About a quarter of the total agricultural land area had been affected by floods, and as a result, it was estimated that perhaps 6% of the anticipated grain harvest for 1957 was lost to floods and droughts (Wu Zhijun 2007: 12). In addition to endangering the already precarious food supply, disappointing harvests hampered the efforts to squeeze agriculture to capitalize heavy industry. All the signs, political and economic, pointed to continuing the strategy of “replacing capital with labor” (*yi gong dai zhang* 以工代商), congruent with the leaders’ Marxist ideas about labor, as a way to increase harvests without investing much money in agriculture. Labor mobilizations previously undertaken to control the Yellow, Huai, and other rivers on the North China Plain offered a possible solution, and in September 1957, the Party Center announced the “Campaign to Build Agricultural Water Conservancy” (*xingxiu nongtian shuili jianshe yundong* 兴修农田水利建设运动). From November 1957 through January and February 1958, armies of rural people, even more massive than before, headed out to tame the waters.

One slogan of the campaign was the “three primarys”: Primarily storage, primarily small scale, primarily managed by the cooperatives (*yi xu weizhu, yi xiaoxing weizhu, yi sheban weizhu* 以蓄为主, 以小型为主, 以社办为主) (Li Chunfeng 2010: 114), but what the projects lacked in size they made up for in number and total volume. Villagers and sent-down cadres spent many weeks in the fields, carrying buckets of earth on the ends of carrying-poles. By January 1958, 100 million villagers had taken part in the effort, putting in an estimated 13 billion days of work (ibid.); the 7 million people who took part in Hubei, for example, were about half the adult labor force of the whole province, and reportedly built 700,235 [!] water projects, 563,223 of them for irrigation, 49,902 for drainage, and 92 for reclamation by diking (Wang Ruifang 2008: 124).

Reports written in the spring of 1958 were ecstatic about the immensity and significance of the results. Manual labor had moved 25 billion cubic meters of earth and stone, which if it had been used to build a road a meter thick and 66 meters wide, would stretch from the earth to the moon (Li Chunfeng 2010: 114).⁵ As a result, total sown area could be expanded by about 4%; irrigated area could be expanded by about a fifth of China’s total farmland beyond its previous extent, irrigation could be improved on a further 8% of agricultural land, and waterlogging problems could be solved on 11% of low-lying land. A further 6.7 Mha of poor land could now be improved, and trees could be planted on 16 Mha of previously unforested land, contributing to the control of erosion on **1.6 million km²**, around 16% of China’s *total* (not just cultivated) area (ibid.: 123-24). Fu Zuoyi, the vice-premier in charge of agriculture, exulted that it had taken 4,000 years for Chinese civilization to bring 15 Mha under irrigation; in a mere four months, the campaign had doubled that amount (ibid.). China would now be able to solve its food problem once and for all, and industrialize rapidly to boot.

There were, however, problems. Li Chunfeng’s summary illustrates all four horsemen of environmental mismanagement, pointed out here in italicized text in brackets:

⁵ I ran the numbers. If the 25 billion m³ is accurate, the road would indeed stretch to the moon. If there were actually 100 million people working, they would have had to move 250 m³ of earth each. From personal experience, I found it possible at age 70 to move 3-5 m³ of earth in a day (albeit for no more than two days in a row). If most workers were well under 70, and they worked 60 days apiece at this pace, I guess they could have done it. Or this may be one of the first instances of “rocket” statistics that culminated in reported grain yields of 10,000 *jin* per *mu*, as reported in 1958. See below.

At the same time, because there existed a psychology of blindly pursuing speed and anxiously looking for results [*disrupting feedbacks*], everywhere [people] did water conservancy without paying attention to local conditions [*top-down, panacea solutions*], resulting in approaches to water conservancy projects that lacked scientific management or proper coordination. This led to simplistic and crude water conservancy equipment, impossible quality control, and water control projects that fundamentally could not achieve the utility they should have had. There were some places that just stressed “storage” and did not stress “drainage,” [*maximizing single variables*] destroying the previously existing surface water network and compounding waterlogging and salinization [*disrupting feedbacks*]. In addition, [the projects] used a large amount of arable land and consumed immense amounts of labor, materials, and money [*cross-scale mismatches*], influenced agricultural outputs, harmed the activist spirit of the masses [*disrupting feedbacks*], and brought about unnecessary waste and damage [Li Chunfang 2010: 114]

These were not the only instances of environmental management problems. Mismatches across spatial scales occurred when larger scale projects inundated villages and required villagers to relocate, and mismatches across temporal scales occurred when many projects did not include plans for future maintenance. Maximizing single variables happened as lack of attention to worker safety caused unnecessary deaths and injuries, and when mobilizing everyone to go to the construction sites interrupted non-agricultural occupations, an important source of income for poor families during the slack season. Panacea solutions were rife, as projects were copied from places where they were appropriate to places where they were not, causing ecosystem damage and ruining drainage systems (Wang Ruifang 2008: 124). Nevertheless, feedbacks were disrupted as the enthusiasm of high officials and fear of being labeled Rightist meant that these difficulties went unacknowledged, preventing local officials and farmers from correcting some of the most disastrous mistakes (ibid).

At the same time, some projects did work despite all these problems, and the experience of mass mobilization led to reinforcing feedback as project enthusiasts began announcing that labor mobilization could lead to a “leap forward (跃进 *yuejin*)” in agricultural production. In fact, there is good reason to count the water conservancy campaign less as a prelude and more as a first act of the tragicomic opera that was the Great Leap Forward (ibid.; Li Chunfang 2010: 113). More water conservancy efforts were to follow in the next two off-seasons in the North, complemented by similar efforts in other parts of the country. Indeed, the winter of 1957-58 was the overture to the drama of the world’s greatest famine, one whose intertwining themes of maximizing a single goal, cross-scale mismatches, top-down panacea solutions, and interrupted feedback combined to obliterate the short-term resilience of local agro-ecosystems.

The Great Leap Itself

The CCP leadership did learn lessons from the Water Conservancy Campaign, but not the ones that speak to us today. Instead, they learned that ideological fervor and labor mobilization could lead to monumental changes in ability to exploit natural resources, a lesson that they quickly extended beyond water to land itself and to the crops that grew on it. If temporary massive collective labor reorganization could mobilize people to construct hundreds of thousands of water projects and double China’s irrigated area, they could pursue this strategy further. They would make the large collectives permanent and regiment (literally) labor more than ever before, creating a pool of surplus agricultural laborers who could be mobilized to undertake ever larger and more ambitious programs of production increase. In a few years they would transform a millennia-old landscape into a modernist paradise. And because the Water Conservancy Campaign had taken place in a political atmosphere of relying on the voluntarist philosophy and strategy, equally momentous social changes would and could accompany the rewriting of the landscape.

These major social changes were of two kinds. First, collectives were enlarged permanently; several former high-level cooperatives merged into one huge collective, usually involving either a standard market town and all its surrounding villages, or even

more than one standard marketing area (Skinner 1965: 382-399), with a population in the tens of thousands. Over the course of summer 1958, these came to be called People's Communes (*renmin gongshe* 人民公社). Second and perhaps more importantly, communes were not only an order of magnitude larger than the cooperatives they had absorbed; they were also much more communal. Previously existing "private plots"⁶ were abolished; all the land, domestic animals, and agricultural implements of the entire commune came under collective ownership and management, and income was distributed throughout the large area. Even more radically, the household was abolished as an economic unit. People ate in the collective canteens (*gonggong shitang* 公共食堂), and ideally at least, collective nurseries took care of children while their parents were at work. The most radical communes in a few areas even razed private housing and built collective dormitories (Wei 1998: 138; Friedman, Pickowicz, and Selden 1990: 217; Yang 2008:88). In this system, the Party could mobilize not only the mostly male labor that had built the dams, dikes, and ditches in the previous winter, but also the female labor that had been tied up in housework or handicrafts, producing "nothing of value," that is to say, nothing considered to be worth any work points (credits toward a family share of the collective harvest).⁷

All this radical reorganization of the landscapes and the people who lived on them was directed toward establishing communism (with a small c), a system in which, in the words of Marx's *Critique of the Gotha Program* (1875), each would contribute according to ability and receive compensation according to need. By effectively abolishing the household as an economic unit, the promise of women's liberation would finally be realized—women would be liberated from the mindless drudgery of domestic labor and from the tyranny of fathers and husbands (Manning 2005). And most importantly, communism would be possible because there would be plenty to go around. Agricultural surpluses would feed industry, peasants would become workers, China would overtake the United Kingdom in industrial production in three years and catch up with the United

⁶ In earlier stages of collectivization, a small percentage of land was left to individual households to farm independently. In Chinese these were called *ziliu di*, or "land left to [families] themselves," but the English-language literature on Chinese collective agriculture developed a conventional translation as "private plots."

⁷ Women's work in collective settings—such as canteens or childcare centers—as opposed to housework, was awarded a few points, but not nearly as many as would be awarded for agricultural work (Brown 2017: 45-46).

States in 15 or less. Little initial capital would be necessary—labor would create capital at the same time it transformed the agricultural landscape.

There was an undeniable logic to this plan, but it was a kind of hyper-logic that led to neglect of both empirical reality and on-the-ground observation. What this logic failed to consider was the biology of plants, the psychology of people, and the limits on both the productivity and the resilience of ecosystems, things that farmers had known at least something about all along. In forgetting these natural limits, policymakers and local leaders—inadvertently for sure—unleashed the Four Horsemen of ecosystem mismanagement, bringing about two kinds of disastrous ecosystem effects: pushing single variables beyond levels where they were susceptible to balancing feedbacks, and direct disruption of ecosystem flows and feedbacks.

Emphasizing Single Variables: Deep tilling,⁸ close planting, and the strange case of the double-wheeled, double-bladed plow.

Henan Province called out great armies of laborers numbering in the millions to eat and sleep in the fields, carrying out deep tilling of the earth day and night in a huge way. Xiayi County took deep tilling particularly seriously, mobilizing 200,000 laborers, operating entirely in a military fashion, organized into brigades, battalions, and companies, divided among 60 great battlefields...attacking to turn over the earth day and night. The masses in Henan adopted the slogan, “harvest a plot, turn over a plot, till deeply plot by plot” [Zhong 2011: 16].

Deep tilling, close planting, and promoting the double-wheeled, double-shared plow were drastic mistakes in ecosystem management that would only have happened as a result of the Four Horsemen: emphasizing a single variable (soil depth or crop density),

⁸ The terms *shen geng* 深耕 and *shen fan* 深翻 are conventionally translated as “deep plowing.” However, it is clear from local accounts that a lot of this deep turning over (深翻) was done with shovels and hoes as well as plows, so it seems that “deep tilling” is a better translation, because one can turn the soil over with either a plow or a shovel.

cross-scale mismatches (extreme collectivization), top-down management (the double-wheeled, double-shared plow) and especially disruption of system feedbacks (doubling down on programs after they had demonstrated the effect of the first three horsemen). Because leaders single-mindedly pursued goals of increases in grain, took no account of scale, were convinced that something that worked in one place would work everywhere, and were unwilling to recognize their own mistakes or take local criticism seriously, they imposed logically consistent programs beyond their empirical use, and thus crashed local agro-ecosystems all across the country.

Deep tilling. Like mass water conservancy projects, deep tilling and close planting (*shenfan mizhi* 深翻密植) did not start with the Great Leap Forward. As early as 1954, collective leader Ma Tongyi in Changge County, Henan, reported that his collective was able to increase wheat yields dramatically by tilling to a depth of a foot and a half. They first spread 60% of available manure on the surface, then turned over the fertile topsoil layer and piled it on one side, then dumped the remaining 40% of the manure on the underlying subsoil, breaking up clods and mixing the fertilizer in, then putting this layer on top, and working down layer-by-layer (ibid.).

This method came to the attention of Mao and other leaders, and the *People's Daily* published supportive editorials in May 1958 and again in September, when deep tilling became official policy. Several factors emerged to contribute to the kind of campaign carried out in Xiayi and eventually not just on the North China Plain, but all over the country. First, the labor was available. It was the beginning of the slack season in the North, but even in places where agriculture continued in the winter, the massive scale collectivization allowed military-style mobilization, and collectivization of household chores such as cooking and childcare meant women were also available to join the brigades for deep tilling and other work (Pietz 2015: 207), or to stay home and tend the fields while the men were out doing construction or deep-tilling (Ruf 1998: 104). Second, the spirit of the Great Leap Forward, embodied in such slogans as “Don’t be afraid of what you can’t do, only be afraid of what you can’t think (*bu pa zuobudao, jiu pa xiangbudao* 不怕做不到, 就怕想不到), along with the recent attacks on people who thought more realistically, meant that it was difficult to point out empirical limits on just

about anything, including soil fertility or the availability of labor. Third, because thinking and policy were not tied to local conditions, panacea prescriptions compelled leaders at all levels to try the same methods everywhere—what’s good for Changge County in Henan must be good for Meishan County in Sichuan (Ruf 1998: 201) or Dongguan County in the Pearl River delta (Chan, Madsen, and Unger 1984: 25). Fourth, even scientists were compelled to put out explanations for just how deep tilling worked to increase soil fertility. A conference held in Changge reported that

[Deep tilling] can increase the depth of the organic layer, adjust the water and air in the soil, increase the ability to hold water and nutrients, prevent desiccation and waterlogging, and improve the soil structure. Dead soil becomes live soil; bad soil becomes good soil. It is advantageous to the growth of the root structure of the crops, allowing them to sink deep roots, thus preventing lodging, crowding out weeds, and eliminating insect pests...[We need to] deep till all of the 1.6 billion *mu* [106 Mha, 80% or so of the country’s agricultural land] across the country that can be deep tilled. The depth should ordinarily be up to a foot and a half, but on bumper-yielding fields it should be two feet or more, and fertilizer should be applied down to the soil horizon [Zhong 2011: 15].

In North China in particular the deep tilling campaign went to extreme excess. An inspection team from the Northwest Agricultural College visited the campaign’s point of origin in Changge in July. They wrote a story featured in *People’s Daily* on the 27th, stating that it was possible, by tilling to a depth of *one and a half meters*, to increase sweet potato harvests to 20,000 *jin* per *mu*, double the maximum yield achieved in optimal conditions in the 2010s (Huobao 2014). By the fall, millions of farmers were deep-tilling all over the country, even in what would seem to have been impossible conditions:

By November, frozen ground in the North impeded the progress of deep tilling. In order to assure that deep tilling proceeded smoothly, and to fulfill their responsibilities, provinces in the North employed all sorts of

methods. For example, in Jilin a few areas used big picks, earth rammers, and other tools to turn over frozen earth, or used explosives to blow it up. Many places in Inner Mongolia used fires to warm the earth so they could continue to deep-till it [ibid.: 18].

Local propaganda in Xushui, Hebei stated that the campaign had reflected the “limitless wisdom and historically unprecedented diligence of the broad masses,” as over 75,000 people braved temperatures of -8 to -10°C to “go on the attack.” Their county slogan was “To change Winter to Spring, if our thought is not frozen, the land won’t be frozen,” (*bian dongtain wei chuntian, zhi yao xixiang budong, di jiu budong* 变冬天为春天，只要思想不冻，地就不冻, and the masses said that “Weather now follows policy” 天气现在都随着政策走). [Zhang and Guo 2008: 145]. By November, 680 Million Mu, about 30 percent of the agricultural land nationally, had been deep-tilled (ibid.: 17).

Close planting. By the same “more is better” logic, deep tilling went together with close planting. With the increased fertility supposedly achieved by tilling deep, farmers could plant many more wheat or cotton seeds, or rice seedlings, in a field than they had planted previously. In southern Fujian, “scientific farming” meant decreasing the space between rice seedlings from the traditional 15 centimeters to 7 centimeters, thus more than quadrupling the number of plants in a plot (Huang S. 1989: 60). In similar ecological conditions in the Pearl River Delta, “they pushed a system of planting called ‘Sky Full of Stars’ where a field would be so overplanted the seedlings starved each other out...the peasants knew it was useless, but there was simply no way to oppose anything, because the orders came from so high above” (Chan, Madsen, and Unger 1984: 25). In Meishan, Sichuan, farmers were instructed to plant up to 800,000 rice seedlings per *mu*, in effect spacing the clusters about 9 cm. apart (Ruf 1998: 201).

The double-wheeled, double-shared plow. The notorious double-wheeled, double-shared plow (*shuanglun shuanghua li* 双轮双铧犁) was yet another case of what Judith Shapiro (2001) has called “dogmatic uniformity,” taking something that had worked well enough at some particular place and some particular time, and imposing it as a panacea to be used uniformly everywhere, always. The plow in question was a Soviet model, originally designed for large-scale non-irrigated farming on the broad Russian plains and the Central Asian steppes, and very efficient and effective there. It was made entirely of steel, unlike traditional Chinese plows that

had no wheels and a single share or blade, with everything but the share made out of wood. Mao had admired it as early as 1950, and it was tried out in many places during the first five-year plan in between 1953 and 1957. In 1956 and 1957, China manufactured 3.5 million of these, not making more only because there was a shortage of steel. As with water projects and deep plowing (for which it was said to be suited), the Great Leap provided an ideal opportunity to use the plow universally, and the Party, though the *People's Daily*, aggressively promoted it, even in rice-growing regions such as Zhejiang and Hunan (Zhu and Hu 2009: 62). However, like other agricultural inputs tried during the Great Leap, it had its problems. In Wenzhou, southern Zhejiang, farmers found that it was too clumsy for many rice fields, too heavy for a single water buffalo to pull, and even with more than one animal pulling, it often got stuck in the mud. It was impossible to use in shallow or rocky soils. Sometimes, farmers complained, it plowed too deep, turning the fertile topsoil layer under, or the roots took up too much nitrogen, so that plants produced too much vegetative growth and fewer grains (Jin 2011). As a result, although some farmers tried to make use of it by turning it into a harvesting machine, in many places people just discarded the thing altogether (Zhu and Hu 2009: 62).

All these measures were supposed to contribute to a Leap Forward in agricultural outputs. Grain yields would multiply by a factor of ten or more, to as high as 35,000 *jin* per *mu* (262,000 kg/ha) for corn in Shandong or 10,000 *jin* per *mu* (75,000 kg/ha) for rice (Shapiro 2001: 76-80). Results were positive at first, but then crashed. 1958, the first year of the Leap, produced a bumper harvest of 200 Mt of staples, but in following years output went down, to around 170 Mt in 1959, and a disastrous, famine-inducing 140 Mt in 1960. Other agricultural products, including cotton and pigs, after increasing in the initial phases of the Leap, experienced similarly drastic declines from 1958 or 1959 on (Dikötter 2010: 139, 141). Combined with increased requisitions of grain by the state—some of them used to pay off loans from the Soviet Union—people starved all over the country; estimates range from 25 million to over 40 million excess deaths in 1959-61 (Becker 1998; Smil 1999; Yang 2008; Dikötter 2010). Not all this was due to direct ecosystem effects of the Four Horsemen. Authorities took grain from already hungry farmers to feed people in the cities. In many areas, believing that they had solved the grain problem once and for all, people planted less area to grain in 1959 than they had in 1958, contributing to the low overall harvest numbers. Social and political systems broke down. Still, ecological overreaching and neglect of system limits, spurred by political enthusiasm, was the

most important factor. In some places deep tilling ended up diminishing rather than enhancing soil fertility, and certainly crops planted at super high densities did not have enough nutrients or water—competing plants starved each other out. Instead of “The fertility of the land is as great as the courage of the people” (*ren you duo da dan, di you duo da chan* 人有多大胆，地有多大产), the hard ecological lesson learned from Great Leap overreaching was less catchy but more profound, something like “no matter how great the courage of the people, the earth still has its limits” (*ren you duo da dan, di rengren you xian* 人有多大胆，地仍然有限), or in less parallel terms, “the fertility of the land has limits, and the people’s courageous labor eventually produces diminishing returns.”

Disruption of Ecosystem Feedbacks: Dams, Dikes, Ditches, and Sparrows

The Four Horsemen also rode roughshod over the natural balancing feedbacks within the ecosystems themselves, resulting in interruption of the cycles of hydrology and predator-prey relations. This was evident in much of the continued waterworks construction as well as in the campaign to “Eliminate the Four Pests,” especially that quarter of it that applied to sparrows.

Water Projects Again. Water conservancy campaigns begun during the slack seasons of 1957-58 continued on a big scale for the next two winters, and also spread to the south of China. In Hubei the efforts were massive. Over two and a half million rural people were mobilized to build ten large reservoirs, along with twenty medium sized reservoirs and almost a thousand small ones. Sluices, canals, ponds, bridges and other waterworks used over 200 million m³ of earth, stone, and concrete. The *Hubei Daily* proclaimed that “The natural landscape of Hubei is beginning to undergo a fundamental transformation” (Zhang and Guo 2008: 143).

Sadly though, not all this landscape transformation worked out well, either locally or regionally. Zhang and Guo present a case from the Taihang mountains on the Hebei-Shanxi border, where a village with 62 adult laborers decided to build a reservoir with a storage capacity of 90,000m³, and by working day and night, sleeping and eating in the fields, they finished it in the space of a few months. However, it was not built to last, and its dam was almost totally collapsed after two years. In Funing County, a big rainstorm in July 1959 wiped out 20 recently-built small reservoirs (ibid.: 143-44).

Viewed at a larger scale,

The replumbing of the North China Plain created a host of soil problems, including waterlogging and soil alkalization/salinization. The construction of reservoirs and channels obstructed drainage. Pernicious salts and other minerals rose to the surface in saturated soils with devastating effects on soil fertility. By the early 1960s, one estimate calculated that two-thirds of irrigated land in North China was threatened by salinization due to poor drainage.” [Pietz 2015: 224]

Interrupting ecosystem flows also affected large-scale, high-tech, mechanized projects like the Sanmenxia Dam on the Yellow River. Planning for the dam had been proceeding with Soviet help since 1954; construction began in 1957 and continued through the Great Leap years until the planned first phase of construction was finished in early 1961. By the end of 1961, many problems were evident, mainly caused by maximizing hydropower and neglecting the importance of silt—underestimating both the amount of silt and the seriousness of the problems it would cause. The reservoir filled and expanded faster than expected because of all the silt on the bottom, and this caused unexpected increases in inundation of farmland, widening of the channel upstream near the confluence of the Wei (渭河) and Yellow Rivers, and backing up of the Wei River, in turn causing rising water tables and widespread salinization (Pietz 2015: 225; Shapiro 2001: 62-63). By early 1962, silt had already reduced the capacity of the reservoir by half. The saga continued well into the 1960s; to this day the dam has never worked as well as intended.

It would be simplistic to assume that all Great Leap waterworks construction led to degradation or disaster. Instead, we need to account for success or failure in terms of the degree to which the projects avoided the Four Horsemen. In some places, waterworks construction was not so disruptive, nor were the results as vulnerable or temporary. In the Chengdu Plain in Sichuan, the Dujiangyan irrigation system, a network of channels and ditches originally created in the 3rd century BCE, was still functioning at the time of the founding of the PRC, and the CCP engineers wasted no time mobilizing local people to enlarge it. They built the People’s Canal

(*Renmin Qu* 人民渠) in early 1953, and enlarged it in the winters of 1953-54 and 1954-55, almost doubling the area irrigated by the diverted waters of the Min River. In 1956, they mobilized over 30,000 people to build several branches of the East Wind Canal (*Dongfeng Qu* 东风渠), which extended irrigation to some of the hilly areas east of Chengdu that had previously had mostly dry farms. Work proceeded on both these systems during the Great Leap, apparently seamlessly continuing projects carried out in earlier years. By the end of 1958, the total area irrigated below Dujiangyan had expanded to 5.9 million *mu* (390,000 ha). Projects begun in late 1959 as the famine was worsening were temporarily halted, but they were completed after 1965, after the food supply had recovered (Shen 1979; Chen and Bao 1993: 222-234).

In other rice-growing regions, many projects were soundly constructed and contributed to agriculture long-term. Construction brigades in the Pearl River Delta built bridges, roads, and dikes (Siu 1989: 178). Lin Village in Fujian built a large reservoir that **inundated half** of its arable land but which was nonetheless welcomed because of increased yields on the remainder (Huang S. 1989: 66). Songjiang County in eastern Jiangsu dug a major irrigation canal and two major drainage ditches (P. Huang 1990: 222-23).

Like the enlargements of the Dujiangyan system, all of these smaller projects and thousands more built during the Great Leap are still functioning today, so it would be too easy for us to completely dismiss all water projects of the Great Leap as wasted time, labor, and suffering (Wang Ruifang 2008: 129). But if Walker and Salt's assertion that "...the more you optimize elements of a complex system of humans and nature for some specific goal, the more you diminish the system's resilience" (2006: 9) is not true in every single instance, it was certainly true for most of the failed projects of the Great Leap. When water projects only enlarged storage, and forgot about drainage, storage actually contributed to waterlogging and salinization. When people built small dams and weirs by cutting down forests and/or flooding farmland, they ended up with less land to farm, as well as erosion on the deforested areas. When Sanmenxia engineers blithely figured that the silt problem would take care of itself, they lost farmland to both inundation and salinization, and never generated much power. By contrast, projects that did succeed, from village ponds to the massive enlargement of the Dujiangyan irrigation area, did not overemphasize single variables in a complex ecological system, and did not apply panaceas top down, but rather adapted projects to local conditions.

Eliminating the Four Pests. Pests are of course a problem for farmers everywhere, as well as a public health menace, and since chemical pesticides were scarce in 1950s China, as early as 1955 central leaders set a goal of mobilizing labor to eliminate rats, mosquitoes, bedbugs, and sparrows. Of these, sparrows were thought to be the most harmful to agriculture, because they constantly pecked around piles of drying or stored grain, taking good food away from people. Like so many other Great Leap programs, the “eliminate the four pests” campaign began as a local experiment, in this case also in Xushui, Hebei, but became a nationwide panacea with the high tide of communization, promoted by an editorial in the *Guangming Daily* in September 1958. All over the country, sparrow-killing teams, often composed of elementary and middle school students, mobilized for the slaughter. In Hebei, these children were reported to have killed exactly 234,856 sparrows, often by exploding firecrackers and banging on drums, gongs, and pans to scare the sparrows into flying around frantically until they fell exhausted out of the sky and the children could move in for the kill. Only later did scientific research show that while sparrows did consume some grain, the mainstay of their diet was insects, including plant pests, and with the sparrows gone, the bugs flourished (Zhang and Guo 2008: 145). Again, disrupting the flows within an ecosystem, in this case, the relationships between predators (sparrows) and prey (insect pests) led to disastrous results that were the opposite of what was intended (Zhang and Guo 2008: 144-45).

Results of both excess inputs—deep plowing, close planting, new implements, houses used for fertilizer—and cyclic disruptions—trapping water and killing sparrows—were horrific. Food shortages already began in the spring season of 1959, when “the green did not meet the yellow” (*qing huang bujie* 青黄不接)—the new harvest did not come until after the old grain was exhausted, undoubtedly due partly to waste, increased requisitions, and perhaps overeating when the canteens served unlimited food. The Four Horsemen had brought about reinforcing feedbacks to their own initial mistakes, leading to ecosystem disruption, reduced planting area, and eventual demoralization or exhaustion. Thus the decline in harvests from 1958 to 1959 and the further decline in 1960, leading to famine. The story of the human suffering has been told exhaustively elsewhere (Becker 1996; Yang 2008; Dikötter 2010) and there is no need to repeat it here.

Figures 2 and 3 use the specific instance of water projects to illustrate the way that the first three Horsemen—maximizing single variables, inattention to scale, and panacea solutions

that took no account of local variation--led to the fourth Horseman—disruption of balancing feedbacks and promotion of reinforcing feedbacks⁹:

Figure 2: Great Leap Forward thinking about water conservancy

The linear thinking of the Great Leap Forward, propelled by the first three Horsemen, does not consider feedbacks at all, but assumes that there is a linear, positive, causal relationship between labor inputs that capture water, water used to irrigate fields, and agricultural yields. However, the reality turned out to be more complex, as Figure 3 illustrates:

⁹ There is a parallel to the classical horsemen of the apocalypse here: war, famine, and pestilence lead to death, in the same way that maximizing single variables, cross-scale mismatches, and panacea solutions led to disruption of ecosystem feedbacks, which of course was the proximate cause of famine and death in the Great Leap.

Figure 3. The empirical results of water conservancy in the Great Leap Forward. Solid arrows indicate intended, desirable consequences of water projects; dashed arrows indicate unintended feedbacks, which planners ignored with their Four Horsemen approach.

Maximizing single goals and ignoring feedbacks led to the triumph of voluntarist enthusiasm and hyper-logic over rationalist science—including ecological science—and often over common sense, unleashing the Four Horsemen.

Summing Up

Looking back through the famine, waste, and ecological devastation, there really was a logic to the Great Leap Forward. In fact, Great Leap thinking was, in one way, the ultimate triumph of pure deductive logic over empirical reality. There were ways to raise

agricultural production by expanding irrigation, and there were perhaps ways to enhance soil fertility without adding chemical fertilizers. Pests were a problem (although not sparrows specifically). The real problem lay in the fact that thinking in terms of the Four Horsemen prevented leaders from recognizing that the ecosystem had its own limits, and prevented farmers, who knew intimately about these limits, from providing effective feedback information to leaders. Thus limits were almost totally ignored. Because tilling a foot deep might improve the penetrability of soil and give plants access to more nutrients, it followed only in the most hyper-logical, non-empirical way that tilling three feet or five feet deep would be even better. Because there was water to capture for irrigation, it followed only in the most hyper-logical, non-empirical way that capturing *all* the water in the ecosystem would allow irrigation on even more land. Because there was definitely labor available during the winter offseason in North China, freeing people to build irrigation works and other infrastructure, it followed in only the most hyper-logical, non-empirical way that people all over the country could work 24/7. Because collectivization could rationalize labor allocation, it followed only in the most hyper-logical, non-empirical way that building enormous collectives would make labor allocation even more rational and efficient. But single-variable maximization, cross-scale mismatches, top-down panaceas, and disruption of feedbacks gave complete license to follow this hyper-logic and ignore what was happening in the fields and streams.

For many years after the Great Leap, Chinese official history blamed the Great Famine on “three years of natural disasters,” claiming that unprecedented acts of nature had cut agricultural production, already marginal, by almost a third. Later research by meteorological historians has revealed a more complex story. In 1959, the year of the first drastic drop in production, weather was better than average, but bad weather did come in 1960, the year of the worst harvests. Surprisingly though, the weather was even worse in 1961, when grain production picked up again (Swamy and Burki 1970: 51), leading to the end of the famine (Kueh 1984). The irony is that the Four Horsemen policy made China’s agro-ecosystems more vulnerable to the bad weather that did happen, showing us that there are natural phenomena but only human disasters. The Four Horsemen had obliterated the short-term resilience of China’s agro-ecosystems, and the farmers, who had contributed so much labor to the effort, paid the price.

Grain output per capita did not reach 1958 levels again until the 1970s. However, grain outputs did return; the agricultural ecology was vulnerable in the short-term to huge disturbances like that caused by the Four Horsemen, but in the longer term, the system reorganized and grew. There have been no further famines in China, and in the 21st century, food is available in cornucopian abundance and variety. Whether this abundance will last in the face of the current effort to build North American-style, large-scale agriculture (Doll, this issue) is a big question, but at a time scale of decades, it appears that China's agricultural ecology has been rather resilient after all.

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