INTENSIFICATION, RESILIENCE, AND DISASTER IN CHINESE HISTORY

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The Three Hard Years and the Absence of Natural Disasters

Between 1959 and 1961, somewhere between 20 and 45 million Chinese people died of starvation and of diseases related to malnutrition (Becker 1998, Yang 杨继绳 2007, Dikötter 2011). Agricultural production sank to only a little more than half of its 1957 and 1958 levels, massive numbers of people took to the roads to try to find food, fertility fell sharply as mortality and morbidity rose, local government and institutions were severely disrupted. Until recently, official discourse not only minimized the scale of this disaster, but attributed it to "nature," referring to the period of hardship as "the three years of natural disasters" (三年自然灾害). Occasionally it was also pointed out that the Soviet Union withdrew its teams of technical and scientific advisors at this time, causing China to negotiate the problems of industrialization and economic development on its own, but the main blame went to nature.

More recently, it has become possible to speak of this period more candidly, and shift the blame from natural events to mistaken policies undertaken as part of the Great Leap Forward (大跃进). Just which aspects of the Great Leap Forward are blamed varies from source to source: undue haste in trying to promote economic development; promotion of "unscientific" programs of development such as local steel manufacture and deep plowing and close planting; exploitative procurement of agricultural products to feed the urban population and pay off international debts; premature adoption of the Communist principle of "from each according to ability, to each according to need" resulting in waste of food; overworking of the populace to the point of exhaustion; a breakdown in the statistical reporting system that caused the leadership to think that agricultural production was greater than it was in fact, and so on.

All of these policy mistakes did in fact happen and are well-documented, and as proximate causes, it was undoubtedly a combination of some or all of these that led to the starvation, famine, and social disorganization of the "three hard years." But these factors are not unique to the Great Leap Forward and its aftermath. Rather they are an example, though admittedly an extreme one, of a process that has manifested itself throughout Chinese history and in fact world history, and continues to plague China as it industrializes, modernizes, and develops. This is the process of *maximizing or intensifying production at the expense of ecosystem resilience*. It is a process that can be seen in the broad sweep of Chinese history beginning as early as the Warring States period (Elvin 2004), but accelerating mightily in the Qing dynasty, and even faster in the People's Republic. The short period of the Great Leap Forward is its most obvious manifestation, but policies and practices both before the GLF, during the First Five-Year plan, set the stage for disaster, and during the 50 years since the end of the calamity, the emphasis on maximizing production and the concomitant inattention to resilience have continued. This has happened both during the period of socialist reconstruction under Mao's regime (Shapiro 2001), and most notably after the 1980s, during the period of rapid economic development. As a result of the continued emphasis on productivity and development, the ability of China's ecosystem to weather shocks and disturbances has been severely curtailed, as manifested in multiple small- and large-scale disasters.

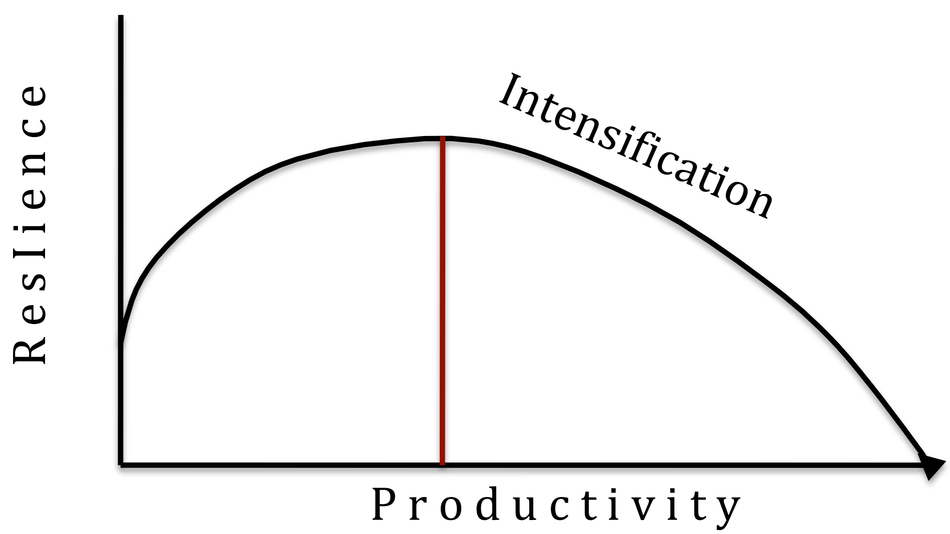
Intensification and Socio-ecosystem resilience

This paper is thus built around the idea that there is no such thing as a natural disaster (自然灾害), but that instead we must understand disasters as events of extreme human suffering that happen when a vulnerable socio-ecosystem is unable to absorb the effects of a disturbance that comes from outside the system. In order to understand this model of disasters, we need to review briefly some of the concepts embodied in it:

- Socio-ecosystem: I use this term to refer to interacting biophysical and human elements that are interrelated in a web of mutual influence (Abel 2007) . This concept forces us to recognize that there is no such thing as a human community or society apart from the natural endowments that it relies on for its livelihood, and that there is, on today's earth at least, no such thing as a natural system without considerable human influence. In classical Chinese terms, this reasoning requires us to discard the dangerous Maoist concept of 人定胜天 and revert to the older and wiser 天人合一. It is also important to recognize that socio-ecosystems occur at different and overlapping scales (Levin 1992 , Cumming et al. 2006), so that we can employ this concept at the scale of a village or local watershed, the economic catchment area of a major city, or even in some cases, like that of the Great Leap Forward, the area of China as a whole.
- Disturbance: A disturbance is simply an event that affects a socio-ecosystem that originates outside the system itself. Natural events such as rainstorms, droughts, insect plagues, or earthquakes are examples of disturbances, but so are military invasions, financial crises, and abrupt policy changes that originate from the national level. In the case of the Great Leap Forward, we can count as disturbances many of the policies enumerated above as disturbances that led to disaster in a system that was already more vulnerable.
- Resilience and vulnerability: Resilience can be defined as the capacity of a socio-ecosystem to absorb a disturbance and continue functioning (Holling 1973, Holling and Gunderson 2002, Walker and Salt 2006). If a natural or human event—a hurricane or a grain procurement policy—can affect a community without the community losing its function, then that event is not a disaster. So if a community has enough grain reserves to feed itself for a year after its crops have been ruined by a hurricane or drought, or after meeting the state's demands for taxes and compulsory deliveries, then the community is *resilient* to disturbance in the form of grain exactions. If, on the other hand, such a disturbance causes massive starvation or out-migration or reorganization or even abandonment of the community, then the community as a socio-ecosystem is *vulnerable* to that disturbance.

Scholars of resilience (Walker and Salt 2006) have enunciated a general principle that whenever we manage a socio-ecosystem to maximize the production of one element within the system at the expense of all the others, this decreases the resilience of the system. For example, if we maximize output by intensifying agricultural production (which is what the Great Leap Forward attempted to do in most rural communities) we decrease the resilience of the system to natural events. This is partly because resilience depends on buffers, on things within the system that allow it to absorb disturbance, but do not necessarily contribute to its productivity. A buffer can be a natural ecological one, such as a wetland to absorb excess rainfall or a forest to prevent hillside erosion, or an artificial one created to replace a natural one, such as terracing to prevent erosion on the formerly-wooded hillside. Institutional buffers, such as community organizations for the upkeep of waterworks or trade networks with people living in different environments, are also important for resilience. And finally, cultural buffers, such as ethics of frugality or taking only what one needs, also protect against disturbances.

For this reason, I think we need to revise the idea that increasing productivity *necessarily* reduces resilience. Moving from slope-planting to terracing increases both productivity and resilience, for example, as does the improvement of transport networks. But it is definitely correct, and very important, that in any system, when the effort to increase production *goes beyond a certain threshold*, resilience will drop and vulnerability will rise. The relationship is illustrated in the following diagram:



There are basically two reasons for this:

- As productivity is increased, buffers are sacrificed. Cutting down a forest to farm a hillside will at least temporarily increase productivity in a local system, but it will definitely increase the vulnerability to rainstorms, both through erosion and through increased probability of the kind of landslides that Li Yongxiang has described in his work (2005, 2012), and also very possibly by altering downstream hydrology.
- As productivity increases, so will consumption, either through population growth or increased *per capita* use of resources or both. The socio-ecosystem thus becomes *dependent* on the very increases in production that decrease its resilience. If a river is diked and the surrounding wetlands converted to agricultural fields, not only will the system be more vulnerable to flooding in severe rainstorms, it will also be dependent on the areas that are most likely to be flooded.

The relationship between intensification and vulnerability is best seen as stages in a process that repeats itself at different spatial and temporal scales. First, population growth, extraction of resources by outside state or corporate forces, or the desire for a better or more secure livelihood leads to intensification of production. Areas that previously served a buffering function are converted to directly productive lands. This requires replacing natural ecological buffers with artificial, infrastructural and institutional buffers, both of which require heavier labor inputs on the part of the population. But at the same time, the productivity of the system is increased, which means that, *in the absence of natural or social disturbances of a certain magnitude*, the system can accommodate more people or a higher standard of living. But when a major disturbance occurs, more people are vulnerable to it, and there is more suffering; what would have been a tolerable disturbance at a lower level of productivity or intensification now turns into a disaster.

This brings us back to the Great Leap Forward, as an extreme example of sacrificing resilience for maximization and intensification of production. Consider the various ways in which that campaign did this:

- Intensification of cultivated area. Statistics report that in 1958, millions of hectares of former "wasteland" (much of it previously serving as ecological buffer land) was brought under cultivation (Dikötter 2011: 177).
- Intensification of agricultural yields. The famous programs of "deep plowing and close planting" were designed to maximize the amount of nutrients in the soil availables to agricultural crops, and to maximize the number of plants growing in an area (Shapiro 2001: 76)
- Intensification of work hours. Under the slogan "three years of bitter struggle, ten thousand years of joy" people were mobilized for both agricultural production and industrial and infrastructural construction, with the result that they became exhausted after a few months (Friedman, Pickowicz, and Selden 1991: 227) .
- Intensification of industrial production. As part of the mass mobilization of labor, farmers and others were recruited to participate in steel production, under the slogan "surpass the UK and catch up with the US" (超英赶美), resulting in unusable steel, exhaustion through wasted effort, and labor diverted from agriculture (Yang 1996: 22).

An important thing to remember about the Great Leap Forward was that in the initial stage, production did in fact increase. Although the steel produced in the local furnaces was useless, infrastructural construction increased the length of the road network and the size of the land area that could be irrigated. Most of the roads presumably survived, and at least some of the irrigation works were durable enough to continue in use to today. Although it is difficult to reconstruct accurate statistics in the wake of the deception and exaggeration that went on in statistical reporting at the time, it seems that in fact in the short term, China had a very good harvest in 1958 (Kueh 1984). All this was accomplished by successful mobilization of labor, with people willing to sacrifice in the present for the promise of a brighter future.

The difficulties came at the next stage of the process, when the two problems with intensification enumerated above began to manifest themselves. Buffers had been eliminated with the expansion of agricultural land and with the expansion of irrigated land. As forests were replaced with farmland, erosion increased, diminishing soil fertility in the newly opened land and causing hydrological changes due to siltation downstream (Shapiro 2001, Yang 1996). Soils were exhausted by close planting, and eventually agricultural labor was displaced for industrial production, making it impossible to maintain the newly-constructed infrastructure.

Even more harmful was the increased dependency on the new and unsustainable sources of production. After the first harvest of 1958 was reported as wildly successful, large numbers of people and some areas of land were taken out of agricultural production and transferred to industrial and construction projects; there was no labor left to farm the newly opened fields, which of course required additional labor (Diköteer 2011:49-55). Many of the new irrigation projects failed after a few years (Shapiro 2001: 62-65), and since the economy had become dependent on them to provide the imagined surplus that China used to feed its cities, fund industrial production, and pay off some of its foreign debts, when these new fields proved unproductive, or when maximal production on existing fields exhausted soil fertility, there was no reserve, and food supplies diminished greatly in 1959 and particularly in 1960. Hence when natural disturbances did occur (Dikötter 2011: 178-84), there was no reserve food and diminished ecological buffers, and also when artificial disturbances, such as policies of grain procurement, continued unabated, there was not only no food reserve, but no labor available to repair the damage in the short run.

China eventually recovered from the Great Leap Forward; by 1962 harvests were approaching pre-Leap levels and local communities were once again functioning (Kueh 1984). Fertility, in fact, took a post-disaster "bounce" and reached its highest levels ever in the mid-1960s (Bannister 1987: 230). But changes to local ecosystems were not necessarily so easily repaired. Many socio-ecosystems functioned differently after the Great Leap. For example, in the Baiwu Valley in Liangshan where I have conducted extensive field research, hillslope forests were eliminated, accelerating erosion, hydrological changes began with the consequent erosion, and biodiversity was decreased as former habitat was increasingly used for farming.

The Great Leap Forward was in many ways an anomaly, representing a grotesque exaggeration of the practices of intensifying production without reference to resilience.

But it is the thesis of this paper that although the Leap was an exaggeration, it also illustrated a pattern that was in place beforehand and that has continued with minor modifications to the present day; a pattern in which attention to intensifying production (sometimes known as development) has always been the first priority, resilience or vulnerability to disturbances took second place, and as a consequence, disasters of many sorts have continued to happen with great frequency. Not all of these disasters could have been prevented; in some cases, such as the Wenchuan earthquake of 2008, the disturbance was so great that it would have been impossible to eliminate all of the catastrophic effects. But in almost every case of disaster that I will mention in the remainder of this paper, attention to intensification and neglect of resilience has at least worsened, if not outright caused the disaster.

Intensification and loss of resilience in the Qing period

The Qing dynasty provides a set of very clear examples of the processes by which intensification of production led to increased vulnerability to natural events, and thus to increased frequency of disasters as I have defined them here. At the outset of the dynasty, around 1650, various estimates place the population of the 18 provinces of China Proper at around 130 to 150 million (Deng 2004). But because the Qing was able, particularly beginning in the mid-Kangxi period, to establish the conditions of good governance and empire-wide peace that enabled social stability, the population grew rapidly during the Qing, reaching an estimated 430 million at the outbreak of the Taiping revolutionary movement in 1850. In a paradoxical way, the good governance of the early Qing, by enabling population growth, set in motion the process outlined above, in which the initial stages of intensification were accompanied by a rise in resilience, but the demand for resources by the growing population eventually led to destruction of ecological buffers, over-dependence on infrastructure and institutions, and eventually a partial breakdown of the social system that led to a dramatically increased frequency of disasters (L. Li 2007). We can illustrate this process with two examples.

Water control on the North China Plain.

The North China Plain is one of the world's flattest regions, and was consequently one of the first centers of intensive agriculture and agricultural commercialization. But its flatness presents challenges for maintaining and expanding agricultural productivity. Even 2000 years ago, the river originally called He 河 became known as 黄河 because of its increased sediment load, which began to build up in the riverbed, necessitating periodic dredging and diking to keep the river from overflowing during the rainy season, and thus ruining the crops (Leonard 1996: 6). By Qing times, the height of the river bottom was actually several meters above the level of the surrounding flat plain, making any breach in the dikes would be disastrous, and preventing tributaries flow into it, so that most of the Plain was contained in the watersheds of the Hai River to the north and the Huai to the south of the Huang He. Also sedimentation over the centuries caused the River to shift course every 600 years or so (Leonard 1996). The North China Plain was also subject to droughts because of climate variability, and to floods because of unpredictable but heavy rainstorms and the slow gradient of drainage to the sea. Finally a human factor intensified the vulnerability of the

North China plain after the Yuan regime established its capital at Dadu, on the site of present-day Beijing, and the Ming regime after 1403 and the Qing throughout its history kept their capitals there, at the northern and least productive edge of the North China Plain.

All this added up to an environment that needed management, at both large and small scales; both infrastructural and institutional buffers needed to be built and constantly maintained. The Yellow River and the Grand Canal needed diking and dredging (Leonard 1996, L. Li 2007) to keep them open to navigation and prevent overflowing; this infrastructure required huge institutional commitments at the imperial, provincial, and local scales. Drainage works needed maintenance, to help prevent flooding in times of heavy rainfall; this required village-level as well as county- and provincial level institutions. And because these infrastructural and institutional barriers to local disaster were sometimes inadequate, the state needed to construct additional institutions, in the form of famine-relief agencies (Will 1990, L. Li 2007), to redistribute surpluses both temporally and spatially to communities affected by shortages.

Neither the ecological and administrative problems of the North China Plain were new to the Qing regime, the dependency of the region on ecosystem management continued to increase as the population grew from about 50 million to about 100 million over the last 150 years of the dynasty (L. Li 2007: 77, Perkins 1968:212). What is remarkable is that the Qing managed the ecosystem very successfully for the first hundred-plus years of its reign, keeping the water system in reasonable repair and maintaining the buffer institutions that prevented famine when extreme weather events struck locally or regionally. In other words, they managed simultaneous rises in productivity and resilience. Lillian Li sums up this process eloquently: “To a great extent, then, the ecological crisis of the nineteenth century was a product of the very successes of imperial engineering of the eighteenth, not of its failures (2007: 73).” The Qing accomplished this primarily by doing two things: maintaining infrastructure to prevent extreme weather events from turning into floods, and mobilizing famine relief in times of drought and at times when wet weather overcame the infrastructure and flood occurred in spite of the institutional and infrastructural buffers against it. (Leonard 1996: 10-18). But as the population on the North China Plain grew, the effectiveness of both infrastructural and institutional buffers was gradually reduced.

One important factor in reducing resilience was eliminating ecological and infrastructural buffers in the interests of productivity. For example, as early as 1755 there were reports of families living within the secondary dikes on the Yongding River, and over the next few decades more and more people were living too near to rivers or lakes, on land that was fertile but subject to flood, in many parts of Zhili, Henan, and Shandong. Authorities would often try to get such people to move, but with increasing population, there was less and less room nearby that they could move to (Li 2007: 54-55).

Another major factor in the decline of resilience was decay of the institutions for famine relief comparison to the 19th century. Granaries were often empty. Waterworks were neglected, and there was a crisis from the 1850s to the 1870s, as the Yellow River shifted its course (Leonard 1996). More and more people were living in areas subject to flood. Even when relief grain was available, it was often was siphoned off by corrupt officials, never reaching its intended recipients. Military crises diverted state attention to other matters than the immediate health of the rural population. Amid this process of dynastic decline, compounded with the great increases in population, the frequency of disasters increased greatly, although there is no evidence of increased frequency of extreme weather events (Li 2007: 29), and there was general deterioration in the system from the mid-18th century, when most major weather crises were managed without great loss of life, to the 19th, when there were almost yearly reports of starvation, refugees, and disruptions caused by hunger (ibid: 34), to the Republican period, when China became known as the "Land of Famine," as exemplified by famines in 1928-30, which killed an estimated 10 million people in North and Northwest China, and in 1942, which also killed millions (White and Jacoby 1946: 169-71).

Erosion and hydrological changes in mountainous areas. An important factor that enabled population growth in the Qing was the late-Ming introduction of potatoes, sweet potatoes, and corn from the New World (Perkins 1968: 47-52). As previously settled areas in the plains and foothills became overcrowded, massive numbers of people moved into various mountain ranges; we can take the Qinling and Daba ranges (on either side of the Hanzhong basin) as illustrative case studies, but similar phenomena happened in mountain ranges all over China.

Although there had been gradual intensification of cultivation in the loess plateau 黄土高原 area of Northwest China as early as the Qin-Han period, and the resulting erosion created the name Huang He 黄河, even at the beginning of the Ming period most of the area of these two mountain ranges was still forested (Ling 1983, Liang 1994, Zou 1998). The forests played an important ecological buffering role in the regional systems: they trapped the rainfalls of summer and early Autumn, broke the fall of the raindrops with their canopy and the litter on their floor, and allowed water to seep slowly into the soil, preventing excessive or sporadic run off. But even in the Ming period, over population in the adjacent lowlands led some poor refugees to migrate to the hills and begin cultivating the previously forested slopes. At this time, they cultivated buckwheat, a crop that was suited to hilly regions, but not particularly productive. When the late Ming saw the introduction of the New World crops, however, virgin mountain soils could produce much higher yields. And with the more dramatic population increases of the early Qing, refugees from Hunan, Anhui, and Shandong were added to the migrants from the nearby plains areas, and by the Qianlong period they poured into the area in great numbers. This initiated or accelerated a three-stage process of ecological change, which led to a much greater frequency of disasters:

The first stage was deforestation, mainly for agriculture. People cut trees, sold the timber, burnt the smaller residue, and used the ash for fertilizer. The soil was so rich to begin with that they did not need to collect manure, finding the ash from burning and the natural fertility of the soil to provide sufficient nutrients for their crops, which included corn and sweet potatoes, as well as potatoes at higher elevations. The fertility of the soil was temporary, however, for two reasons. First, without any kind of fertilizer to replenish the nutrients, the intensively grown crops quickly exhausted the natural fertility of the soil. Second, the erosion (described below) washed away the fertile topsoil, leaving much less fertile subsoils (Liang 1994, Zou 1998). So people farmed for a few years and moved on; in some places continuing to use the secondary growth after the abandonment of their lands to make charcoal (ibid.). In addition to agriculture and charcoal, other reasons for cutting forests included lumbering, iron smelting, papermaking, and fungus growing.

The second stage was the erosion referred to briefly above. As had happened in the Loess Plateau earlier, erosion began with topsoil loss and the consequent decline in soil fertility, and in many places eventually led to gullying, which rendered the land useless altogether, and also difficult to return to forest.

The third stage was hydrological changes. With soil eroding ever more rapidly in the absence of forest cover, local streams silted up, and in heavy rainstorms there were many landslides and rock avalanches. Streams and rivers carried heavy sediment loads and could dam rivers and block irrigation canals (Liang 1994: 82). Eventually, this sediment was washed downstream and raised the level of river beds in tributaries or even in the main stream of the Wei River, which migrated 2.5-4 km northward between 1900 and 2000 (Zou 1998: 67). In Hanzhong, this sediment silted up many irrigation systems, rendering previous rice land no longer irrigable.

In this situation, landslides and floods abounded in places where they were previously relatively rare. In the Wei River Valley, for example, between 1810 and the establishment of the People's Republic in 1949, floods occurred almost yearly, exceeding their frequency at any other historical period (Yin et al. 2005). And according to the estimates of environmental historians, floods were more serious during this period than previously, because the larger population relied more on the output of marginal lands (ibid: 99-100).

Development and Disaster in the People's Republic

The Communist regime that took over China in 1949 thus inherited a set of socio-ecosystems that were maximally stressed by population increase, elimination of ecological buffers such as forests and wetlands, and social institutions mired in decay and dysfunction. Consequently, they also inherited a history of frequent disasters of all kinds; it is little exaggeration to say that during the late Qing and Republic, almost every major weather event turned into a disaster, and the ecosystem effects were compounded by military disturbances from the anti-Japanese and Civil Wars. Quite naturally, the Communist regime was very concerned with putting a stop to the disasters, and embarked on ambitious programs of ecosystem stabilization. They proceeded, however, under a set of assumptions that paid little or no attention to ecosystem resilience, but instead strove to maximize stability and productivity:

- The biophysical world exists to be tamed for human use. Judith Shapiro (2001) has neatly encapsulated this assumption in the Maoist slogan 人定胜天， or humanity is destined to prevail over nature.
- The way to tame nature is through the use of science, or 科学, a word that in its specific Chinese Communist usage means not so much investigation of natural phenomena through experiment and observation, as applying a set of known concepts, rules, and formulae to the world. In this conception of science, there is

little room for adaptation or adjustment to local or new circumstances or phenomena.

- In taming the natural world for human use, stabilization is possible; taming nature means eliminating much of its fluctuation and irregularity.
- Poverty and backwardness are the root causes of environmental instability and frequent disasters; stabilization of the environment and protection against disasters are best achieved by growth or development.

In other words, the CCP regime saw economic growth and disaster prevention or avoidance as part of the same process: by applying a kind of engineering science to the natural world, poverty and the disasters that come with poverty can be severely reduced or even eliminated.

These assumptions and the policies they entailed did in fact help at various scales of time and space. There has not been a famine in China since 1974, and China continues to have a food surplus. This is a major achievement, especially considering that the population has grown from around 650M in 1950 to over 1350M today, a magnitude of increase that rivals that of the Qing period. But ecological disasters are still a severe problem, and if anything have increased in recent years. It is often stated that China is in environmental Crisis (Smil 1993, Shapiro 2001, Grumbine 2011, etc.), but we should be careful employing that term. The magnitude and frequency of disasters seems to be a continuing phenomenon rather than anything acute enough to be called a crisis. When we look at China's recent history through its recent disasters, we come back to the curvilinear relationship between productivity and resilience discussed and illustrated above; China and almost all of its local socio-ecosystems are now quite demonstrably on the downslope of that graph. In the remainder of this paper, I will examine several examples from the 1960s to the present, mostly from the literature but also from my own experience, of how the ideology of scientific development and command-and-control environmental management (Holling and Meffe 1996) have directly increased the China's vulnerability to disturbance and thus its propensity to continue to suffer major and minor disasters.

Irrigation, vulnerability, and disaster on the North China Plain. The problems of floods and droughts on the North China Plain, which were the occasion for the Qing period infrastructural and institutional arrangements described above, continued into the 20th century, and were compounded in the early years of the People's Republic by population growth, from 129 million in Hebei, Henan, and Shandong in the 1953 census to 151 million in the 1964 count. The regime at first pursued a strategy similar to what the Qing had done—shoring up the dikes and re-establishing institutions for water control and famine relief—with the addition of attempting to capture much of the surface water in the area to increase the irrigated area, something that in their view would both increase and stabilize harvests. And the policy was relatively successful at first, increasing the irrigated area in those three provinces from 1.4 Mha in 1949 to 7.7 Mha in 1970, accompanied by a similar increase in yields (China Data Online). The famous Red Flag Canal in northern Henan, though built in an area that is not strictly part of the Plain, was a good example of mobilizing labor to move water to stabilize and increase agricultural yields. In addition, over-reliance on capture of surface water led to reckless construction of dams an other waterworks, many of them not stable, which in turn brought about the collapses of the Banqiao and other dams in 1976 (Fish 2013), described in more detail below.

This old strategy, however, was not enough, and in the middle 1960s, the regime attempted to increase the irrigated area dramatically by drawing on the large aquifer that underlies most of the Plain. This ground water had previously not been exploitable for irrigation, since it lay from 3 to 6 meters below the surface, and could not be brought up in necessary quantities: people dug wells and hauled water with winches for household use and perhaps to irrigate vegetable gardens, but there was no way to irrigate large-scale.

The solution was in tube-wells and gasoline pumps. These narrow wells can penetrate quite deeply, and gasoline-powered pumps can easily draw water in large quantities. Beginning in 1965 almost all agricultural producers' cooperatives on the North China Plain were supplied with the necessary pumps, and as a result, the irrigated area in 1990 increased to 11.6 Mha and the grain output to 91Mt; in addition, because irrigation water was not dependent on rainfall, there was little danger of drought (Wang et al. 2005).

This strategy was not, however, without its problems. In attempting to maximize productivity and stability, the regime sacrificed both long-term sustainability and, more importantly for this paper, also created new kinds of vulnerability. Long-term sustainability was sacrificed simply because the aquifer is being drawn down much faster than it recharges (about 500 times as fast, in fact) with the result that on some parts of the Plain the water tables are as much as 80 meters down now, and certain already close to running out of groundwater altogether (Foster et al. 2004). And whereas the inhabitants of the Plain in the early Qing, for example, got by fine without groundwater irrigation, the population that has to be fed today is six times greater, and has become dependent on the groundwater for their livelihood, so they are now vulnerable to the water running out.

Vulnerability has increased in at least two ways. In many heavily populated parts of the Plain, lowering the water table has caused the ground to shift, in what are known as cones of subsidence (ibid: 87). This might have made little difference if the areas had remained agricultural, but with multi-story buildings and streets running along many of them, foundations and roadbeds crack, making the buildings dangerous and the roads undrivable.

In addition, many of the structures built for water control, beginning in the 1950s, were poorly built or poorly planned, making the area even more vulnerable to heavy rain events than it was previously. The most notorious case was that of the Banqiao dam on the Huai River, built in 1962. It was an earth-fill dam that held behind it a reservoir of 700,000 m^3, and was one of over 100 dams built on the Huai and its tributaries during the 1950s and early 1960s, for flood control as well as for irrigation purposes. It was supposedly built to withstand a 1000-year flood, and after cracks appeared in the early 1950s, it was reinforced. But in August, 1975, 1060mm of rain fell in 24 hours as the result of a freak weather event, and the Shimantan earthen dam, upstream of Banqiao, gave way. When the water from that flood crested at Banqiao, it too collapsed, releasing a torrential flood that took out at least 62 other dams, basically destroying the entire infrastructure upon which the population and agricultural output of this area depended. It has been estimated that about 30,000 people living in downstream villages died by drowning during the several hours that it took the reservoir to empty, and perhaps as many as 140,000 others died of consequent epidemics and famines (Fish 2013).

The Banqiao dam collapse presents a clear example of both dependency and vulnerability created by attempts to maximize system output. The population downstream was dependent on the dams for irrigation and thus livelihood, and in fact was dependent on them for protection from small floods. But protecting from small floods in fact made them much more vulnerable to a larger flood. The cycle of increasing productivity creating increasing dependency and reducing resilience is no more clearly illustrated than in this case. Of course, a 1060mm rainfall in 24 hours would probably have created some human problems even for a population not dependent on a vulnerable infrastructure. But the scale of disaster is as much attributable to the policy of building dams to increase output as it is to the magnitude of the 1975 rainstorm.

Landslides in Mountainous Areas of Yunnan. Our conference organizer, Dr. Li Yongxiang, has presented a classic example of the process of production increase and its role in increasing vulnerability to natural events, turning weather events into disasters. In his native Xinping County, Yunnan, for hundreds of years a number of different ethnic groups, primarily Dai, Han, and several subgroups of Yi, farmed a variety of valley and foothill environments for subsistence, adapting different crops to different altitudes, slopes, aspects, soils, and microclimates.

According to the local people with whom Li discussed environmental change, landslides were not a prominent danger previous to the establishment of the PRC, and in fact older people did not remember their parents telling stories about landslides, even in the hillier areas inhabited primarily by Yi people. But this changed in recent years, particularly at the beginning of the present century, when a recent history of small landslides was capped by two major disasters in 2001 and 2002, both of which killed 20 or 30 people and wiped out many houses and destroyed farmland (YX Li 2005: 173-76).

As Li points out, geologists summoned to Xinping to determine the cause of landslides attributed them to a loose layer of soil overlying bedrock in many of the mountainous areas, which of course does make an area susceptible to sliding. But the loose-lying soil did not slide in the memory of the older people in the villages. What changed between the pre-revolutionary and the contemporary periods was that in the interests of production intensification, many hill areas were cleared of their native forests beginning in the 1960s, and sugarcane and other cash crops were planted on those slopes.

Xinping was and still is to some extent a poor county, and it is understandable that local officials would want to increase production and improve livelihoods. But they did so at the cost of vulnerability to heavy rainstorms. Any kind of annual crop has a period when its field is either fallow or just plowed or has new, small plants without big root systems, and during this period the crop, unlike the trees of a sub-tropical forest, has no ability to hold soil in the event of a severe rainstorm. And so, even though Li states that "[sugarcane planting] was not the main reason for the landslides" (2005: 133)," in fact the landslides would not have happened if not for the deforestation, and the primary reason for deforestation was to increase short-term productivity, or, we might say, following Walker and Salt, to maximize a single aspect of the socio-ecosystem. Li also points out that disasters are not caused by nature alone.

Again, however, we must not neglect the social fallout of the policy of planting the slopes, particularly the dependency on the intensified use of resources. When their villages were severely damaged by landslides, then villagers faced not only a very disruptive move, sometimes to places where there was no productive land, so they had to return to the non-slid portions of their former land to farm, but they also faced a loss of livelihood, since they had previously become dependent on the intensified production in order to make their living.

Li also mentions that in the wake of the landslides, which came not long after the 1998 middle-Yangtze floods, local officials became environmentalists, strongly supporting the policy of "Returning Farmland to Forest" 退耕还林. (ibid: 198)Given that so many environments over the course of Chinese history have been rendered vulnerable to extreme weather and other sudden events by intensification in the form of deforestation, reforestation of course makes sense. But it is not always possible to repair the damage after a disaster and return a socio-ecosystem to the *status quo ante*. Soils may be gone, the species chosen for reforestation may not be suitable either to the environment or to the current stage in ecological succession; social and cultural changes (including dependency) may have happened in the interim. Returning farmland to forest is a good idea, but it cannot necessarily actually "restore" an ecosystem in current conditions of productivity intensification and dependency on the intensified resources.

Air Pollution in Beijing, Winter 2012-13. Probably the environmental problem in China that has received the greatest amount of attention worldwide in the past year or so has been the increase in air pollution in many large and medium-sized cities, but particularly in the Capital. Although pollution is not conventionally something we think of in the category of disasters, I would like to look at the dramatic pollution of last winter using the same model as I have used in this paper to analyze other disasters.

Beijing and in fact the North China plain in general has always had a problem with pollution; the haze of traditional times (much of it generated by windblown dust eroded from the Loess plateau in the Northwest) meant that even on cloudless days the Western Hills were not always visible amid the coal smoke in the stagnant air of winter. But for reasons of productivity (in this case the productivity of administrative services) regimes starting with the Yuan have kept their administrative centers there, and as the population of successive capitals has grown, the process of intensification, loss of resilience, and finally disaster has taken place there as in the other areas I have been discussing in this paper.

The first stage of the process in Beijing was decreasing resilience in the interests of productivity. For many centuries, this process was a simple one of population growth; the capital has grown from about a million people in the Qing to something over 12 million urban population today. Until recently, much of the urban population burned coal for cooking and heating, which created even pre-modern haze and smog especially in the winter,when stagnant air conditions were frequent and few rainstorms came to blow and wash the stagnant air away (Xue 2013).

But the recent process of economic development has greatly accelerated the vulnerability of the capital, and it has done so partially in the form of gasoline- and diesel-powered vehicles, which of course improve the mobility and the consumption ability of the population (Zheng et al. 2005). But the population has become dependent on automobiles as a mode of transportation, as anyone can tell who has witnessed the stalled streams of traffic on the ring roads—even though they know the traffic will be there, and they know that cars cause smog, the citizens of the capital have no choice but to take to their cars if they want to get places.

It is this dependency on the infrastructure that enables the production increase that makes the capital more vulnerable to disturbances, which in this case take the form not of sudden, violent events such as rainstorms or earthquakes, but rather of periods of calm, stagnant, dry air that does not move the pollutants away, which combine with the continued emission of pollutants by cars and trucks—both particulate matter (already a problem for centuries, but increasing lately) and ozone-forming chemicals (something new) to create the smog that has been reported as so disastrous in the national and international press.

It seems very unlikely that there is any quick or easy escape from the Beijing pollution predicament. The socio-ecosystem has moved into a lamentably stable state, in which the infrastructure, the consumption habits, and the spatial organization of the city mean that whenever there is a natural event of stagnant air, the city is so vulnerable to the effects of polluting processes that it is going to have smog. This is not a crisis, as I indicated above; it is an ongoing state of a broken system that has almost no resilience whatsoever to natural weather patterns.

Yangtze floods of 1998. For my final example, I return to something that we would conventionally be much more likely to consider as a disaster. In the summer of 1998, the provinces of Hunan, Hubei, and Anhui were severely affected by what were called the worst floods in decades (Yin and Li 2001). Hundreds or thousands of people lost their lives, and millions became homeless. Many days of heavy rain had increased the flow in the river to more than twice its normal summer high-water level, and even the giant (for its time) Gezhou Dam saw its reservoir unable to contain the greatly swollen amount of water in the River.

At one level, the Yangtze floods were just another example of intensification or production maximization at the expense of ecosystem resilience. And at some level, the official response to the disaster reflected knowledge of this principle. Three actions were taken to try to prevent future occurrences of such large mid-Yangtze floods: a commercial logging ban was imposed in the upriver provinces of Guizhou, Sichuan, Yunnan, and Tibet; two nationwide reforestation programs were instituted: the Natural Forest Protection Program 天然林保护工程 and the Returning Farmland to Forest Program 退耕还林工程; and although it had already been started about five years earlier, construction on the really massive dam at Sanxia now had a justification in the form of flood prevention as well as electricity generation.

In fact, it is probably no exaggeration to say that the 1998 floods and the response of the regime marked a real turning point, from complete priority on intensification and development, with only light lip service to environment, sustainability, or ecosystem resilience, to a more balanced approach, in which development still has priority, but the regime recognizes that there is a real tradeoff between development and environmental health.

Also, it is almost impossible for a rational person to oppose such projects as the logging ban and the two reforestation policies. In some places, they have been carried out in less than ideal manner (Robbins and Harrell 2014, Trac et al. 2013), but the impulse is right, and they have achieved some results. But there is an irony in all this, which is that there appears to be no evidence that deforestation on the Upper Yangtze caused the floods on the middle reaches of the River. In a careful study of sediment flows in the Jinsha and other major tributaries of the Yangtze, Amanda Schmidt has shown that there is little reason to think that either increased runoff from the upper reaches actually got to the middle course of the river, or that erosion upriver caused hydrological changes downriver that might have contributed to the loss of resilience and thus to the vulnerability to heavy rainstorms.

It appears, in fact, that the cause of the floods was much more local (Schmidt et al. 2011). In other words, the ongoing development of the middle-Yangtze region, a process that has been documented as contributing to floods and hydrological changes as early as the late Ming and then more intensively in the middle Qing (Perdue 1982) is responsible for local disasters. And this, of course, is a much more difficult problem to solve than that of deforestation in the upper watershed.

It seems to me that there is a lesson here for the study of disasters in general, that has to do with the way that socio-economic forces shape the vulnerability of ecosystems to extreme events and disturbances. Even when authorities or local communities recognize that natural disasters are not really natural, or at least not purely natural, they tend to seek simple explanations and to blame simple causes, rather than recognize that really creating a sustainable and resilient socio-ecosystem is not easy as long as they are committed to, and their citizens and constituents are expecting and depending on, continued development or intensification. Blame the loggers, or blame the "ignorant" minority peoples of the Southwest, even blame the erroneous policies of the previous regime, including those of the Great Leap Forward and the Cultural Revolution. Don't openly try to resolve the basic contradiction between intensification and resilience.

Concluding thoughts

I hope these examples can illustrate the usefulness of a paradigm or pattern. A regime desires to accommodate a rising population, stabilize livelihood, and/or increase the material and energy extraction from an ecosystem to raise the standard of living for a population. This leads to a process of intensification of production or productive capacity, elimination of buffers, loss of resilience and increase of vulnerability, and finally, inevitably in the long run if stochastically in the short run, the transformation of an otherwise absorbable disturbance into the cause of a disaster.

At the same time, I want to qualify the usefulness of this paradigm for understanding all of recent Chinese environmental history, in three ways.

To begin with, of course, we need to consider whether China is any sort of special case. We can find examples all over the world that illustrate the principle and follow the process outlined and illustrated so many times here. Is there anything special about China?

I would, in fact, say yes, there are two things that are special about China. One is the *level* of the intensification, the fact that China's recent intensification began on top of a baseline created by several earlier cycles of intensification, loss of resilience, and increase in disasters, particularly the one that happened in the Qing period. Present-day China in fact is building on an already highly intensified productive system, intensifying it further.

A second special characteristic of China is the *speed* of the intensification. This is particularly evident in the sustained economic growth since 1990 and the demonstrable relationship between this growth and many of the disasters that have happened recently, including those illustrated here. There has been little time to think. But of course, going back to Mao's time, we find an urgency for development that precedes the Great Leap Forward and picks up again after that series of disasters was over. Haste has certainly contributed to making development more of a tradeoff against resilience than it would otherwise have been.

Third is the faith in top-down environmental planning, supported by the ideas of science and engineering discussed briefly earlier in the paper. Lack of attention to the possible range of variation of responses of an environment to various changes and disturbances, faith that the environment, like everything else, can be planned rationally, has led to an increased frequency of what Lance Gunderson (2003) has called "ecological surprises." So China is, in fact, special, at one end perhaps of the range of variation, but not off the scale.

Another consideration is the rigidity and thus perhaps lack of resilience of the paradigm itself (Ostrom and Cox 2010). Not everything can be explained by lack of resilience; some disasters were going to happen to any ecosystem. I do not have room here to consider the major earthquakes in Tangshan in 1976 or in Wenchuan in 2008. I think, however, that in both cases, different approaches to rapid development probably made those two natural events more disastrous than they otherwise would have been. But development did not *cause* those earthquakes to be disasters. They would have been disasters in any environment in which very many people were living at all.

Finally, I need to say something about the most vexing problem of all. If there is, beyond a certain threshold, a negative relationship between development and resilience, what do we do about it? It seems politically impossible to stop development, and in most of the world development, getting out of poverty, is a universally recognized and laudable goal.

One way to approach the big dilemma of the big tradeoff is to think about reducing global inequality, about transferring or redistributing resources from the rich countries to the poor, or in the case of China, from the rich regions and cities to the poor regions and the countryside. This would attack the problem of poverty without increasing the overall pressure on the national-level ecosystem. How much of this is politically feasible, however, remains to be seen on the China scale and seems close to zero on the international scale.

Another approach, which seems more promising, would be if a regime would first consider the *range* of possible environmental consequences, the degree to which buffers might be reduced by the implementation of any developmental policy. Then perhaps it might choose to slow, not stop, the rate of development, realizing that the tradeoff between intensification and resilience is not a one-for-one swap. Dare to think at a longer time-scale and consider the effects of a policy decades in the future, rather than resolve to develop first and clean up later. This would take a lot of political will on the part of a leadership, as well as a lot of skill in explaining the principle to the people likely to be affected. But it seems to be one of the few options if the frequency and severity of "natural" disasters is not to keep on increasing.

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