Chapter 6: Prelude: K to Ω in the Qing and Republic

> [A] historian preparing herself to write, say, about the eighteenth century ends up writing mostly about the seventeenth century because it comes to seem so fundamental to the question at issue.
>
> James Scott, *The Art of Not Being Governed*

The Significance of the Qing and Republic for the PRC Story

In 1949, the Chinese Communist Party did not have an easy task ahead of itself. Aside from deposing the Guomindang, consolidating its rule at every scale from the village to the country, neutralizing real and imagined class enemies, getting rid of imperialists of all stripes, making itself militarily strong, and educating its people in the revolutionary ideas of Marxism-Leninism, it had to insure that its nearly 600 million charges could feed themselves. And they had to do so from a severely degraded environment, whose productivity using traditional agricultural methods was probably at a maximum and whose resilience at most scales in most places was near zero. The events of the Qing (1644-1911) and Republic (1911-49) had presented the Communists with this daunting task.

It was not entirely this way at the beginning of the Qing. Although there had been slow expansion of population, cultivated area, and irrigation works, along with slow deforestation of the East Asian continent, for over two thousand years prior to the Qing's seizure of power (see Elvin 1998, 2004; Marks 2011, Ling 1993), the estimated population of 150-200 million in the early 1600s could easily be fed with the technology available at the time. Famines and other disasters that happened during the previous 2000 years of Chinese history can be attributed almost entirely to the breakdowns of the institutional and infrastructural buffers that had been built up slowly over the course of time, rather than to any kind of overshoot of long-term carrying capacity.

The Qing during its century of greatest glory, from around 1680 to 1780, might well have been the world's most sophisticated and efficient governing machine. It faced resistance from Ming loyalists and Han Chinese nationalists in its early decades, but by 1680 it had established effective control over the Intensive Agricultural Zone (Wakeman 1985: 1124-7), and it also very quickly adapted the Ming methods of indirect rule in the Upland Zone, expanding and deepening its rule, though not without opposition, throughout the 18th and into the 19th centuries (Giersch 2006; Hermann 1993, 2007; Weinstein 2013, Whittaker 2007). Controlling the pastoral zones was more problematic (Barfield 1989, Perdue 2005) but it was necessary for geopolitical and increasingly for ecological reasons, and is thus part of our story.

During the Qing, however, slow variables undermined the abilities of both the regime and local communities to maintain the necessary buffers against weather and other disturbances. The initial empire-wide population of 150-200 million grew to well over 400 million by 1850 (Lavely and Wong 1998; Lee and Campbell 1997; Lee and

Wang 1999, but see K. G. Deng 2004[1]), and this increased population had to be fed. That meant increases in agricultural production, which could come from two sources. First, productivity had to increase on existing farmlands, and second, new lands had to be brought into cultivation. In other words, agricultural output was increased by both intensification and extension. This process constituted a series of positive feedback loops or turns of the Malthus-and-Boserup Ratchet (Wood 1998; see chapter 2, figure 2.10). As productivity and cultivated area increased, so did human fertility, and consequently population grew at a rate unprecedented anywhere in the world for a continental-sized entity (Harrell 1995: 6-16; Lee and Wang 1999: 27-28), in turn necessitating further increases in productivity and cultivated area **[References to Microdemography book]**. During the first century and a half of its rule, the Qing was remarkably effective at increasing productivity and maintaining resilience at the same time, building infrastructure and promoting institutions that served simultaneously to increase productivity and to buffer against disturbance. But as we have seen in our model of productivity-resilience interaction (Figure 2.9), eventually productivity and resilience came into conflict with each other, so that further increases in productivity led to decreases in resilience. This process threw first local- and regional-, and then empire-scale systems into a series of backloops that effectively stuck the Intensive Agricultural Zone as a whole in the omega and alpha phases of the adaptive cycle for over a century. Only in the 1950s did the infusion of resources from fossil-fuel based industrialization allow the system to ratchet itself up again, to a previously unthinkable level of population and resource use. The present chapter is the story of how the Qing's early political and ecological success led to unsustainable increases in productivity, how the system overshot its sustainable levels of production, and how this presented the CCP with such an impossible task at the beginning of its rule in 1949.

Intensification and Expansion: Logics of Ecological Degradation in the Agrarian Zones

The ecological history of the Qing and Republic is best pursued zone-by-zone. In the Intensive Agricultural Zone of China Proper, Perkins estimates that agricultural production increased to keep pace with population, or nearly so, and that about half this increase was due to productivity gains (intensification) and the other half to increases in cultivated area (expansion) (Perkins 1968: 13). Both intensification and expansion diminish ecological buffers at various scales, but in different ways. In the Qing, local cycles of intensification began, as adaptive cycles do, with an exploitation phase. In previously cultivated lowland areas during this phase, communities and official agencies could often compensate for lost ecological buffers—wetlands, surpluses, and crop diversity—by building infrastructural and institutional buffers. Production and resilience could increase together. Eventually, however, production was intensified so much—more double cropping, more marginal lands cultivated, more labor inputs—that excessive

[1] K.G. Deng (2004) presents a revisionist narrative based on a re-interpretation of official population figures during the Qing, revising the initial figure down to about 38 million, and the figure in 1850 downward as well, to about 380 million. Paradoxically, though his figures are lower than those commonly accepted, the rate of increase implied is even faster, with the population increasing by tenfold rather than merely tripling.

amounts of energy went into maintaining these replacement buffers, and the system entered into a conservation phase, becoming rigid and fragile, so that when the replacement buffers failed, a local or regional system could undergo collapse and reorganization. We can diagram this process in Figure 6.1:

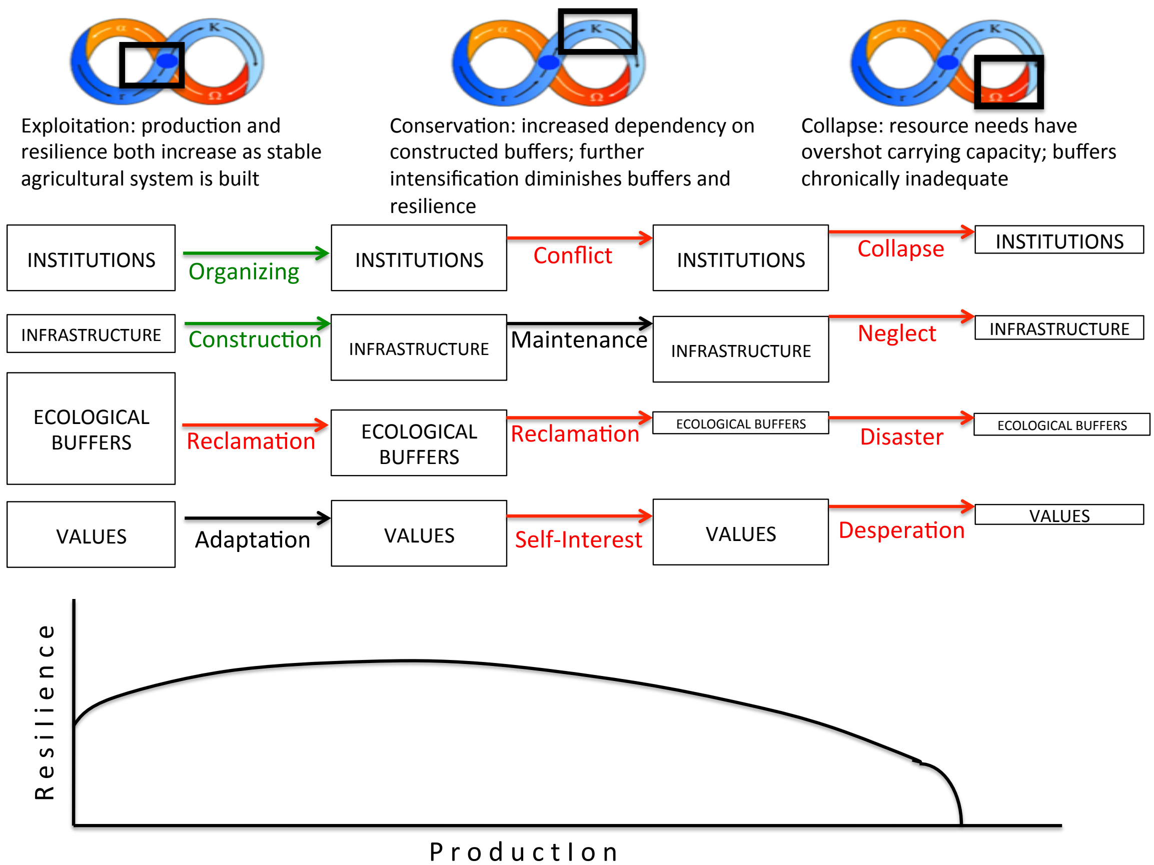


Figure 6.1: The complex process of intensification, ecological buffer reduction, infrastructural and institutional buffer construction, and eventual fragility and collapse in lowland areas that have been farmed intensively for a long time.

I illustrate this process at different spatial scales below, with the case studies of the North China Plain, the Dongting Lake Basin, and the Qiantang River region, along with a partial exception in the case of the Chengdu Plain.

When intensive production was expanded into the previously lightly used mountain areas within the Intensive Agricultural Zone, as well as into the Upland Zone, however, ecological buffers, once gone, could not easily be replaced with infrastructure, so that there was nothing for institutions to maintain, and resource degradation happened very rapidly; essentially the adaptive cycle skipped the conservation phase and went directly from exploitation to collapse, as illustrated in Figure 6.2:

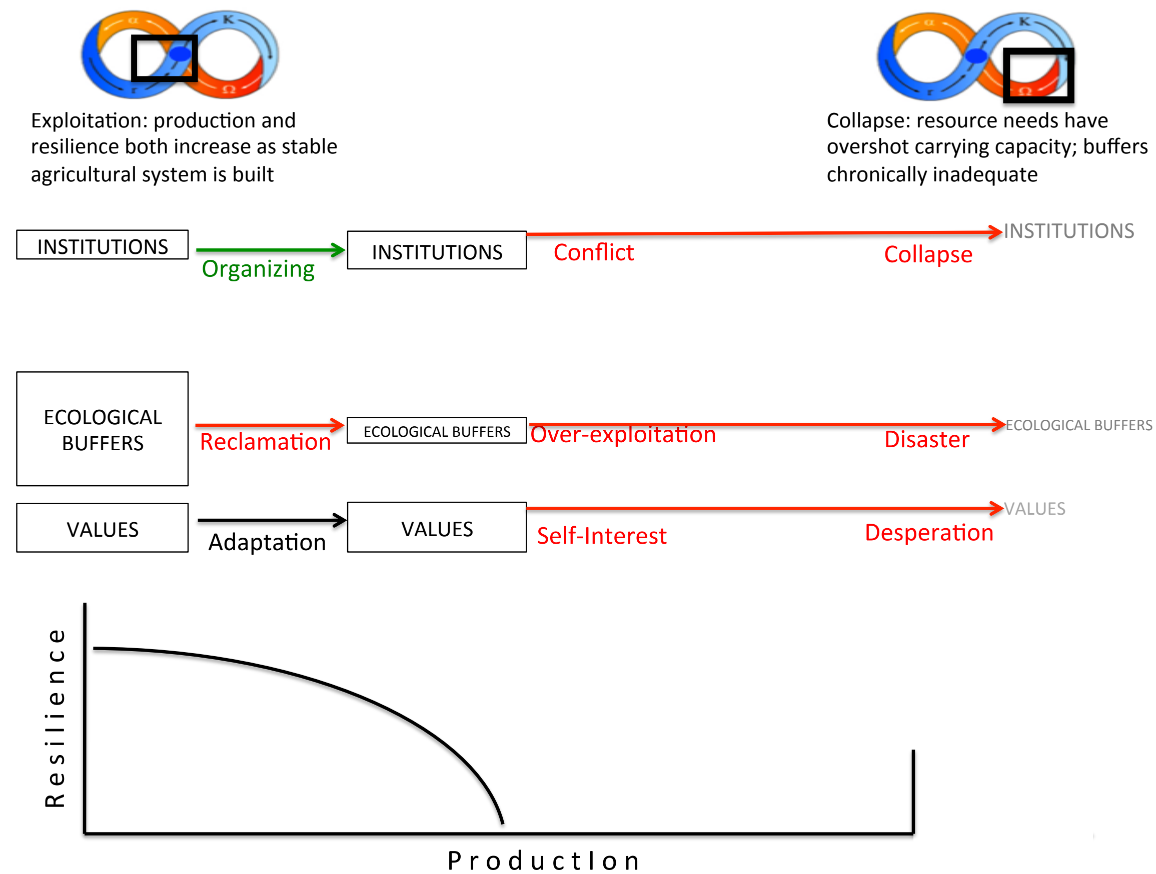


Figure 6.2: The rapid process of intensification, overshoot, and resource degradation in highland regions brought under cultivation.

After analyzing the four cases of intensification mentioned above, I then move to describe three cases of the process of expansion into upland areas: in the Qinling and Daba mountains that separate the Wei, Han, and Yangtze watersheds, in the Huaiyu, Qianligang, and Huang ranges along the Jiangxi-Zhejiang border, and in the Nanling range separating the Lingnan region from the Yangtze watershed to the north. In all these mountain ranges, a comparatively rapid sequence of deforestation, soil transport, and hydrological change combined to degrade not only the mountain areas where the deforestation occurred, but also many of the adjacent lowlands.

The Intensive Agricultural Zone: Agricultural Intensification and Waterworks Dependency

> **射小利, 害大谋, 急近功, 遗远患:** *Aim at small advantage and ruin a great plan; anxiously attack for the short term, leave behind a disaster in the long term.*
>
> **Lin Yuan (n.d.)**

Farmers during the Qing managed to achieve increases in production, or agricultural intensification, by a variety of means. The most important of these were new crops, improved varieties, increased labor inputs, and intensified water-control technology, including both irrigation and flood control. The most important new crops were those introduced from the Americas during the second half of the Ming: potatoes, sweet potatoes, and corn (Perkins 1968: 50). When these crops replaced traditional Old World grain crops on existing farmland, they ordinarily did not have adverse effects. The primary advantages of corn, potatoes and sweet potatoes on lowland fields over the traditional wheat and millet grown in North China were in their productivity per acre (Buck 1937: 224-25) and their greater adaptability to both drought and cold (Zhou Hongwei 1999: 11). When introduced in areas that had previously been devoted to other grain crops, these new grains and tubers allowed farmers to diversify and in some cases to increase cultivated areas modestly. In hilly areas, however, these crops allowed farmers to increase cultivated acreage dramatically, because they could be sown on lands too dry, too cold, or too steep to support the traditional crops. But because these new crops often replaced forested lands that served as ecological buffers, increases in cultivated area could not be sustained and often brought about ecosystem degradation.

Improved varieties, by contrast, were on the whole, ecosystem freebies, but not entirely. New varieties of rice, introduced and further improved from the Song to the Qing (Ho 1959: 169-76), often enabled double cropping, but to extend the rice season from one crop to two requires supplying irrigation water for a longer season, and may also tax fertilizer supplies (Perkins 1969:45). Additional irrigation works necessary to capture additional water often meant less water available downstream, and usually increased the social costs and labor requirements to maintain the system. Finally, lack of fertilizer to compensate for two crops taking nutrients from the soil could result in overshoot of long-term carrying capacity.

More important than new varieties or new crops, however, in increasing agricultural yields during the Qing, was the increase in irrigation and flood control. As we have seen previously, moving from rain-fed to irrigated agriculture brings increases in productivity. In the beginning it can also provide infrastructural and institutional buffers that increase stability and resilience against weather disasters. In many regions during the Qing, new varieties, new crops, and intensified waterworks for flood-control and irrigation led to initial increases in both cultivated area and productivity, and thus to the ability of local regions to accommodate increasing population. But population seriously overshot long-term carrying capacity. Bringing more land into cultivation, as well as building the necessary waterworks to irrigate both previously unirrigated and newly reclaimed land, involved destroying ecological buffers, as well as increased costs of maintaining the infrastructure and institutions. There is also evidence that the institutions themselves began to deteriorate (Will 1980: 311-18; Li 2207: ch. 9) Eventually these led to a K-phase in which costs were disproportionately invested in maintaining the increasingly fragile buffers, on which the productivity of the system increasingly depended. And because of diminishing marginal returns for labor, surpluses, which are themselves another kind of institutional buffer, decreased. In this kind of situation, a disturbance in the form of a natural, political, or military event can easily overwhelm the diminished resilience of the system and lead to a famine or other disaster. Floods, droughts, and famines increased after about 1780 and especially in the 19th century, setting into motion backloops of rebellions, military repression, and diversion of investment into military rather than public-works expenditures, which in turn weakened the resilience of local responses even further. Three regional and local case studies illustrate this process.

The North China Plain: The Seeds of Self-Destruction. The North China Plain is one of the world's flattest regions, and was consequently one of the first places where people domesticated of plants several millennia ago. The Plain was originally the lower watershed of the Yellow River, extending from where the River emerges from the gorges to the sea, and covering parts of the modern provinces of Hebei, Henan, Shandong, Anhui, and Jiangsu (**Figure 6.3, map to come**). By the beginnings of empire in the third century BCE, it was already almost completely deforested (Marks 2012: 234-37; Ling 1983: 26 , Elvin 2004: 42-49) and given over to intensive agricultural production. Its flatness meant that it was an easy place to cultivate and to build land transport and market networks that encouraged marketing of an agricultural surplus.

But the flatness of the North China Plain also presented challenges for maintaining and expanding agricultural productivity. There is a reason why the Huang He, or "Yellow River," has its name. The name of the river was originally just He. The Chinese word *huang* really covers a range of colors from yellow to tan to deep brown, and in the case of the River, the color became part of the name in the late pre-imperial period, when the He changed hue, from blue to tan because of the mud washed down from the Loess highlands in the River's upper watershed, particularly in the summer rainy season (Leonard 1996: 6). So the proper English translation of Huang He is really not Yellow River at all, but Brown River or Big Muddy, though that name in English seems to be taken already by the much-less muddy Mississippi. Because of the sediment transport and also the seasonal variability in the River's flow, by Han times it was laying down massive amounts of sediment along its slow course across the North China Plain from the mountains to the sea, and this sediment began to build up in the riverbed, necessitating periodic dredging and diking to keep the river from overflowing and ruining the crops during the rainy season, which is also the prime agricultural season (**Figure 6.4)**. By early Han times, the bottom of the river bed was actually several meters above the level of the surrounding flat plain, creating a "river suspended above the earth" (地上悬河, **F个微日亿 6.5**), and making a breach in the dikes into a sure disaster. In fact 1590 serious breaches are recorded between 602 BCE and 1938 (Li Guoying 2002, Zhao Shuling 2002: 52). At present, the level of the river in its lower courses is 2-6 meters above the surrounding plain. Over time, the suspended river quit having tributaries flow into it, since their river beds were below the level of the River, so that water would have had to flow uphill to be tributary (Li Guoying 2002). As a consequence, most of the Plain became included in the watersheds of the Hai River to the north and the Huai to the south of the Huang He. **(Figure 6.6)**. Finally, the process of sedimentation over the centuries was such that every 600 years or so the river would block its own channel around the region of Kaifeng, breaching its dikes and changing course, flowing first north of the

Shandong peninsula and then south of it—the last two changes were from north to south in 1128 and then back to its present course to the north in 1855 (Baidu Encyclopedia, accessed Nov 2014).

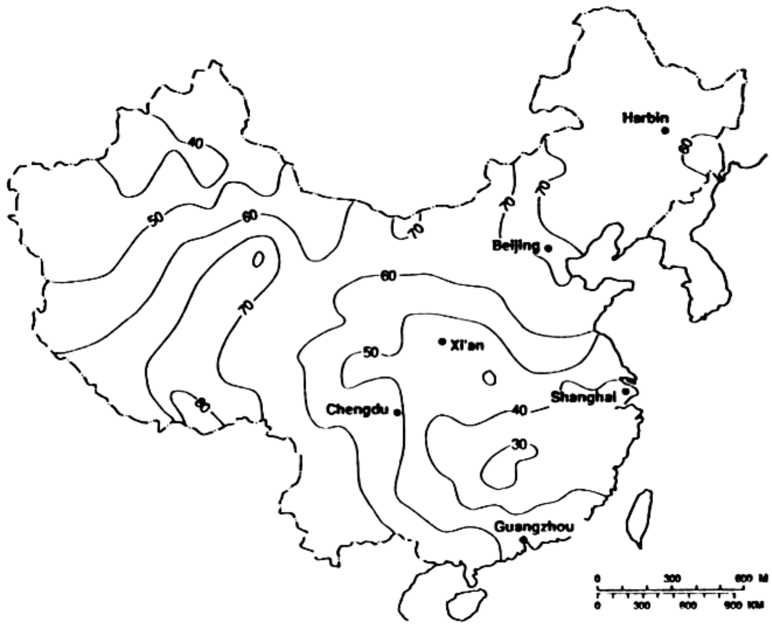


Figure 2.2. Distribution of the annual share of summer (June to August) rains shows their dominance throughout northern China. Redrawn from Domrös and Peng, *The Climate of China*, 6, 169.

Figure 6.4. From Václav Smil, *China's Environmental Crisis*, page 40.

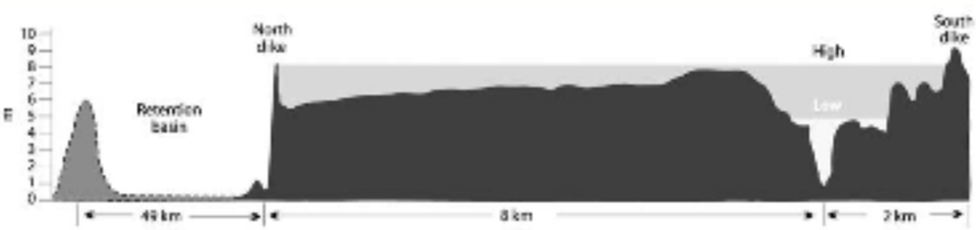
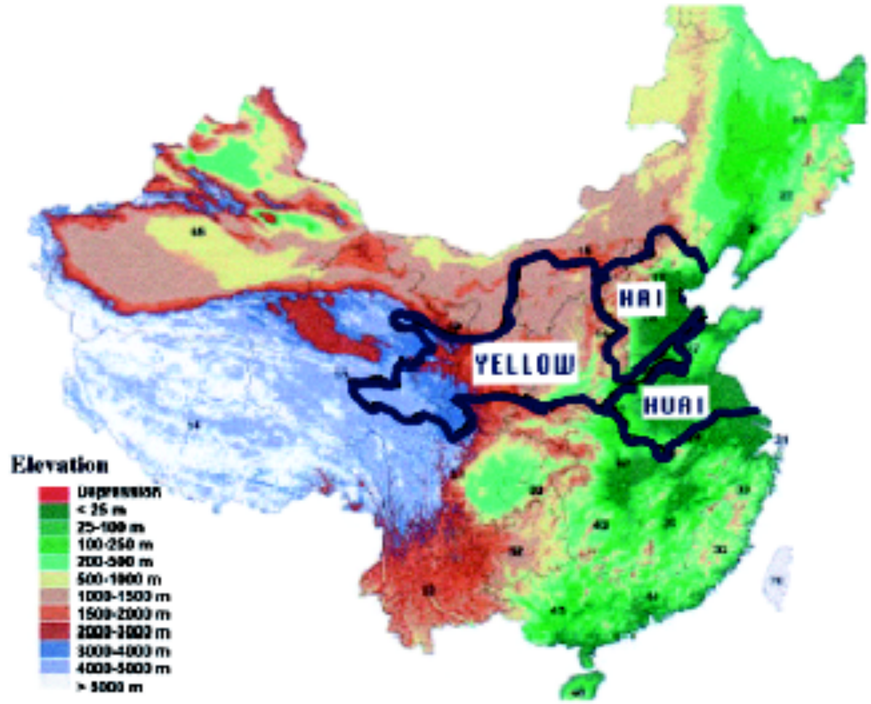


Fig. 5.4. Schematic representation of a cross-section of the Yellow River.[1] Source: after Ronan, 1995.

Figure 6.5: From Molle and Webster 2009: 114



Source: WB 2001

Fig. 1 Relief map of China showing the 3-H basins.

Figure 6.6: The drainage basins of the Huang, Hai, and Huai Rivers. Note that the Huang basin on the eastern part of the North China Plain consists almost entirely of the River itself.

The flatness of the plain also meant that water flowed very slowly to the sea in the rivers on the surface of the plain, so that when there were large-scale rainstorms, a frequent occurrence during the growing season, the waters were slow to drain, often causing crops in the fields to become waterlogged and rot (Huang 1985: 64-66). But floods are not the only problem. Even though rainfall is concentrated in the summer months in North China, the yearly variations of the East Asian Monsoon mean that the area is also subject to drought (Zhao Shuling 2002: 53). Droughts and floods, however, are different kinds of crises, because droughts build up slowly over months or even successive years of low rainfall, while floods happen suddenly and unexpectedly. Also, floods are often local, while droughts typically effect wider regions (L. Li 2007: 132-33).

Add to this one more factor. The Yuan regime established its capital at Dadu, on the site of present-day Beijing, in 1267, 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. The population of the capital at the end of the Ming has been estimated at anywhere from 300,000 to over a million (Gao Shoushan 2003), and is estimated to have been something over a million during most of the Qing (Perkins 1969:148), but it could not feed itself from the North China Plain's resources. It had to import rice and other foodstuffs from the more fertile regions to the south, primarily from the Yangtze Delta and surrounding regions (Perkins 1969: 149). To do so, the three dynasties all had to maintain the Grand Canal (Perkins 1969: 149-51), which not only cut across the Plain from south to north, but also intersected the Yellow River in western Shandong.

All this added up to an environment heavily dependent on management at both large and small scales; both infrastructural and institutional buffers had to be built and constantly maintained. The Yellow River and the Grand Canal needed diking and dredging 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 buffers against local disaster were sometimes inadequate, the state needed to construct additional institutions, in the form of famine-relief agencies, to redistribute surpluses both temporally and spatially to communities affected by shortages.

Neither the ecological nor the administrative problems of the North China Plain were new to the Qing regime, but the Qing had to deal with these problems while the population of the region swelled as never before. Population figures for the beginning of the Qing are not reliable, but between 1749, when we have our first believable counts, and the end of the dynasty in 1911, the population of Zhili (modern-day Hebei) about doubled, from approximately 13 million to at least 26 million (Li 2007: 77; Perkins 1968: 212), and it is likely that the figure at the beginning of the dynasty was considerably less than the 1749 count, indicating that the population probably tripled over the entire course of the Qing. Comparable figures for Henan are 12 million in 1749 and 36 million in 1893 (Perkins 1968: 207, 212); Shandong shows somewhat less of an increase, from 24 million in 1749 to 37 million in 1893 (ibid.); if we add the three major Plain provinces together, we find an increase from 49 to 99 million over the course of the last century and a half of the Qing.

Perhaps the most remarkable thing about this story is that the Qing managed to accommodate population growth successfully for the first hundred-plus years of its reign. It kept the water system in reasonable repair and maintained the buffer institutions that prevented famine when extreme weather events struck locally or regionally. In other words, they managed simultaneous increases in productivity and resilience, as shown in Figure 2.9. But in doing so, they turned up the Malthus-and-Boserup ratchet and set the stage for the region to cross the line between plenty and misery once again in the late 1700s and early 1800s, into the territory of flood, drought, famine, and eventually rebellion. 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).”

There were two main elements to Qing management of the North China Plain socio-ecosystem: maintaining infrastructure to prevent extreme rainfall events from turning into floods, and mobilizing famine relief when floods happened anyway, as well as in times of drought. Infrastructure in this case meant mostly diking and dredging the River, and maintaining navigation on the Grand Canal. There were two philosophies of diking: the first method was to make the dikes wide and low, and build an outer system of parallel dikes in case of overflow; the zone between the inner and outer dikes served as a retention basin, in effect an infrastructural buffer, and excess water could serve for irrigation. But this method slowed the flow of the water, increasing the rates of siltation that caused the problem in the first place. The other philosophy was to build the dikes more narrowly, so that the River would flow faster and scour some of the sediment; but it also meant expending even more effort and funds on maintaining the dikes, which would be subjected to increased water pressure in high-flow seasons. And scoured sediment did not always reach the sea, meaning increased buildup downstream and sometimes backed-up floodwaters (Leonard 1996: 10-18).

In addition to dikes and drainage basins, the Qing also supervised the construction and maintenance of canals throughout the North China Plain region, not only the Grand Canal for transport, but also local canals for drainage (ibid.: 18-23). Maintaining all these waterworks depended on efficient coordination between state agencies, which took on large-scale projects, and local communities, who maintained the local waterworks.

Even more than infrastructural maintenance, the Qing system of famine prevention and relief, was dependent on state-community collaboration through granaries, price controls, and redistribution in hard times. Drought was difficult to prevent, and could sometimes last several years (**Li 2007:** 131-32). Floods, though they could be partially prevented by the efficient diking and draining methods described above, sometimes overwhelmed the system, and did so suddenly. When either of these calamities happened, the redistributive apparatus could swing into action. It consisted of several elements. To begin with, all counties maintained granaries for purposes of famine relief. They were supposed to be replenished yearly with new harvests ,to keep the old, stored grain from rotting and being wasted. When they detected a poor harvest, local officials were required to notify the imperial center, reporting both the degree of harvest shortage and the anticipated needs of communities for relief. After imperial approval, local governments were authorized to distribute grain for consumption or for the following year's crops, or to sell grain at below-market prices to supplement supplies and discourage speculation that might drive prices out of range of poor, starving people. County authorities were also to establish shelters with provisions for famine refugees, and to distribute seed grain so that the next year's planting could proceed on schedule and so that refugees would return to their homes to farm their land as soon as was feasible (Li 2007: 221-49).

These measures usually worked, in the 18th century. For example, in the major drought of 1741-43, which severely affected over 30 counties in Zhili and others in Shandong, there was very little loss of life, because state-organized famine relief proceeded according to plan (Li 2007: 236-41). It is clear that the system worked because of both infrastructural and institutional measures. Infrastructural measures to increase productivity, such as flood control, were combined with measures to boost resilience, such as drainage basins. Thestate and local communities were also able to construct effective institutions that allowed communities and regions to deal effectively with disturbances in the form of extreme weather events (and also non-weather disturbances such as locust plagues). 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 the gradual chipping away at 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, a tributary of the Hai that runs through Beijing; and the court became aware over the next few decades that more and more people in Zhili, Henan, and Shandong were living too near to rivers or lakes, on land that was fertile but subject to flood. 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). As we shall see, this was a problem hardly confined to the North China Plain.

Another major factor in the decline of resilience was decay of the institutions for famine relief in the 19th century. A combination of increased population and growing inefficiency of tax-collection procedures meant that 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 matters of more immediate concern than the 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). The entire socio-ecosystem deteriorated between 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." Famines killed an estimated 10 million people in the north and northwest of the Agrarian Zone, including the North China Plain, in 1920 and again in 1928-30 (Pietz 2015: 81), and another two to three million perished in Henan in 1942-43, a disaster dramatically reported by Theodore White and Annalee Jacoby in *Thunder out of China*:

> The smaller villages were even worse than the market towns. The silence was frightening…The villages echoed with emptiness; streets were deserted, compost piles untended waiting for spring, doors and windows boarded up. The abandoned houses amplified the slightest sound. A baby crying in a hidden room in a village sounded louder than the pounding of our horses' hooves…There were corpses on the road. A girl no more than seventeen, slim and pretty, lay on the damp earth, her lips blue with death; her eyes were open, and the rain fell on them. People chipped at bark, pounded it by the roadside for food; vendors sold leaves at a dollar a bundle…the strong had fled earlier; all who were left now were the old, the weak, and the few hardy characters who were staying to guard the spring wheat that would soon be in full growth. The people were slicing bark from elm trees, grinding it to eat as food. Some were tearing up the roots of the new wheat; in other villages people were living on pounded peanut husks or refuse. Refugees

> on the road had been seen madly cramming soil into their mouths to fill their bellies…[White and Jacoby 1946: 169-71]

The Lower Qiantang River Watershed: Building and Destroying Resilience. The Qiantang River rises in the Yellow Mountains on the Anhui-Zhejiang Border, flows in to the Qiandao ("Thousand Island') Reservoir, constructed in the 1950s (**see chapter xx GLF**), traverses the western parts of what is now Hangzhou Municipality, and debouches into Hangzhou Bay below Hangzhou, the provincial capital of Zhejiang. The river in its lower reaches is tidal, and the spectacular bore that forms below the city of Hangzhou and roars upstream past the city at high tides is a major tourist attraction; there is now a festival held on the 18th of the 8th lunar month, when the tides are likely to be at their most spectacular (Baike.com 2013).

The lower watershed of the Qiantang has a long history of settlement, and as early as the Tang period its dense population was highly dependent on waterworks. Hangzhou served as the imperial capital of the Southern Song from 1132-1280, and during this time population intensified, along with the infrastructure that enabled agricultural productivity to rise to a level that could feed a major city. From that time on, clear to the end of the Ming, seawalls on both banks of the river were repeatedly built and breached by new configurations of river and tidal flows (Elvin 2004: 144-150). During the Qing, similar forces were at work; marine sediment deposition on one bank of the river caused changes of course in both the river flow and the incoming tides, and endangered the opposite bank. There was thus a battle between waterworks, built to increase agricultural production and protect newly-opened or vulnerable lands from incursion by the sea, and the relentless forces of rivers and tides. The battle was a long-term draw: shorelines shifted, rivers changed course, and waterworks produced short-term productivity gains, which never lasted very long.

Maintaining this standoff, keeping the waters at bay, required continued and repeated feats of hydraulic engineering, as Zhejiang's population nearly tripled from 11 million in 1749 to 30 million in 1851 (Perkins 1969: 207). Combined with continued urbanization of the entire lower Yangtze region in the Qing period (Skinner 1977a), failure of these engineering works had disastrous consequences for local agriculture and food security. Cuts in the maintenance budgets for locks on the rivers draining into Hangzhou Bay and the seawalls at the mouth of the river could cause breaches, which would drown low-lying farmland. The whole region thus remained in a state of what Elvin (2004: 162) calls "technological lock-in," what in the figure 6.1 labels the conservation phase of the adaptive cycle. Long after ecological buffers have been eliminated or severely reduced by production intensification (which happened in the Qiantang region well before the Qing), infrastructure and the social and fiscal mechanisms required to maintain that infrastructure are the only buffers against disturbance turning into disaster.

Within Qiantang watershed, but at a much smaller scale, Xiang Lake has been the site of disputes over the relative desirability of increasing economic production vs. maintaining ecosystem buffers and thus resistance (Schoppa 1989). Originally constructed in the 1110s on the approximate site of a previous natural lake that had silted up a few centuries earlier and had been turned into farmland, the lake has gone through repeated cycles of production intensification and retreat to more resilient landscapes (Schoppa 1989: 10-13). Original construction of the reservoir flooded about 2Kha of farmland in the previous lakebed, but compensated for this by reliably irrigating about 10Kha of land and also providing the important ecosystem service of flood control. In balance, the lake rendered the local agricultural area both more productive and more resilient to flood and drought disturbances. At the same time, it rendered the dense population of the area dependent on maintaining the infrastructural and institutional buffers that kept the lake functioning.

From a few decades after it was built (Schoppa 1989: 16-25) clear through until the early People's Republic, Xiang Lake was the site of struggles between community and private interest. Attempts to encroach on the lake's margins and create more farmland were resisted by officials and local gentry concerned with maintaining the lake's ecosystem services. The Qing period was no exception. The first ecological crisis came in 1689, when private interests built a dike across the lake and reclaimed part of its lower portion, aiming to use the lakebed to dig clay and build kilns for making tiles. This followed two earlier incidents of diking and reclamation in various parts of the lake; a legal case finally led to the destruction of the new dikes and restoration of the lake's area (ibid.: 105-109).

The demographic and technological progress of the High Qing period, however, brought a different kind of challenge to the ecosystem services provided by the lake, indicating again the problems caused by overshoot in times of plenty, which led to population pressure, impoverishment, and increasing temptation to put short-term livelihood gains ahead of long-term ecosystem sustainability. There were several manifestations of this. One was encroachment on the lake by poor households attempting to secure livelihoods by living and farming on former lake land. A second was slightly wealthier families using the land to dig clay and built tile kilns (ibid.: 124). A third was wealthy families' building private outlets in order to divert the lake's irrigation water to one's own land and disturbing the equitable distribution through the community-maintained public outlets (ibid.:134). A final harmful practice was gathering aquatic grasses for fertilizer, which loosened the soil of dikes and may have contributed to eutrophication of the lake (ibid: 135). Schoppa's otherwise outstanding monograph attributes the increase in threats to the lake's functioning primarily to what we would call the decline in institutional buffers—the inability of public spirit to overcome private interests. However, I would maintain that the institutional buffers themselves were not strong enough to overcome the pressure of increased population during the flourishing of the High Qing and the subsequent half century—in Zheijiang from 11 million in 1749, when figures become directly accessible, to 30 million in 1850—on the eve of the Taiping rebellion (Ye Jianhua 1999, Ho 1959: 246).

The Taiping insurrection, which came to Zhejiang only late in its history, after 1860, struck the final death blow to the lake. Though the insurrection temporarily relieved population pressure (estimates range as high as 40% mortality in the areas near Hangzhou), the damage had already been done by three severe floods, in 1850, 1861, and 1865, that damaged the entire system of waterworks of which Xiang Lake had been a part. The rehabilitating society from 1864 on was never able to mobilize the labor or the will to reconstruct the system of waterworks, and by 1900 Xiang Lake was reduced to a rump system, limping along until 1952, when the PRC government decided to eliminate it altogether and reclaim the remaining 600 ha for agricultural land (Schoppa 1989: 229-230).

But Xiang Lake Lives. Currently, it has an area of about 1000 ha, and is the site of such tourist attractions as the Hangzhou Polar Ocean Park, the Xiang Lake Scenery City, and the Xianghu Tourism Resort, which recently garnered a 4-star review on Google Maps. It is trumpeted by Chinese encyclopedists as a major archaeological site that has yielded among other things the world's earliest dugout canoe (Baidu: Xianghu). This later story of restoration, however, must wait for its proper context, as part of the narrative of environmental "restoration" in the 21st century.

The Dongting and Poyang Lake Areas: Short-term development, desperation, and short-sightedness.

Dongting and Poyang might be called China's Great Lakes; they were once the two largest freshwater lakes in China's Agrarian Zone, each with surface areas at flood stage estimated at of over 6000 km^2 (Bian 2011). Dongting Lake lies in a flat plain in the north part of Hunan, south of the Yangtze River, and is fed by the Xiang, Ci, Yuan, and Li Rivers draining off the northern slopes of the Nanling Range, which separates the Lingnan from the Middle Yangtze macroregions, and the eastern slopes of the Wuling range, which marks the eastern edge of the Yunnan-Guizhou Plateau. A complex network of rivers and canals forms the outlet of the Lake and connects it to the Yangtze. The gradient between the lake and the Yangzi is extremely gradual, so that depending on the season, as the volume of both the Yangtze and the feeder rivers to the south rises and falls, the level of the lake surface is higher or lower than that of the great River, and accordingly water flows either from Dongting to the Yangtze or vice-versa (He and Bian 1983: 465c). Poyang Lake lies similarly situated in north Jiangxi, fed by the Gan, Xiu, Rao, Xin, and Fu Rivers, and the flow also alternates between it and the Yangtze, to which it connects directly, depending on the river flow and the lake level at particular times of year (Q. Hu et al. 2007).

There is evidence that two thousand years ago, Poyang was not really a single lake, but rather a swampy landscape crisscrossed by rivers and lakes in an ever-changing pattern (Tan and Zhang 1982: 43); the Dongting region was similar (Bian 2011). Over the course of history, the size of the lakes rose and feel with a combination of natural changes and a cycle of construction and neglect or purposeful destruction of waterworks. In early Ming Hunan, people living along the margins of these swampy areas fished in the lake and gathered reeds for fuel and weaving into mats (Perdue 1982: 752). Hunan was not heavily populated at the time; Jiangxi had a denser population, and areas around the north margin of the lake, such as the provincial capital of Nanchang and the pottery and porcelain center of Jingdezhen already had flourishing industrial and commercial economies, to go with rich rice agriculture.

In the Ming period, population growth accelerated in Hunan, and people began to encroach on the lake margins. They first began cultivating the surrounding wetlands during the relatively dry spring season, building temporary huts and trying to harvest a crop in the springtime before the summer floods brought water into the lakes from both directions (ibid.). As population increased more, they began diking off areas to build polders where they grew rice in the summer flood season, for both local consumption and export (ibid.). This polder-building reduced the surface area of the lake. In addition, intensified forestry in the upper watersheds of both lakes increased the sediment flow into the lakes. These twin processes, while they contributed to the economic growth of the regions, reduced the area of the lakes, making flooding more likely, and rendering local communities dependent on the dikes as infrastructural buffers, and elaborate local governance structures as institutional buffers to reduce the chances of disastrous floods.

Both lake regions experienced an ecological respite in the demographic and economic downturns of the Ming-Qing transition, and many places around Dongting reverted to partial wetland status as people moved out, many of them to Sichuan (ibid.: 754). But as the economic prosperity of the High Qing period began to accelerate, the ecological changes proceeded at a faster rate than even in the previous dynasty. In just five counties around the southern rim of Poyang lake, perhaps 300 km^2 of previous lake surface was converted to paddy fields by the mid-19th century (Wei 2010: 97). Deforestation upstream, cutting trees for purposes as varied as charcoal manufacture, papermaking (Chen Anchun 2001), shipbuilding, lumber export, and fuel for the kilns of Jingdezhen and other pottery centers, greatly increased runoff and thus sediment transfer to the lake. This caused both a rise in the lakebed level and the formation of lot of sandbars and islands, further reducing the surface area and capacity of the lake and thus the volume of water it could hold at flood state could hold at flood stage, and increased the incidence of flooding. Wei (2010:98) estimates that the frequency of floods and droughts in the Poyang region increased from once every 19 years during the Tang (essentially before the lakescape was substantially altered at all), to once every 4.7 years in the Song, once every 2.6 years during the Ming, and every 1.1 years in the Qing. Floods increased drastically despite the construction of hundreds of flood-control dikes in the low-lying counties near the lake.

Around Dongting, similar processes occurred. Because Hunan was severely depopulated in the Ming-Qing interregnum, landowners in Xiangyin County which covers much of the east-central part of the Lake, did not begin building dikes until around 1690 (Perdue 1982: 756). When polders were enclosed and farmed, local communities had the responsibility of maintaining the dikes, but by 1747 so much land had been enclosed in polders that two successive provincial governors attempted to stop it. They were relatively unsuccessful, however, because once dikes had been built and farmers moved in, they were dependent on the fields created, and could not be moved without endangering their livelihoods (ibid.). Even a compromise suggestion by one official, that old polders be allowed to remain but no new ones constructed, was ignored, and by the end of the century, many of the dikes had been.

By the late Qing, then, as on the North China Plain, agricultural intensification in the Poyang and Dongting Lake basis, which had been so successful in the early part of the Dynasty, came back to bite local communities and officials alike in the 19th century. Rice agriculture had been the engine of growth of both the subsistence and export economies for about a century, but eventually the economy overshot the carrying capacity of the basins. The construction of polders had eliminated the wetlands as ecological buffers early in the process, rendering the population dependent on both the infrastructural buffers provided by the dikes and the institutional buffers embodied in the mechanisms of local governance and state supervision. But as the Qing state weakened under the pressure of an exploding population and a decaying bureaucracy, and eventually under the weight of major rebellions (themselves caused largely by deteriorating livelihoods in several regions), and as local governance institutions came under ever greater strain from pressure on resources and declining infrastructural buffers, the floods came.

The first serious floods in Hunan occurred in 1831, and then every summer for 50 years there was flooding somewhere in the Dongting Basin. At the same time, dikes along the Yangtze to the north of the River also failed. The largest flood of all occurred in the Republican times, in 1931, covering almost all of Hunan, and it was blamed on siltation that had blocked the drainage channels out of the lake (Perdue 1982: 757). In Jiangxi disasters also became ever more frequent. Averaged over the whole dynasty, there were 62 serious floods during the Ming, but 157 over the course of the Qing. More interestingly perhaps, there were 41 *droughts* during the Ming and 86 during the Qing (Wei 2010: 97). This was not a matter of different weather, but a measure of the degree to which social-ecological systems had lost resilience, so that lesser and lesser weather events turned into human disasters.

Yuan critique of Song waterworks construction 射小利、害大谋, 急近功、遗远患

The Chengdu Plain or Western Sichuan Plain

There were, however, intensively farmed systems in China Proper that partially escaped this cycle of intensification, loss of resilience, and collapse. Primary among these is the Chengdu Plain or West Sichuan Plain, situated at the western extremity of the Sichuan Basin, below the foothills of the Min Mountains that are the easternmost range of the Tibetan Massif. The Plain is flat as a pancake from south of provincial capital of Chengdu northwest to the city of Dujiangyan, named after the waterwork that directs irrigation water and deflects flood waters from the fertile agricultural plain. The Dujiangyan was constructed by the engineer Li Bing and his son Li Erlang, beginning in 256 BCE, and turned what was originally an inland delta mosaic of farmland and wetland into a wholly agricultural area, enabling the Qin kingdom, which had conquered the area a few decades before, to produce a grain surplus to feed an army, sometimes estimated at half a million men, and accomplish the military conquest of most of the Agrarian Zone and form the first imperial government of China in 221.

The city of Dujiangyan was formerly known as Guan County, Guan 灌 being the Chinese word for “pour.” Before the Dujiangyan was built, the Min River poured a large volume of water (today over 90 km^3, or more than twice the amount moved by the South-North Water Transfer Project), with a maximum flow of 7000 m^3/sec, out of the mountains to the north and onto the plain, causing seasonal flooding over much of the Plain with the summer rains (Zhang Shanghong et al. 2013: 539). The Dujiangyan put a stop to that by creating an infrastructural buffer against seasonal changes and even massive storms. Its workings are complex, but in simplified form, Li *père et fils* dredged two sides of what was originally a sandbar in the middle of the river to different depths. The so-called Outer River or *waijiang* is broad but shallow, and the Inside River or *neijiang* is narrow but deep. In the drier weather of winter and spring (there is no really *dry* season in Sichuan), all the water pouring out of the mountains flows into the Inner River. There any remaining excess flows across a spillway, called the Feisha Yan (Flying sand weir) that has two functions: it helps sediment settle out, meaning that little sediment is deposited downstream in the irrigation canals, and it discharges excess water back into the Outer River (Shanghong Zhang et al. 2013). The water that remains in the Inner River goes through an artificially constructed bottleneck (called, in Chinese, Baoping Kou or Bottle-mouth) and then into a web of irrigation ditches that fans out over the plain, extending to the city of Chengdu and beyond, and can be used to irrigate an estimated 680Kha of farmland, growing the spring crop of rapeseed that furnishes the majority of lipids in the traditional Sichuanese diet (ibid: 539). In the late spring and summer, when the rains come to the Min Mountains and the volume of the river swells, its surface rises to a level where much of the water flows into the wide but shallow Outer River, from whence it is diverted harmlessly around the agricultural areas, while the remaining water in the Inner River irrigates the summer rice crop that supplies the majority of calories. The Dujiangyan thus increased both the productivity and the resilience of the Chengdu Plain agro-ecosystem.

The Dujiangyan itself is a low-maintenance apparatus, with no moving parts, and requires primarily that the tip of the divider between the Outer and Inner Rivers, called the Yuzui or Fish Mouth, be reinforced against the force of the onrushing river, usually accomplished with riprap (Xiang 2014). In addition, every winter accumulated sediment must be removed from Feishayan. The irrigation network also requires yearly dredging. In imperial times, dredging the main canals, which required larger teams of workers, was managed by local officials, while the smaller branch canals were dredged by local communities (Keke Li and Xu 2006: 55; Cao et al. 2010: 10). And downstream of the Dujiangyan itself, there is nothing above grade such as dikes, and nothing mechanical such as sluices, that will go wrong if left unattended for a short time.

The population of the Chengdu Plain has fluctuated along with that of the Sichuan Basin as a whole over the course of the history of Agrarian China, and at the beginning of the Qing Sichuan was quite severely depopulated by the depredations of the warlord rebel Zhang Xianzhong (Ho 1959: 139).[2] As part of the effort to repopulate the area, beginning in 1669 the Qing court implemented policies to encourage repopulation, lowering land taxes for both families who had fled during the troubles and new immigrants from the middle Yangtze and Lingnan regions (Fang and Zhou 2011: 84). During the time of depopulation, the Dujiangyan fell into disrepair—the Baoping Kou was blocked and the main channels of the Inner River were not transporting water. In order to provide irrigation for the newly resettled lands, the provincial government undertook a large-scale

[2] How severely it is apparently impossible to figure out; debates continue to this day.

repair project, lasting from 1681 to 1706, and restored the irrigation works to full functioning, providing irrigation for lands being settled by new and returning immigrants (ibid.).

Incentives for migration and restoring the irrigation system set the stage for renewed population growth. Lee and Wang estimate that 10 million migrated from the middle Yangzi to the Upper Yangzi macroregion (in administrative terms, Sichuan) in the early Qing (Lee 1999: 119), and there were migrants from Lingnan as well. Chengdu prefecture, in the middle of the Chendgu Plain, had a population estimated at only 695,000 in 1728, but was already 3.8 million in 1812. This appears to have been close to the maximum carrying capacity; in 1910 the population of the prefecture had grown only to 4.12 million, as migration spread to nearby areas, including the foothills of the surrounding mountains (Fang and Zhou 2011: 85). Population figures for the entire region in the 18th century are, unfortunately, not reliable,[3] but there were 44 million by the mid-19th century (Ho 1959: 142; Perkins 1969: 207).

Still, even with a bigger population increase over the period of the Qing (because of the low baseline), the Chengdu Plain appears to have escaped the extreme decline in resilience that happened in so many of our other cases. Visitors to the area in the late 19th and early 20th centuries commented on both its prosperity and its ecosystem health. Baron Ferdinand von Richthofen (an uncle of the WWI flying ace) visited the area in the early 1870s**,** and his impression is worth quoting at length:

> This big city lies in a plain that is actually not very broad, but hardly can find its equal in fertility and density of population or advantageous natural relations anywhere in the temperate zone. In a circumference of 18 [German] miles are 18 cities, of which I have seen three. The land between them is thickly settled with courtyards and groups of houses, each surrounded with Bamboo brush and cultivated trees. Nature and art have made the plain into a model of irrigation works…in the northwest corner a mighty, water-rich river breaks out of high mountains, which, as soon as it reaches the plain, divides into several branches. [Richthofen 1907: 255-56]

Mrs. Isabella Bird Bishop, an English adventurer and travel writer, commented in a similar fashion upon a visit to Guan County in 1897:

> From any height the plain looks like a forest of fruit trees, while clumps of cypress, cedar, and bamboo denote the whereabouts of the great temples and fine farmhouses, with which it is studded.

[3] Ho 1959: 142 gives a figure of 8.5 million in 1776, and states that most of the migration took place before 1850. If we calculate a rate of natural increase of 2% per annum between 1774 and 1850, that would bring the population to 36.3 million, which would still require 8 million immigrants *after* 1776 to bring the population to 44M. And 2% natural increase is extremely high for a society before modern public health measures. If we reduce the rate of natural increase to a more reasonable but still high 1.5%/year, that would bring the population as a result of natural increase to 30M, requiring 14 M to account for the 1850 population of 44 million. This suggests that the 1776 figure is too low, though it is impossible to know by how much.

> …Oranges reappear in splendid groves, mixed up with the vivid foliage of the persimmon; mulberry trees are allowed to grow to their full height and amplitude; spinning and weaving are going on everywhere; the soil, absolutely destitute of weeds, looks as if it were cultivated with trowels and rakes, "tilled," as Emerson felicitously said of England, "with a pencil instead of a plough."
>
> …This population of four millions depends not only for its prosperity, but for its existence, on the irrigation works of Li Ping and [his son]…Without these, as has been truly said, "the east and west of the plain would be a marsh, and the north a waterless desert," and this great area with its boundless fertility and wealth, and its immunity from drought and flood for two thousand years, is the monument to the engineering genius of these two men, whose motto, "Dig the bed deep, keep the banks low," had it been applied universally to rivers of insubordinate habits, would have saved the world from much desolation and loss." [Bishop 1899: II: 78-80]

Finally, American forester Norman Shaw described the plain thus:

> This portion is densely populated and carefully cultivated, this cultivation not being confined to agriculture alone, but extending to the planting of useful and ornamental trees such as the bamboo, tung, mulberry, cypress, varnish, and a variety of fruit-trees. The most important part of the Red Basin is the Chengtu plain, which has been described as the most densely [cultivated?] area of the earth's surface. The vegetation is in most parts of the basin of almost tropical luxuriance owing to the extreme dampness of the climate, which permits, in the Chengtu plain, an admirable system of irrigation. Seen from a height, the plain looks like a forest, for every farm has its grove of bamboo, cypress, palms, and fruit orchards while tung and varnish trees abound [Shaw 1914: 140-41] .

More strikingly, when we look at the history of famines in Sichuan, which as a whole was not spared through the ages, we find that the Chengdu area almost invariably got off lightly. In the Song dynasty, for example, there were 28 major famines recorded in Sichuan, but only three of these affected the Chengdu Plain, while 13 affected the immediately surrounding areas (Wei and Xu 2014: 61). When famines did happen, as in 1108 and 1114, the lack of water could be attributed to neglect of the yearly maintenance of the Dujiangyan (ibid: 63). In 1936-37, famine struck Sichuan hard, as a result of drought throughout most of the province, floods in the western part, and perhaps misgovernance by warlords, "Everywhere *but the counties of the Chengdu Basin* was disaster area" (Anonymous 2008: 51, Zheng 2001:55).

All these four cases of agricultural intensification and increased dependency on waterworks illustrate the same general lesson, namely that intensification, when it proceeds beyond a certain point, diminishes buffers and thus reduces ecosystem resilience. However, the nature of the infrastructural buffers created to replace ecological ones makes a difference. The North China Plain, Qiantang, and Poyang-Dongting cases all illustrate the control of water by means of dikes, sluices, and other above-grade devices. Failing to maintain this infrastructure, whether through conflict between public and private interests, lack of coordination between officials and local communities, or breakdown of governance structures, creates immediate vulnerability to natural events. Infrastructures washed away in floods, or allowed to fall into disrepair, cause catastrophic declines in yields when they give way, often leading to a vicious circle of desperation measures and further deterioration of the infrastructure. Productivity and resilience, though they are in inverse correlation, are both harmed by the same events. In the Chengdu Plain case, however, the whole irrigation system, as mentioned above, has no above-grade components. Its efficient functioning does depend on infrastructure and institutions of governance, namely regular maintenance of the irrigation ditches that course through the plain. There were a few famines caused by drought in the Chengdu Plain, but not very many, and even they can be attributed primarily to failures of governance.

Cultivating the Mountains: Deforestation, Soil Transport, and Hydrological Change

Within the Agrarian Zone, however, productivity increases were not the only means of dealing with an increasing population. There was expansion as well as intensification: much previous forest or grassland was converted to cropland during the Qing. At the beginning of the dynasty, there were many areas, particularly the mountainous margins between watersheds and provinces (on the peripheries of Skinner's physiographic macroregions) which had little or no agriculture. They were often forested, and of course they contained the headwaters of the tributaries of the major rivers that flowed through the lowlands. Many of these areas had been used for centuries in a kind of low-level resource production, with sparse populations extracting forest products and perhaps growing a bit of food for subsistence in the most favored areas near valley bottoms or on relatively level uplands. There had been times in the past when they were brought under more intensive cultivation, as with the Qinling and Daba mountains in the Han and Tang periods, when the imperial capital had been at Chang'an in the Wei Valley just north of the Qinling, but most mountains remained uncultivated until the middle or late Ming.

In these mountainous internal peripheries, the import of New World crops, including corn, potatoes, and sweet potatoes, (Perkins 1969: 47-51; Ho 1959: 183-90) made cultivating formerly forested mountains feasible, and thus prompted poor and landless people from densely populated lowland cores to migrate into these mountainous peripheries. But the productivity of these newly-opened lands could not last (see Figure 6.2). Not only were soil nutrients lost and not replaced, but in many places deforestation caused erosion of topsoils, so that people who had moved to these areas, brought new land under cultivation, and had lots of children to cultivate it, experienced a rapid loss of productive resources, exacerbated by the previous generation's high fertility, in the familiar pattern of overshoot of long-term carrying-capacity leading to a crossover from plenty into misery. In ecosystem terms, ecological buffers were eliminated or severely reduced, and there were few if any institutional or infrastructural buffers set up to replace them, so that the adaptive cycle in these regions was short, measured in decades rather than centuries from r to Ω, largely skipping K, and in many places remained in the Ω phase for many years after that, sometimes providing the manpower for rebellions, which constituted severe disturbances at larger spatial scales.

Deforestation is thus, as we shall see in the following case studies, the prime ecological mover in resource degradation in peripheral mountainous regions of the Agrarian Zone during the Qing. Near the beginning of the dynasty, much of China was still forested; Ling Daxie (1983) estimated that in 1700, there were about 198 Mha of forests in the directly administered area known as the 18 Provinces; if we exclude Guizhou and Yunnan, which lie mostly in the Upland Zone, the total was 166 Mha. By 1937, 26 years after the end of the dynasty, this figure was reduced to about 42 Mha, about a quarter of the area that was forested at the beginning of the dynasty. Over half of China's forests in the Republican period were now in Manchuria and the Upland Zone of the Southwest. Simply put, China Proper was virtually devoid of large forests, and in fact no longer had very many small ones.

Province	2700 BCE Mha (%)	1700	1937
Total	476 (49.6)	291 (26.1)	91.4 (8.12)
Hebei	15 (68)	5 (22.7)	0.12 (0.9)
Shanxi	10 (63)	3 (18.8)	0.97 (6.0)
Inner Mongolia	9 (20)	2 (4.4)	
Liaoning	16 (69)	3 (13.1)	1.25 (5.0)
Jilin	22 (76)	20 (63.9)	7.62 (27.0)
Heilongjiang	67 (93)	65 (90.3)	16.2 (28.0)
Jiangsu	7 (64)	0.5 (4.6)	0.27 (2.6)
Zhejiang	9 (90)	3 (30.0)	0.81 (8.0)
Anhui	9 (69)	4 (30.8)	0.71 (5.0)
Fujian	10 (83)	8 (66.6)	2.18 (18.0)
Jiangxi	14 (82)	8 (47.1)	2.01 (12.0)
Shandong	7 (46)	0.2 (1.3)	0.10 (0.7)
Henan	10 (63)	1 (6.3)	0.10 (0.6)
Hubei	15 (79)	9 (47.4)	2.36 (13.0)
Hunan	19 (90)	13 (61.9)	4.09 (19.0)
Guangdong	20 (91)	13 (54.5)	2.23 (10.0)
Guangxi	21 (91)	9 (39.1)	1.10 (5.1)
Sichuan	47 (84)	35 (62.8)	13.7 (34.0)
Guizhou	16 (89)	7 (38.8)	1.58 (9.0)
Yunnan	30 (79)	25 (65.8)	9.61 (23.0)
Tibet	10 (08)	3 (3.5)	1.81 (2.0)
Shaanxi	9 (45)	5 (25.0)	3.12 (16.0)
Gansu	45 (77)	20 (34.5)	2.28 (6.0)
Qinghai	10 (14)	5 (6.9)	1.45 (2.0)
Ningxia	5 (29)	3 (17.7)	
Xinjiang	20 (12)	12 (7.3)	8.21 (5.0)
Taiwan	4 (100)	3.6 (90.0)	
Xikang			0.94 (2.0)

Table 6.1: Estimates of Forest Cover by Province, 1700 and 1937 (Ling 1983:). Shaded provinces lie outside the extent of the Agrarian Zone as of the early Qing.

Almost all of the deforestation occurred in the hilly and mountainous areas within the Zone; the map in figure **6.x** presents a partial picture of the mountainous areas where deforestation and consequent erosion occurred: **When I go through and add cases, be sure to notice the Jiangxi ones quoted in the Poyang Lake article by 魏左国。**

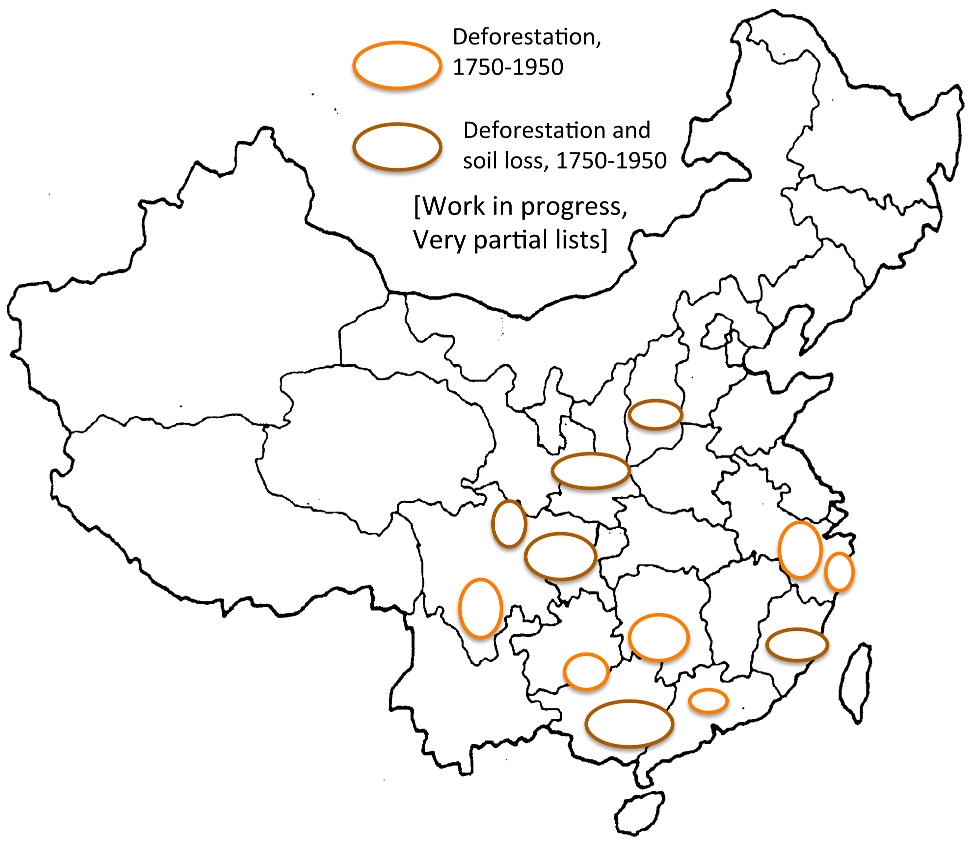


Figure 6.x: Preliminary map of mountainous areas recorded as experiencing deforestation and/or erosion between 1750 and 1950.

Everywhere that massive mountain deforestation occurred, it happened as a result of large-scale migration of poor people and refugees from overpopulated, overtaxed, and often buffer-busted lowland areas. And wherever it happened, deforestation set into motion a cascade of environmental degradation, including erosion (Lowdermilk and Li 1930), sediment transport, increased flooding, and watercourse changes. Three case studies from three very different mountainous areas will illustrate the process graphically:

The Qinling and Daba mountain region between Sichuan, Shaanxi, Hubei, and Henan

All over Northwest China, beginning in pre-imperial times an ecological system developed, characterized by intensive production in the plains areas, with the mountains providing ecological reserves and ecosystem services, particularly by keeping the hills forested.[4] The lowlands were cultivated very early on; in fact the lowlands in the Fen and Wei River valleys, along with the westernmost parts of the North China Plain where the Yellow River emerges from the loess highlands, were some of the earliest cultivated areas in China, where millet agriculture emerged in the Neolithic, supplemented by wheat in the first millennium BCE (Marks 2011: 32-33, 65, **d'Alpoim Guèdes et al.**). During that early era, however, forests of various sorts provided substantial ecological buffering. Gallery forests lined the rivers, deciduous forests covered most of the foothills, with perhaps brushier landscapes on the sunnier slopes, and the higher mountains were dominated by coniferous forests. The severely eroded areas that we see now as part of the Loess landscape (Von Richthofen 1870-72, quoted in Lowdermilk and Li 1930: 138; Liu Xin 2000: 4-5) were not there. So for the first few thousand years of human occupation the forests on the mountainsides performed an important function—they trapped the rainfalls of summer and early Autumn, as both the leaves of the canopy and the litter on the forest floor broke the fall of raindrops and allowed water to seep slowly into the soil, keeping runoff to a minimum, in rivers that did not flash very much.

Because of climate change and population growth and concentration during the Qin-Han period, however, people began to cultivate more arid areas or and areas that became more arid. The result was the beginning of erosion on the desiccated parts of the Loess Plateau. This continued in the Tang when center of population and political power was again in the Northwest, with capitals at Chang'an in the Wei River Valley and Loyang at the western edge of the North China Plain.

At the beginning of the Ming, however, much of the area was still forested, including all the important mountain ranges that were the sources of the Wei, Han, Fen, and other rivers (Ling 1983, Liang 1994, Zou 1998). The Qinling range, which separates the Wei from the Upper Han drainage, still had many old forests (Zhou Yun'an 1993: 58). Large numbers of refugees from Anhui, Shandong, and Shanxi began to move into the Qinling foothills during the Ming—the higher mountains remained sparsely populated—and rented land from locals, first in W. Henan (whose underpopulated areas were quickly filled up), and then particularly in the Han river headwaters in northwest Hubei and southern Shaanxi. Before the 16th century, they mostly grew oats and buckwheat—yields were low but there was much land (Zou 1998: 63). But after the introduction of corn and sweet potatoes, these became major crops, and when grown on virgin, newly deforested soils, it was reported that you could "sow one grain and reap a hundred" (种一收百) (Liang Sibao 1994: 83, Zhou Hongwei 1999: 11).

Migration accelerated greatly with the Qing, promoted first by the migration policy of the Kangxi Emperor, and then by people fleeing disasters and famines (again, from Anhui, Shanxi, and Shandong). Particularly after mid-Qianlong, they began to pour in—in the Jiaqing period Zhuo Bingtian estimated there were already several million

[4] There is, however extensive debate over the extent and type of forests, particularly in the Northwest, in pre-imperial times (Menzies 1994: 15-19).

immigrants in the mountain areas (cited in Zhou Hongwei 1999: 11), and Zhang and Hui (2006:14) call this "the area of our country where corn cultivation was the most common and the most concentrated"—setting in motion a rapid process of serious and rapid environmental degradation, which came in three steps.

The first step was deforestation, clearing the land so that refugees could make a living, mainly by 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, but merely to add the ash from burning to enhance the natural fertility of the soil and 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 after the ash from the original burning was used, the intensively grown crops quickly exhausted the soil nutrients. Second, as detailed below, erosion followed deforestation, and whatever nutrients remained after a few years of intensive cultivation were then washed away. When the soil fertility was exhausted, farmers moved on to the next area and repeated the process. Whole counties went from forested to denuded in the space of decades (Zhou Yun'an 1993: 62).

Secondary causes of deforestation were lumbering, mainly in the mountainous peripheries of the Hanzhong and Ankang region on the south flank of the Qinling and the north flank of the Daba Mountains on the other side of the Han River. In the mid-Qing, loggers floated the larger logs out on the Han, sawing smaller timbers into boards to be used locally, and used the smallest wood for fuel or to feed paper mills (Liang Sibao 1994:83; Zhou Yun'an 1993: 62). Where primary forests were logged but not farmed, seven or eight years later enough small trees could be used to make charcoal to fuel nearby iron mines and lime kilns, but many mines in Xunyang, on the south flank of the Qinling range in Ankang prefecture, closed after the early 19th century because of a lack of fuel (Liang 1994: 83). The process happened somewhat later on the drier, less productive northern slopes of the Qinling, but from the mid-19th century to the end of the dynasty, lumbering and paper industries exploited and then exhausted the forest resources suitable for lumbering and papermaking in the northern counties (Zhou Yun'an 1993: 63).

A minor cause of deforestation was fungus cultivation: both wood ears (木耳)and mushrooms （香菌）were grown on wood frames, often cut from relatively valuable species such as oak, chestnut, and catalpa (Liang 1994: 83).

The second stage of environmental degradation was erosion, which was very apparent by the mid-Qing. Without the protective cover of trees, summer rainstorms washed away the fertile topsoil, leaving much less fertile subsoils (Liang 1994, Zou 1998). After the forest cover had been cut, erosion accelerated. In heavy rainstorms sometimes even large rocks were washed downhill in avalanches and landslides, so that loss of topsoil due to erosion compounded the effect of nutrient depletion from agriculture to make farming impossible, causing people to move on to clear another mountain. Lowdermilk and Li estimated, based on studies in Shanxi in the 1920s, that runoff from denuded sloping lands was at least fifty times the runoff from vegetated slopes (Lowdermilk and Li 1930: 140)

But of course soil once eroded does not just disappear; it moves downstream as sediment, and is eventually deposited, mostly in river beds, bringing about the third stage of environmental degradation, hydrological changes. With their banks no longer protected by vegetation, streams began to carry heavy sediment loads. These would both dam rivers and block irrigation canals (Zhou Yun'an 1993, quoting Liuba County gazetteer), with many disastrous results. In the Ankang area, at least three formerly navigable rivers, the Yue, Ren, and Xun, were no longer passable by mid-19th century (Liang 1994: 83). Also many silted-up irrigation systems caused farmers to abandon rice cultivation, the most productive type of grain agriculture in much of the Hanzhong region, thus putting further pressure on the remaining agricultural fields (Zou 1998: 67). Eventually sediment transport raised the level of river beds in tributaries and even in the Wei River itself, which migrated 2.5-4 km northward between 1900 and 2000. Finally, the frequency of floods in the Wei River valley increased steadily after 1810, so that by the 20th century they occurred almost yearly, more often than at any other period in history. And such floods when they did occur had greater detrimental effects on human welfare, since the population was increasingly dependent on the output of marginal agricultural lands (Yin et al. 2005).

The Mountains of the Jiangxi-Zhejiang-Anhui border

The Huaiyu, Qianligang, and Huang (Yellow) mountains in the border region where Jiangxi, Zhejiang, and Anhui converge form part of the watersheds between the Qiantang River and Poyang Lake watersheds, whose downstream portions were described in previous sections, and between the Qiantang and the Yangtze. These ranges were somewhat deforested as early as the Song, through a combination of processes including clearance for agriculture, commercial and state logging, fuel-cutting for pottery and porcelain manufacture, and papermaking (Chen Boquan 1985: 210): Yushan County in the heart of the Huaiyu range was one of China's largest papermaking centers (Wang Anchun 2001). But partly because of reforestation during the Yuan, these areas still retained considerable forests at the beginning of the Ming. During the early part of the Ming, however, they experienced considerable deforestation. Large trees (some of them reported to be 600 or more years old) were logged and used in constructing the new dyansty's capitals, first at Nanjing and then at Beijing, and in the Yongle period in the early 1400s, to build the large ships for the maritime fleets of Zheng He (Chen 1985: 212-13). And Yushan was reported to have had 500 paper mills by the end of the Ming (ibid.: 67). Still, at some level, it appears that logging in this area had been sustainable before the Qing, since large logs continued to be extracted for several hundred years, and in fact an official logging ban was imposed in Yushan county in 1601.

The most important changes came in the late Ming and early Qing, after corn and sweet potatoes, both New World crops, were introduced from Fujian. This made cultivation possible in these mountains. And several phenomena in the lowlands generated pressure to migrate; desperate people were willing to take advantage of this opportunity. First, in the Ming-Qing transition, there were many refugees, primarily from lowland parts of Jiangxi and from Fujian. Second, beginning in the Yongzheng and Qianlong periods, prosperity brought population overshoot in lowland areas, forcing people to seek cultivable land in the mountains. Third, the Taiping wars in the mid-19th century also caused devastation in the Zhejiang lowlands, driving even more people into the already severely compromised mountain environment. Thus mountainous areas, where resource extraction had already exerted considerable pressure, received the added stress of intensive cultivation of previously forested slope land. This set in motion a sequence of "when the wet fields are exhausted, farm the dry fields; when the dry fields are exhausted, farm the mountains [田仅而地地仅而山 (ibid: 210)."

The immigrants from impoverished and lowland areas moved into these mountains to cultivate corn and sweet potatoes, often renting land from local landowners on three-year contracts, living in temporary shelters and thus earning the name of "shed people" (棚民)。 Corn cultivation in particular (Zhang and Hui 2006) set off, in turn, the familiar succession of cultivation, abandonment, erosion, and hydrological changes. The 1879 gazetteer for Wuning, slightly to the west, describes this process nicely: "the shed people clear the mountains…the soil is rich and their yields multiply by ten. Then when there are big rains, the creeks and rivers overflow, and after just over a decade there is no fertile soil left; the strength of the ground is exhausted." When the ground was exhausted, "when they had completely consumed one mountain, they would move on to another mountain" (Yan Xiaohong 2011: 86).

But even when the shed people moved to different mountain and built a new shed, the environmental results of their short-term cultivation remained for decades. The most obvious one was local erosion, rendering the area no longer fit for cultivation. In Qimen County in Anhui, every time there was a major storm in the mountains, "The mountains slid and gullies opened; the rocks moved and the sand rode them (山崩土裂, 石走沙驰)" (Zhang and Hui 2006:18, quoting 环溪王履和堂养山会簿); "when the rains were concentrated, the sand and the rocks descended together (雨集则砂石并陨)" (ibid, quoting 祁门县志).

But downstream effects were at least as serious, effecting both rice cultivation and water transport. Again from Qimen, the Tongzhi period gazetteer complains that "Nearby wet fields in recent years have had discharged sand and formed gullies because of clearing the mountains (其临溪田亩, 近年山垦卸沙 成壑)" (quoted in ibid.), and similar effects were reported in northwestern Zhejiang, where an early 19th-century treatise on waterworks pointed out that the only way to solve the problem of siltation in downstream irrigation works was to prohibit land clearing upstream (Yan 2011: 86).

The effect on downstream river transport was perhaps even greater. In Yi County, Anhui, when land was rented out for corn cultivation, and no grass or other land cover was left, "Water ran down the hillsides, from the creeks into the streams, so that after clearing sand brought rocks with it, and this blocked up the rivers, so that boat traffic had trouble getting through, (Zhang and Hui 2006: 20), and in neighboring Qimen, the road through the Dahongling Mountains was piled up with sediment coming down from uphill clearings and rendered difficult to pass (ibid: 18).

Responses to Deforestation and Erosion

The connection between New World Crops, hillslope cultivation, erosion, sediment transport, waterworks damage, and disruption of both river and land transport is not difficult to see, and the two foregoing case studies could be multiplied by examining just about any mountain region within China Proper. In fact, as Zhang and Hui point out (2006: 19-20) in all upland regions where corn and sweet potatoes replaced forests (even forests previously heavily exploited for timber and other resources), local and provincial-level officials became aware of the problems, particularly beginning in the early 1800s, and proposed a series of measures to alleviate them. These included prohibitions on disturbing the Feng-shui of graveyards in the vicinity of upland cultivation, prohibitions on new land clearances, a combination of prohibitions on renting land to Shed People and forcing the Shed People to leave an area altogether, and a combination of prohibiting corn cultivation and switching to other, usually perennial crops (such as tea and fir trees) that would have less destabilizing effect on soil than would cultivation of annual field crops. The government of Huizhou prefecture, which included most of the mountainous areas in southern Anhui, issued just such a regulation in 1807. Also, in some areas such as Kaihua County in Jiangxi, there were attempts to build waterworks and make cultivation permanent, to contain the damage and to protect against further erosion and landslides. But many of the waterworks themselves were shoddily constructed, and when they broke down, this led to even larger floods and slides (Wu Qinglin 2015: 87).

The effect of such programs seems to have varied. There is evidence, for example, that in many parts of the Zhejiang-Jiangxi-Anhui border, there was a move away from annual field crop cultivation toward more permanent crops such as indigo and tea, depending on the markets for the products. But at the same time, people in some areas such as Changshan in Jiangxi also turned to sugarcane cultivation because of favorable market conditions, selling the cane and buying rice to eat, and this brought about market dependency, without alleviating the problem of erosion and landslides (we will see more of this in the Reform period in Yunnan in **chapter xxx)**.

If officials and scholars in the late Qing were acutely aware of the problems of deforestation, however, there was in fact little they could do. The Shed People of the Jiangxi-Anhui-Zhejiang region, along with others who moved into other parts of the mountains, went there out of desperation, to the point that some of them in the Hanzhong region of southern Shaanxi and northwestern Hubei turned to millenarian rebellion in the White Lotus revolt of 1790s, an event that we could use to mark the start of the long and agonizing decline of the Qing regime. There were too many people, and for those who moved to the mountains to clear the forests, sell the timber, and plant corn, having many children was a short term advantage, thus further exacerbating the demographic and ecological crisis. Desperate people are difficult to control, and for Qing officials, short of rebellion many of them felt that there was no alternative but to allow them a bare means of livelihood, whatever the longer term consequences. But in the upland ecosystem, as we saw at the beginning of the chapter, there were few if any buffers against the disturbances of flood and drought. The ecological buffers were destroyed when people cut the forests and planted on the hillside, and there were few if any institutional buffers with a mobile population and an increasingly corrupt regime. Infrastructure was also little help.

The end result was best summed up, perhaps by the authors of the Gazetteer of Fenshui County in Zhejiang:

> 至若布种苞芦,非不足以尽地力而便民食,实则利在一 时, 害 贻百世 *When it comes to planting corn everywhere, there is no place where it does not exhaust the earth's entire ability to provide for the people's nutrition, but in reality the advantage lasts but an hour, and the damage is left for a hundred generations.* [Quoted in Wu Qinglin 2015: 88].

Such were the cross-scale interactions in the ecosystem of China Proper during the Qing. In the temporal realm, short-term advantage caused long-term degradation, some of which has lingered even unto today. In the spatial realm, everything turned out to be connected, and in a manner unprecedented before the Qing population explosion. Desperate peasants, driven from the lowland regional cores by crowding, poverty, war, and floods, colonized the highland peripheries, previously connected to the heavily populated areas only by sporadic trade, and through their actions influenced and disrupted the functioning of the agrarian ecosystem in the cores. This was possible because of an even wider-scale phenomenon: the diffusion of New World crops through the Columbian exchange. To give credit to the Qing, they dealt with about a doubling of the population, from 1650 to 1780 or so, by intensifying labor and strengthening infrastructural and institutional buffers, something eminently possible in a grain-based, partly marketized economy with a strong bureaucracy. But eventually the prosperity that the early Qing expansion both created and took advantage of ran up against the carrying capacity of the lowland cores, and entered that region of the development curve where production and resilience stand in inverse relationship to each other. Intensification in the lowlands and the move into the highlands provided a temporary reprieve, (though it eventually led to even greater challenges at a longer time-scale), but even it was not sufficient to accommodate population growth even in the short term. As a consequence, the Qing, unlike most of its predecessor dynasties, expanded into the Upland and Pastoral Zones not just for military control, but to try to intensify production there. The results were either failure or, as in China Proper, short-term success creating long-term problems.

Expansion into the Pastoral Zone.

The Qing, however, and its successor Republic, could neither satisfy their security concerns nor meet the needs of their growing population solely through intensification in the lowlands and expansion into the uplands of the Intensive Agricultural Zone. They also sought to maintain their control over the Upland and Pastoral Zones, and under pressure of population increase also to increase the productivity of those zones and to move population from overcrowded China Proper into the uplands and grasslands. Expansion into the pastoral zones was mainly the result of two imperatives: one military and one demographic. They differed in their relative importance and in their timing in different parts of the pastoral zone.

The early Qing regime's concern with expansion into Xinjiang and adjacent areas of western Gansu was primarily one of security, as it was faced at its inception with two rival empires: the Zunghar empire, established in parts of what are now western Mongolia, Xinjiang, and the Central Asian Republics, and the Russian Empire, which was expanding eastward across Central Asia and Siberia. From the late Kangxi to the mid Qianlong periods, the Qing pursued aggressive military policies, eventually ending up with total conquest of the Zunghar empire in 1760. But to meet its security concerns, both during and after the process of pacification, the Qing had to take two steps that had important ecosystem consequences: they territorialized administration of populations that were originally organized on kinship principles, and they expanded agriculture in those meso-scale environments where it was possible.

As Perdue (2005) and many others have pointed out, there is no rigid line between the Intensive Agricultural Zone and the Pastoral Zone. Along the Mongolian frontier, despite the uniformity of ecology in the more remote grasslands, there has always been a frontier zone that has oscillated between cultivation and nomadic pastoralism after pastoralism was first established in the first millennium BCE. In Xinjiang, the mesoscale environments are quite varied (see chapter 4), and there have always been islands of agriculture in a sea of nomadism. So one way that the Qing conquerors provisioned their forces was to establish military colonies, both in the frontier zone in the north and in the islands of cultivable land in the northwest.

Inner Mongolia

The Qing had security concerns in the eastern and northern Mongolian regions to be sure, especially with the Russian empire's steady expansion eastward during the whole Romanov period. At the same time, the prime mover of migration into the "inner" parts of Inner Mongolia (those areas closest to the Intensive Zone and thus marginal between pastorally- and agriculturally-suited environments) was relief of population pressure in North China. As many writers have pointed out (Lattimore 1940, En 2003, Bao and En 2009, Wu et al. 2015), livelihoods in this zone had alternated throughout history, from as early as the Qin and Han periods. But the Qing expansion of farming in this area was greater and probably more permanent than any previous episode.

There are reports of poor people migrating from north China to the Horchin and Tumed areas, roughly between the modern cities of Hohhot and Baotou, as early as the late Ming; it was reported that there were at least 700,000 farmers in these districts by the 1582 (En 2003: 4). How many of these were Han migrants, however, and how many of them were ethnic Mongols who had adopted agriculture, precursors to the large percentage farmers among ethnic Mongols today (Khan 1996). During the Qing, however, land conversion went on at an unprecedented scale. The Qing, because of strategic concerns, actually prohibited Han migration into Inner Mongolia until 1902, but the regulation was honored in the breach from the beginning. By 1713, there were reportedly 100,000 cultivators in **get all the names of these places** and in the 1740s the Chifeng or Kharchin area just to the east was basically converted to a farming region, which it has remained ever since. Estimates of the population of the Inner Mongolian region in 1800 place the Han population already at 1,000, 000, only slightly less than the Mongol population of 1,300,000.

Han immigration, and conversion from pasture to farm continued throughout the 19th century, but was accelerated greatly by two events toward the end of the Qing. The great drought of 1877-79 in North China created tens of millions of refugees, and a large number of these moved to Inner Mongolia and converted grasslands for cultivation, in the Ordos area in the southwest in particular. Then in 1902 the Qing officially reversed its policy of nominally prohibiting immigration, encouraging Han farmers from much of north China to resettle in Inner Mongolia, in order to alleviate security concerns through the technique of 移民实边, or "securing the borders through migration." This resulted in further grassland conversions from Ordos to Horchin, estimated at a total of about 2,000 km^2.

The Republic saw further conversions, throughout the inner parts of the region, including an estimated 180 km^2 in the Suiyuan region between 1912 and 1928, and an undetermined amount under the colonial policies of the Japanese invaders after 1931. Most of the Qing and Republican landscape conversion happened because of the loss of buffers against disaster in the North China Plain and surrounding areas, much as other victims of ecosystem decline moved into the mountains within China proper. The effects on ecosystem resilience were not as dramatic as in the mountains, but some historians have directly linked these conversions, from late Ming through the Republic, with degradation and desertification of former pastures. But degradation is in the eye of the beholder (Blaikie and Brookfield 1994: 4-5) and whether this change was degradation or not depnds on how one chooses to define degradation. But because the local ecosystems lost the buffers of diversity and mobility, they were no doubt more prone to disaster as farmlands than they had been as pastures. However, we evaluate these conversions, however, they merely set the scene for much larger, and probably much more harmful, land conversions after 1949.

Xinjiang

Although the oases of Xinjiang had been agricultural areas for hundreds of years, the Qing expansion of agriculture into these areas was relatively minor until after the final conquest of the Zunghar empire in 1760. During the early 1700s, the Qing's main reason for colonization was to lessen the fiscal and logistical burden of feeding a large army, which had its biggest base at Barköl, east of Turpan, but also maintained important garrisons along the western part of the Gansu corridor, which was the main transport route from China Proper into Central Asia (Perdue 2005:329).

After the destruction of the Zunghar Empire, agricultural colonization accelerated greatly, mainly in a northern corridor extending from Qomul or Hami in the east, through Turpan and Urumchi, to Ili in the far west. Five primary kinds of colonists were moved in to farm these areas: military colonists, both Bannermen and Green Standard soldiers, who grew wheat on a kind of state farm; exiled criminals who were made into farmers under duress; Han civilians from Gansu and other parts of the Northwest, who in Ili cleared over 1200 km^2 in the Ili Valley, and Turkic peasants from the oases of the Tarim

Basin, who were moved north (ibid.: 342-43. These farmers not only grew grain to feed the soliders, but also established stud farms to raises horses for the troops (ibid.: 354).

Interestingly, military and civilian colonists neither adopted the local methods of agriculture used by Turkic farmers, nor imported techniques from China proper without alteration. Instead, they developed new methods by experimentation; General Ming Rui in Ili, for example, found by using test plots that in that environment he obtained higher yields by sowing less intensively, and in fact obtained yields that compared favorably with some of those for comparable crops in China Proper (ibid: 362), a lesson apparently never learned by the architects of the Great Leap Forward two hundred years later.

Perdue (ibid: 357) sums up cogently the way these intensification policies increased dependence on infrastructure and its maintenance at the local scale, while it strengthened interregional ties at the empire-wide scale:

> Colonization and integration policies intensified the exploitation of natural resources and encouraged substantial immigration from the interior. To some extent, emigration from the northwest eased pressures on resources there. By compensation, the officials had to invest heavily in irrigation works, tools, seed, and animals in Xinjiang to keep its agricultural settlements viable. They raised the productivity of the soil, expanded the land area at the expense of pasture, and generated important commercial links with the interior. Xinjiang became closely bound to the Han core in a way it had never been before [Perdue 2005: 357].

Migration into Xinjiang and the concomitant intensification of both agricultural production and interregional trade did not, however, in contrast to superficially similar phenomena in Inner Mongolia, fundamentally alter either the ecology or the demography of the region. These had to wait for much more aggressive, larger scale, and technologically "sophisticated" policies of the PRC.

Expansion into the Upland Zone.

The Qing and Republic both pursued, in addition, policies of expanding the IAZ into the southwestern uplands. As in the case of the pastoral zone, they did this both for military reasons and as an outlet for overpopulation in China Proper. Neither this expansion nor either of the reasons for it were new with the Qing; in fact the first export of Chinese agrarian civilization to the Upland Zone came during the Han period, 2000 years ago. When the Mongols united China Proper with many of its peripheral territories in the 13th century to form the Yuan empire, they also brought much of the southwest into the imperial orbit, and the Ming continued this practice, particularly in Guizhou and to a lesser extent in Yunnan (Herman 2007; Whitaker 2008). Unlike the situation in both China Proper and the Pastoral Zone, Qing expansion into the Southwest was not qualitatively different from what had happened in previous dynasties. But the process reached its greatest extent during the Qing, when population growth in China Proper was at its height, as was the military and economic power of the Manchu-ruled state.

Politically, this process consisted of two stages. First an independent native polity was brought under imperial suzerainty by making the ruler into a nominal subordinate of the empire, conferring an imperial title and imposing certain, usually light, obligations of fealty to the imperial center. This scheme of indirect rule is known to historians as the *tusi* system, after the informal designation of local rulers. In the second stage, the local ruler was removed and replaced by ordinary civil administration, a process known in the Qing as *gaitu guiliu*, roughly translated as removing local officials and returning to posted officials. Decades or centuries might elapse between the establishment of a *tusi* local ruler and the imposition of civil administration, and in some remote regions the local ruler persisted into the Republic, only to be abolished by the Communist Democratic Reforms in the 1950s.

At a regional scale, the nearly 600 years of the Ming, Qing, and Republican periods were times of huge demographic increases, agricultural intensification, and economic commercialization throughout the Upland Zone. James Lee has estimated that between the Yuan consolidation of power in the 1250s and 1850, the population of Guizhou, Yunnan, and the Liangshan region of southwestern Sichuan increased from about 3 million to 20 million, as processes of agricultural intensification, increased forest and mineral resource extraction, and economic commercialization went hand-in-hand both with local natural population increase and massive migration from China Proper, before the Qing primarily for military reasons and during the Qing primarily in response to overcrowding in the areas of origin.

Because of the uneven topography of the Upland Zone, however, this process of colonization and economic "development" happened very unevenly. Some areas experienced almost no change until the Republic, while others were basically converted from indigenous-ruled or acephalous polities to bureaucratically-administered territories at different times. A few examples will illustrate both the process and its variation in time and space.

In areas such as Sipsong Panna, on the border between modern-day Yunnan and Lao, not much changed. When The *chao phaendin* or local Buddhist king was made into a *tusi* by the Yuan rulers in 1293, the rich subtropical plains were already given over to wet-rice cultivation (Hsieh 1995), undertaken by Dai serfs under the rule of local lords. Few Han people moved into the area until the very late Qing and 20th century, and almost all of them were petty traders who settled in the upland villages inhabited by Lahu, Akha, and Jinuo (Hansen 2004: 38-40) By contrast, the upland areas remained in swidden cultivation until the mid 20th century (Sturgeon 2004: 122; **Hathaway 2013**).

The situation was similar in much of the Liangshan region in southern Sichuan, at least until the very late Qing and Republic. The Yuan and Ming had established *tusi* rule over most of the region west of the Anning River and even in "Old Liangshan," the heartland of Nuosu culture, incorporating the high-ranking *nzymo* stratum of native Nuosu society into the local administration system of the dynasties. But the real changes in these areas came with two waves of introduction of new crops. In the late Ming, potatoes and corn came from the Americas (the area is too high and too cold for sweet potatoes), and this seems to have enabled an unsustainable demographic increase, which in turn led to increased clan fighting and the losers in these fights migrating to areas west of the Anning River, where they settled high-elevation and steeply sloping terrain, and practiced swidden cultivation, since the upland plains were already occupied by the ancestors of today's Prmi and Na (Harrell 2001). It also resulted, paradoxically, in local revolts that drove out the *tusi* and re-established acephalous clan-based rule (Ma Changshou 1985: 102-03). There was thus agricultural intensification and population pressure, but as a result of agricultural innovation rather than Han migration. The second wave of crop introduction came in the form opium in the early 20th century, beginning in the last decade of the Qing and extending to the end of the Republic. Increasing demand for the drug among Han populations generally led to accelerated trade, intensified taking of slaves from surrounding Han populations, and greater accumulations of silver (Hill 2001: 1037-38). All of this was accomplished, however, during a period of several hundred years when Han settlement was almost exclusively limited to the lowlands around the Anning River.

In other areas, however, imperial expansion clearly brought both demographic growth and concomitant livelihood changes. In the early Ming in the Mu'ege kingdom in the Shuixi region of western Guizhou, the primary crops were buckwheat, oats, and barley, produced by shifting cultivation. The main product entering into trade was horses, but there were also large numbers of cattle, sheep, and goats (Herman 2007: 78). This of course indicates a very low population density. But Ming colonization changed this, as large numbers of troops and their descendants were recruited to clear land for intensive agriculture in military settlements, or *tuntian*. They imported not only more intensified forms of traditional Han agriculture, including a large increase in irrigated rice farming; they also brought the classic New World Crops to the uplands, increasing population density there (Herman 2007: 134-37). Mu'ege rulers themselves also encouraged colonization at times. Herman recounts the thinking of a Chinese adviser to the Mu'ege king in 1595:

> The leaders of the Luoluo realize they can generate more revenue by farming the land like Han than if they continued with traditional methods of slash-and-burn agriculture, and they use Han to introduce these farming techniques to the barbarians [Herman 2003: 271].

At the same time, exploitation of mineral resources increased, and small-scale mining controlled by indigenous peoples was replaced with larger scale extraction of mercury, iron, lead, and other minerals. The area was opened up to increased trade (and concomitantly increased migration) by building new roads and bridges, and thus both local and interregional travel flourished (Herman 2007: 152-58). Thus the combination of agricultural intensification and a commercial mining economy encouraged continued large-scale Han immigration into the area, leading to a major native rebellion in 1621-29, which was put down at huge cost by the Ming rulers. The area remained in relative turmoil and was somewhat depopulated during the Ming-Qing transition, however, and it was not until the defeat of Wu Sangui's rebellion and to the eventual abolition of the Mu'ege ruler's *tusi* status and the imposition of direct bureaucratic administration in 1701 (ibid.: 219).

Similar processes happened during the middle and late Ming in another Yi kingdom, the Luho northeast of Kunming. Yi-language sources from the mid-Ming speak actively of a transition from an earlier extensive economy based on swidden agriculture, large herds of pastured animals, and considerable hunting in forest reserves not threatened by incursion of agriculture, to a present-day (probably 16^{th}-century) economy in which irrigated rice agriculture dominates the lowlands, animals are kept for draft and penned at night, and Han settlers not only engage in extractive activities such as mining, but also are beginning to convert former hunting territories to (presumably upland, dry land) to field agriculture (Whitaker 2007: 238-41, 268, 309).

The Qing continued and intensified this process of political, demographic, and ecological change. The above narrative is repeated in many parts of the Southwest. There is a native polity, based on extensive agriculture and personal loyalty of farmers/herders to a hierarchy of chiefs culminating in the ruler. These local chiefs are given *tusi* titles and mostly left to rule on their own. But immigration, and very likely natural demographic increase enabled by New World crops, put both political and demographic pressure on the local polity, and the Imperial authorities become interested in the potential of the area for military security, colonial resource extraction, and an outlet for surplus population. Although emperors and their representatives are eager to avoid trouble with natives who are not in active rebellion, Han settlers eventually provoke confrontations, and rebellion results, as with the She-An rebellion in Shuixi described above, or the Nanlong rebellion among the Zhongjia (now Buyi) peoples in southwestern Guizhou in 1797 (Weinstein 2013: chapter 5). When the rebellion is defeated (as it always is), and danger of military opposition is past, local polities are abolished and the territory comes under bureaucratic administration. But this does not bring the entire region under either intensive agriculture or bureaucratic rule; more remote mountainous regions retain "The Art of Not Being Governed" and preserve tribal polities and extensive subsistence strategies until they are finally overwhelmed by the Communist project beginning in the 1950s. The Upland Zone remains a mosaic to this day, but most of the tiles are now cultivated intensively.

The gradual transformation from swidden to permanent cultivation brought, like so many other processes, contradictory effects on the resilience of socio-ecosystems. On the one hand, swidden systems are only sustainable below a certain threshold of population density, allowing cultivated lands time to recover before the next growing cycle. So population increase and increasing commercialization in a previously swiddened area will need to lead to permanent cultivation and the construction of infrastructural and institutional buffers to manage the more intensive system. This may bring an increase in resilience (Henley 2005, Conelly 1992). But permanent cultivation in many parts of the Upland Zone, in particular when it involves deforestation of steep slopes, can lead to loss of soil and fertility and of ecosystem services in general, as happened in the Baiwu Valley of Liangshan under communist pressure to increase production (Urgenson et al. 2010). This process is similar to that outlined above for the mountainous peripheries of the Agrarian Zone.

Perhaps this is due to element, which is somewhat different among many nan-Han peoples of the Southwest. Stemming perhaps from their longtime adaptations to the extensive and versatile agro-silvio-pastroral systems described in chapter 4, the peoples of the Upland Zone used cultural buffers to maintain ecological buffers, and rarely built infrastructure to increase resilience, until the processes of economic development and demographic expansion brought Han settlers and officials with both the ideologies and the techniques of intensification. As mentioned above, these often created more resilient systems, but not in previously forested, steep terrain. Shaw's description of northeast Yunnan around Zhaotong is illustrative:

> Many of the hills of which it is composed are clad only with grass and fern and present a bleak appearance, but others are covered with firwoods. This portion of Yunnan has, however, been far better wooded in the past than now. [This area] was the last part of China to produce in large quantities and great size the famous nan-mu tree. But the bare surface of the ills there testifies to the tragedy of the reckless clearing of the timber. The Chinese traditions are that once all this country was forest-clad. Now, indeed, it would be left quite treeless but for two reasons: firstly that the landlords are largely Nosu—…who always build their houses at the foot of a small wooded hill if possible, sthus obtaining a picturesque setting for them—any vassal who dared to cut down one of these trees would be severely punished. Secondly, the Nosu graves are surrounded by trees [Shaw 1914: 163-64].

As a consequence of all this development, the frequency of disasters in Yunnan increased greatly in the late Qing and Republic (Jiang Liwen 2012). It appears, however, that the demographic expansion of the Ming and Qing periods did not lead to overall systems collapse in the Upland Zone as it did in many parts of China Proper.

The Environmental Legacy of the Qing and Republic

Such was the legacy of China's early-modern population explosion and the concomitant changes in its ecosystem. On the one hand, we must admire the ability of the early Qing rulers and local elites, as well as the innovation and industriousness of the common people, to be able to feed an exploding population so well for the first hundred and fifty years of the dynasty. They not only understood agricultural techniques; they also understood at an intuitive level the tradeoffs and curvilinear relationship between productivity and resilience. But given the contradiction between the short-term advantages for families of having more children—gaining increased labor and security—and the eventual strains put on the system at larger scales by the ecological transformations necessary to feed the increased population, we can see that the Qing was on a centuries-long road to ecosystem collapse and to a kind of permanent backloop of instability and lack of resilience. We must realize, of course, that within this permanent backloop were eddies of stability where even poor people avoided disaster for years or even generations at a time. But the general trend was downhill or around in circles from the late 18th century to the mid-20th.

We must also admire the ability of the regime and the people of Qing and Republican times to make do in a system of high productivity and low resilience in a context of fixed inputs of energy and resources. None of the Qing productivity increase involved outside injections of energy, directly or indirectly, from inputs of fossil fuels. All was achieved, as it were, with "premodern" technologies, dependent on energy and resources that were already present in the system—land, water, and labor. Although the

Republic saw a few attempts at agricultural development or modernization, in 1949 the farmers and herders of all three zones of China were still employing the same basic technologies as their forebears in the Song dynasty a thousand years earlier. And still the situation was not so uniformly dire as to prevent continued increases in population and expansion of cultivated area even during the chaotic years of the Republic.

The Communists were thus faced with a daunting task of bringing stability to an ecosystem that had remained unstable, in a kind of permanent alpha-phase, for a century and a half. They had only two tools at their disposal—social revolution, which they thought would unleash the productive power of the masses of laborers, and fossil-fuel based industrial technology, which they used almost exclusively to build industrial and military strength, and thus did not apply to agriculture except in a few areas. The following two chapters tell the story of how they began a reasonably successful program of ecosystem stabilization and resilience increase in from 1949 though 1957, and how their attempt at a radical transformation of the productive system in the Great Leap Forward led to a tragic transformation that no one had envisioned, much less wished for.