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Campaigning for Extinction: Eradication of Sparrows and the Great Famine in China

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Campaigning for Extinction: Eradication of Sparrows and the Great Famine in China*

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Abstract

How do large disruptions to ecosystems affect human well-being? This paper tests the long-standing hypothesis that China's 1958 Four Pests Campaign, which exterminated sparrows despite scientists' warnings about their pest-control role, exacerbated the Great Famine—the largest in human history. Combining newly digitized data on historical agricultural productivity in China with habitat suitability modeling methods in ecology, we find that, after sparrow eradication, a one-standard-deviation increase in sparrow suitability led to 5.3% larger rice and 8.7% larger wheat declines. State food procurement exacerbated these losses, resulting in a 9.6% higher mortality in high-suitability counties—implying nearly two million excess deaths.

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"Damned Creature. Criminals for thousands of years. Today is payment day"

-*Chinese anti-sparrow poem*

1 Introduction

Scientists, politicians, and popular media frequently argue that the continued degradation of ecosystems will negatively affect human well-being (Dasgupta 2021; Heal 2000; IPBES 2019). Most noticeably, warnings regarding the devastating consequences of "ecosystem collapses" have emphasized the complex non-linearities of natural systems (Cooper et al. 2020; Strona and Lafferty 2016)—agriculture in particular as it is strongly connected with its surrounding ecosystems (Foley et al. 2011; Mendenhall et al. 2014). While the potentially catastrophic costs of such tail events have long been theorized in environmental economics (Weitzman 2009), empirical evidence remains scarce. The rarity of "ecosystem collapses," the difficulty in clearly tracing their triggers, and the lack of granular data, all pose barriers to rigorous empirical investigations.

In this paper, we study one of the most cataclysmic ecosystem collapses in history, the 1958 "Four Pests Campaign" (FPC) in China, which successfully drove sparrows to local extinction within two years. As part of the FPC, which aimed to improve agricultural productivity and public health, the central government ignored scientific advice and ordered local officials to exterminate sparrows—targeted because they were eating grains. However, while adult sparrows do feed on grains, they also feed their fledgling with insects, making them an important predator of crop-damaging pests. In their absence, anecdotal evidence claims that the country experienced severe crop-pest infestations (Ashton et al. 1992; Chen and Wang 2021). A key contribution this paper makes is to provide quantitative evidence for how this local extinction event played a role in contributing to the conditions that led to the Great Chinese Famine—as long hypothesized by environmental historians (Butt and Sajid 2018; Harrell 2021; Mao 2019; Steinfeld 2018)—in which an estimated 16.5 to 45 million people starved to death between 1959 and 1961 (Meng et al. 2015; Smil 1999; Yao

1999).

Combining newly digitized data on historical agricultural production in China with well-established habitat suitability modeling methods in ecology, we compare how counties with higher habitat suitability for sparrows were differentially affected by the FPC, relative to their low-suitability counterparts. Our use of models from ecology to assign treatment status builds on previous uses of such methods to overcome the challenge of missing measurement on wildlife populations before they decline sharply (Alsan 2015; Frank and Sudarshan 2024). We find that the sparrow suitability score was orthogonal to agricultural production prior to the FPC; but after the start of the FPC, the high-suitability counties experienced a 5.3% (8.7%) drop in their rice (wheat) yields, relative to those counties less suitable for sparrow habitation. These effects are economically significant—our calculation suggests that sparrow killing can account for 19.6% of the national crop yield reduction during the Great Famine.

We find two main channels through which farmers responded to the eradication of sparrows. First, the yield reduction caused by the FPC was primarily driven by above-ground crops such as rice and wheat, which are more vulnerable to pests (locusts and planthoppers in particular). In contrast, the yield of below-ground crops, such as sweet potatoes, increased more in sparrow-suitable counties during the same period—likely reflecting farmers' substitutions across crops to mitigate pest risks induced by the FPC. Second, the counties more suitable for sparrow habitation, which suffered from larger drops in crop yields, saw marginal increases in sown areas. These two effects, taken together, are consistent with the historical context in which the central government permitted farmers to cultivate more land and grow sweet potatoes—exempt from procurement—in order to cope with the famine.[1]

Investigating the government's response to the sparrow eradication shock, we show that the higher-suitability counties, which suffered from larger reductions in crop yields, surprisingly faced significantly *heightened* procurement quotas during the famine. This aligns with

[1] We observe an additional margin of adjustment in that farmers apply pesticides more frequently following sparrow killings, although these results are noisier and more tentative—likely reflecting constrained access to pesticides in this context.

the idea that, contrary to widespread scientific advice at the time, the central government genuinely expected sparrow eradication to boost agricultural output. It also echoes prior research on how the rigidity of the procurement system exacerbated the famine (Meng et al. 2015). The decreased agricultural output, combined with the increased procurement requirement, presented the high-suitability counties with significantly heavier burdens during the Great Famine. As a result, these counties experienced an increase in their death rates, and a drop in their birth rates, as compared to counties less suitable for sparrow habitation. Our calculation indicates that sparrow eradication was responsible for nearly two million lives lost between 1959 and 1961.

In 1960, three years after the initiation of the FPC and following the nationwide killing of approximately two billion sparrows, the central government realized their importance and removed them from the list of Four Pests, replacing them with bedbugs. Given that sparrows had already become locally extinct in most parts of the country, to reboot the sparrow population, it was reported that the Chinese government had to import 250,000 sparrows from the USSR. After this reversal of sparrow eradication, we observe rice and wheat yields gradually returning to their pre-FPC levels, while the growth in sweet potatoes persisted even after the FPC.

Through several robustness checks, we address a variety of concerns regarding the internal validity of our analysis and its interpretation. We validate that sparrow suitability—our approach to assigning treatment intensity—correlates with scientifically collected data on bird abundance. To rule out that our sparrow suitability measure is simply capturing variation in crop suitability, we demonstrate the weak correlation between the different suitabilities, and report that the environmental conditions that are most predictive of sparrow suitability fail to predict rice and wheat suitability. Throughout the paper, we report that our results hold whether we use the suitability score as a continuous measure or as a dummy variable for being above the median sparrow suitability, and that the results persist when controlling for the interaction of baseline population or crop suitabilities with year fixed effects. To benchmark our results on agricultural productivity, we simulate a predator–prey model—commonly used in ecology to describe the population dynamics of interacting species—and validate that our baseline estimates of reduced rice and wheat production are compatible with the magnitudes we obtain from the simulation.

In addition, we establish that spatial clustering of the standard errors does not meaningfully affect the precision of our results. Furthermore, we report results for balanced and unbalanced panels of the data, where we show that different sample compositions yield similar effects, and that the chance of data being missing in any given year is uncorrelated with sparrow suitability. Finally, we report detailed estimation results where we include multiple controls in the form of more fine-scaled time trends, procurement quotas and prices, changes in livestock, growth in the production of steel, and the use of mechanized tools in agriculture. These additional controls help us reject that other features of the Great Leap Forward might be driving the observed patterns. Taken together, our findings highlight the dire consequences of ecosystem collapse, and echo the conjectures proposed in historical research that the eradication of sparrows was an important contributing factor to the largest famine in human history.

Relevant Literature.— Our distinctive contribution is documenting the consequences of a sweeping, nationwide ecosystem collapse—a classic tail event in environmental degradation (Weitzman 2009). The empirical setting we study—where a government policy first decided to eradicate sparrows, and then proceeded to exacerbate food shortage conditions—speaks to the caution that is required when implementing momentous interventions to the environment. Notably, our findings on the agricultural impacts of eradicating sparrows provide some of the first rigorous evidence on the extent to which large, non-marginal disruptions to agricultural ecosystems—canonical examples of the economic importance of ecosystem balance—can have dire consequences for humans (Cardinale et al. 2012; Jenkins 2003).[2] Our

[2] Severely destabilizing agro-ecosystems can increase food insecurity, potentially culminating in famines (Diamond 2005; O'Rourke 1994; Ravallion 1997), yet there is scarce causal evidence on this relation-

study expands the scope of a growing body of work in environmental economics examining how changes in species abundance can affect various outcomes, such as air pollution from invasive-species–induced tree die-offs (Jones and McDermott 2018), road-safety impacts via wolf–deer interactions (Raynor et al. 2021), malaria incidence after declines in mosquito-eating amphibians (Springborn et al. 2022), agrichemical pollution when bats' pest-control services are replaced (Frank 2024), and human mortality risk following the loss of vultures' sanitation services (Frank and Sudarshan 2024).

This paper speaks to two additional strands of literature. Our findings shed new light on the determinants of China's Great Famine, the largest in human history. An extensive body of literature has investigated various political economic determinants of the Great Famine, such as farmers' free-riding incentives (Lin 1990), urban bias in food distribution (Lin and Yang 2000), excessive grain procurement (Li and Yang 2005), political promotion incentives (Chen and Kung 2011), rigid procurement quotas (Meng et al. 2015), grain export (Li and Kasahara 2020), and social capital (Cao et al. 2022). However, while environmental historians have long suspected that the elimination of sparrows contributed to these disasters and thus the famine (Shapiro 1999; 2001; Dikötter 2010; Becker 1998; MacFarquhar and Fairbank 1987; Manning and Wemheuer 2011; Yang 2012; Marks 2017; Harrell 2021), to the best of our knowledge, there has been little rigorous examination of this explanation. Our paper fills in this gap by providing systematic evidence that echoes this hypothesis, that the intentional disruption of the ecosystem was another substantial contributing factor to the famine. In addition, our findings also support those of Meng et al. (2015), in showing that the procurement quota failed to properly adjust according to FPC-induced output losses until 1961, highlighting how the rigidity of the procurement system exacerbated the famine.

More broadly, our findings also add new evidence to the perils of over-centralization and campaign-style policy initiatives that have little regard for scientific evidence, which could

ship. Historically, large human-induced disruptions to ecosystems occurred when species were locally extirpated either due to their roles as pests (Musiani and Paquet 2004) or their value as resources (Taylor 2011). Birds, for instance, have long been recognized for limiting the abundance of crop-damaging insects (Evenden 1995; Garcia et al. 2020).

distort well-intended policies and lead to disastrous policy outcomes (Kornai 1960; Nove 1971; Lin 1990). Our results imply that, the ecological system, very much like the economic system that it is connected to, functions in subtle and complicated ways, making it hard to accurately foresee the general equilibrium consequences of a man-made non-marginal shock without sufficient *ex-ante* learning through trial and error.[3] Beyond the Chinese context, one can also view our findings as a general cautionary tale for more prudence and deliberation in environmental policymaking (Weitzman 1998; 2009; Nordhaus 2019).

The remainder of this paper is organized as follows. In Section 2, we introduce the background of the FPC and the Great Famine. Section 3 explains the construction of various historical and ecological datasets, and presents the summary statistics. In Section 4, we elaborate on the identification strategy. In Section 5, we discuss the empirical results, including the agricultural impacts of sparrow eradication, the responses from farmers and governments at the time, and the eventual demographic consequences. Section 6 evaluates the robustness of our findings and benchmarks them against simulations of a simple ecological model of predator–prey population dynamics. Section 7 concludes.

2 Background

In this section, we introduce the background of the Four Pests Campaign, and the subsequent Great Famine between 1959 and 1961.

2.1 The Four Pests Campaign

In 1955, China was formulating a decade-long plan to help accelerate agricultural development and collectivization between 1956 and 1967. In the process of drafting that plan, the Chairman of the Communist Party of China, Mao Zedong, received feedback from farmers

[3] Having experienced various such failures following the implementation of drastic policies under central planning, after 1978, China's leadership decided to move away from campaign-based policy initiatives and towards gradual policy experimentation, an institutional feature that later became the pillar of policy making in China (Heilmann 2008; Xie and Xie 2017; Wang and Yang 2023).

that sparrows consume grains and damage agricultural production. Mao therefore decided to include sparrows, alongside flies, mosquitoes, and rats, in the list of the "four pests," which should be eliminated nationwide within seven years.[4]

Three of the targeted pests—flies, mosquitoes, and rats—were included because they spread diseases and were considered public health threats, so there was relatively little controversy about eradicating them. However, sparrows were included because they eat grains, but as pointed out by biologists, sparrows are also the natural enemies of many grain-eating insects, such as locusts, rice borer, rice planthopper, among others. The share that insects make up in the diet of sparrows changes throughout the year. In winter, when house sparrows tend to not migrate, sparrows mostly feed on grain and other agricultural products. During the spring and summer months, insects constitute a large share of their diet, as high as 70-80% for fledgling sparrows (Yu et al. 2007). As a result, when the FPC included sparrows in their list of eradication, there was widespread opposition from scientists in China.

Most notably, Zhu Xi, a renowned biologist from the Chinese Academy of Sciences, voiced his opposition citing the historical episode of the Prussian king Frederick the Great trying to eliminate sparrows in 1744, but ended up with pest outbreaks and had to import sparrows from other countries to repopulate them. Zhu also analyzed examples of various cities in the US and Australia importing sparrows to help pest control, and warned Mao that more research is needed before deciding on the overall cost and benefit of sparrows. However, despite the opposition, Mao decided to go along with his plan to quickly eradicate sparrows nationwide.[5]

In late 1957, the "Great Leap Forward" formally kicked off, which also marked the start of the FPC. From March to May in 1958, Mao repeatedly emphasized the importance of eradicating sparrows in multiple meetings, which got widely covered by national and local media outlets. In addition to Mao's personal push, being the easiest target among the four

[4] National Agricultural Development Outline from 1956 to 1967 (Draft). See the following for more details: https://searchworks.stanford.edu/view/43324. Accessed 2/22/2024.

[5] Source: https://chinadigitaltimes.net/chinese/322533.html. Accessed 2/2/2024.

pests also made sparrows the priority in local eradication efforts. Many local governments set up "special operation teams" for sparrow eradication, which mobilized millions of state employees and citizen volunteers to systematically destroy sparrow nests, break sparrow eggs, and kill sparrow chicks. In addition, in many regions, people also targeted sparrows flying in the sky by directly shooting them with slingshots, or by hitting noisy pots and pans to prevent them from resting in their nests, with the goal of causing them to drop dead from exhaustion (Cheng 1963; Harrell 2021).[6]

Within two years, the campaign effectively depleted the sparrow population: it is estimated that approximately two billion sparrows were killed between 1958 and 1959, pushing the species to near extinction within China. Anecdotally, it was also reported that insects became widespread following the eradication of sparrows. In 1959, the rural areas experienced a salient increase in insect outbreaks, and many major cities in China saw their trees turning bald as the leaves got eaten by insects.[7]

By the end of 1959, seeing the widespread surges in insect outbreaks, a large number of prominent scientists again voiced their strong opposition to the sparrow eradication movement. In November 1959, the party secretary of the Chinese Academy of Sciences (CAS), Zhang Jinfu, wrote a report titled "Report to the Chairman Regarding the Costs and Benefits of Sparrows," which provided detailed data on the dietary composition of sparrows, as well as extensive scientific findings in foreign literature. This report was read by Mao, and forwarded to all scientists at the CAS. The CAS later held two conferences discussing the costs and benefits of sparrows, and established a team of scientists to further investigate this matter. Finally, in March 1960, Mao decided that "we should stop killing sparrows, and we can replace sparrows with bedbugs in the FPC list," which was formally enacted in April

[6] Some sparrows found a refuge in the extraterritorial premises of various diplomatic missions in China. The personnel of the Polish embassy in Beijing denied the Chinese request to enter the premises of the embassy to scare away the sparrows who were hiding there, and as a result the embassy was surrounded by people with drums. After two days of constant drumming, the Poles had to use shovels to clear the embassy of dead sparrows. See: https://wyborcza.pl/1,75248,140878.html?disableRedirects=true. Accessed 2/2/2024.

[7] Source: https://chinadigitaltimes.net/chinese/322533.html. Accessed 2/2/2024.

1960. However, by this point, sparrows were already functionally extinct in China. In order to re-populate the species, China was reported to have to import 250,000 sparrows from the USSR in the 1960s.[8] The FPC posters from 1958 vs. 1960 depict how sparrows were initially included, but later excluded, from the list of the four pests (Figure 1).

Figure 1: Recognizing the Error of Exterminating the Sparrow

(a) Four Pests Campaign Poster 1958

(b) Four Pests Campaign Poster 1960

Notes: The posters show the transition from 1958 to 1960 in the composition of the four pests. The 1960 campaign replaced sparrows with bed bugs after China stopped sparrow killing and decided to import 250,000 sparrows from the Soviet Union to replenish its sparrow population.

[8] While difficult to find a formal validation of this purchase, it appears in books written about the era (page 177 of Žižek (2022)), and was referenced in popular writing about the end of the eradication campaign: https://www.thelondoner.ca/news/local-news/a-tale-of-sparrows. Accessed 2/22/2024.

2.2 The Great Famine

Between 1959 and 1961, China experienced what is generally believed to be the largest famine in human history, with an estimated death toll of 16.5 to 45 million (Meng et al. 2015; Smil 1999; Yao 1999). To place this in greater context, the World Peace Foundation's historic famine database reports a central estimate of the death toll of 36 million people, ranking the Great Famine as the highest death toll across famines recorded in the data starting as far back as 1876 (World Peace Foundation 2025). This estimate is an order of magnitude higher than the other largest recorded famines. According to estimates by Cao (2005), during the Great Famine, the most stricken provinces were Anhui (18% death rate), Chongqing (15%), Sichuan (13%), Guizhou (11%) and Hunan (8%).

There are two main schools of thought in terms of explaining the root causes of the Great Famine. The first considers agricultural output during this period. As shown in Figure 3a, China maintained robust growth in agricultural output in the years leading up to the Great Famine, but then experienced four consecutive years of dramatic productivity decline between 1959 and 1962, and economists have examined various potential explanations for that reversal. Lin (1990) points out that when the agricultural communes stopped allowing farmers to freely exist in 1958, a prisoner's dilemma with free-riding incentives emerged, which paralyzed agricultural production. Chen and Lan (2017) show that the collectivization of agriculture also led peasants to slaughter household draft animals to consume the meat, which reduced the input for agricultural production in the subsequent years.

In contrast, another more recent line of work has pointed out that production-based explanations alone are insufficient to explain the magnitude of the famine, and one must also combine them with severe distortions in the distribution of agricultural output—in agreement with the point raised by Sen (1981) regarding distribution failures as a necessary condition to generate severe famines. Consistent with this view, as shown in Figure 3b, the excessive death rate was the highest in 1960, and partially recovered in 1961, when the central government started sending grains to the rural areas in need.

Local inequality in food availability is considered to be a critical driver of the Great Famine. Specifically, Li and Yang (2005) suggest that the procurement quota—the amount of agricultural produce that was collected from the county and redistributed—was excessive. Meng et al. (2015) show that in addition to the excessiveness, the rigidity of the agricultural procurement system played a key role in causing the famine. Li and Kasahara (2020) find that grain exporting during the famine period worsened the situation. Evidence has also documented that political and cultural factors contributed to the distributional distortions (Chen and Kung 2011; Cao et al. 2022).

The Chinese government officially referred to the Great Famine as the "Three Years of Natural Disasters." Later research has shown no sudden and abnormal changes in basic weather conditions between 1959 and 1961, which partially contradicts the official narrative. That being said, historians have long suspected that the Four Pests Campaign, by eradicating sparrows and destabilizing the ecosystem, also contributed to the drop in agricultural output and hence the famine (Shapiro 1999; Dikötter 2010; Becker 1998; MacFarquhar and Fairbank 1987; Manning and Wemheuer 2011; Yang 2012). This version of production-based explanation of famine origin received much attention in qualitative discussions, but rigorous empirical evidence remains limited.

3 Sparrow Suitability, Agricultural Production and Population Data

The empirical analysis aims to examine whether eradicating sparrows during the 1958-1960 FPC played a meaningful role in the conditions that resulted in the Great Famine. To do so, we need data sources that allow us to define exposure to the sparrow eradication shock, measure agricultural production, and summarize total mortality. In this section, we briefly summarize the core data sets used in the analysis: (i) sparrow suitability scores derived from a habitat suitability model; (ii) previously used as well as newly digitized crop production data; and (iii) population levels and all-cause mortality counts. We summarize the key variables in Table 1, map cross-sectional variation in sparrow suitability in Figure 2, and plot national-level trends for agricultural production and mortality in Figure 3.

3.1 Suitability Scores

3.1.1 Sparrow Suitability Score

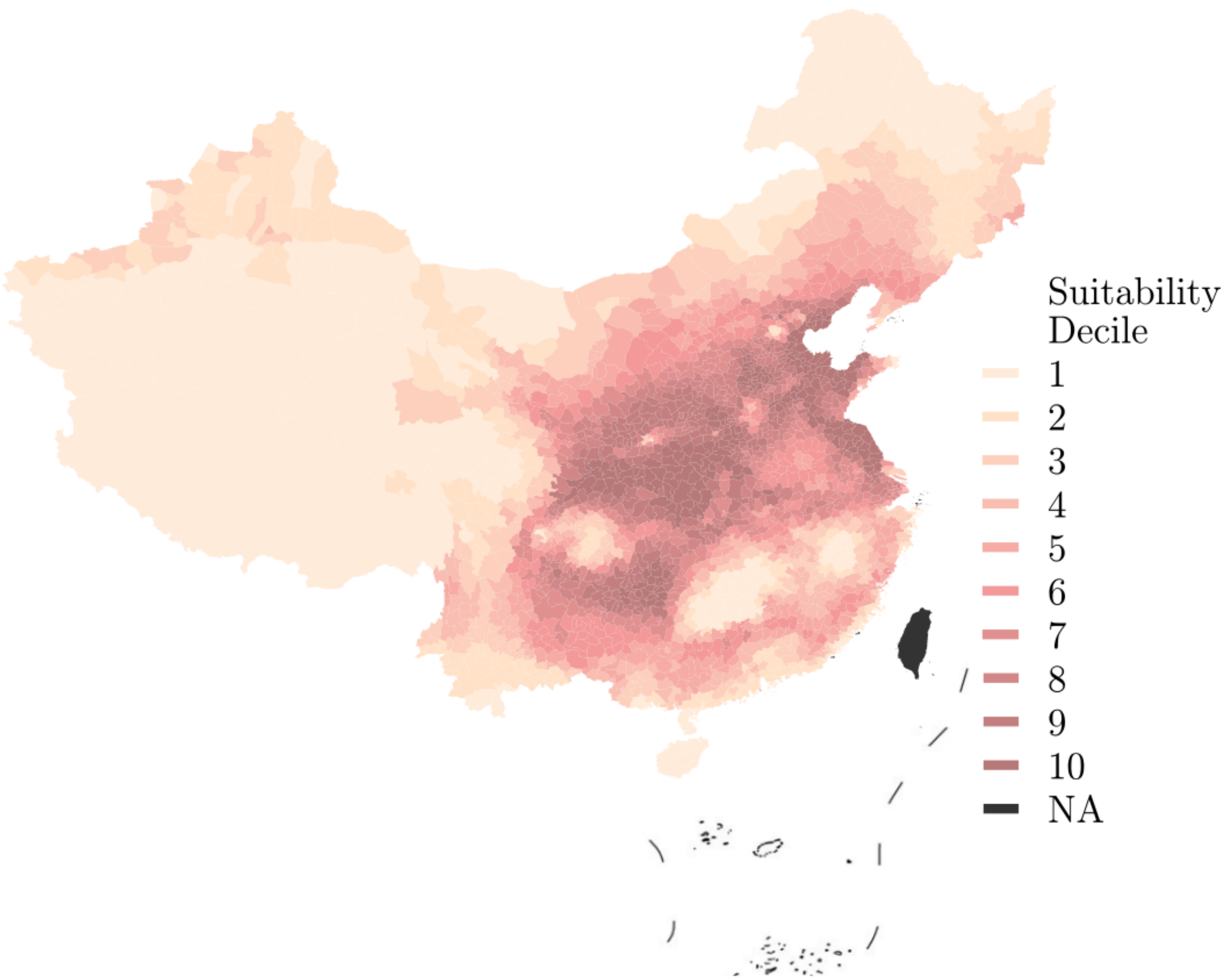
We use a proxy for sparrow population levels during our study period in the form of a habitat suitability score for each county and province. This score combines data on current observations of sparrows with the environmental features in each county to quantify the degree of habitat suitability for sparrows. Because sparrow population levels were not monitored during our study period, the sparrow suitability score provides a numerical value that is proportional to the sparrow population when it is in equilibrium. Our approach of using suitability scores in the absence of detailed wildlife population counts is similar to that used by Alsan (2015) and Frank and Sudarshan (2024). In the Online Appendix Section A.1 (Table A1 and Figure A1), we provide results from an empirical exercise that validates the agreement between habitat suitability scores for birds and scientifically collected counts of these bird species.

We calculate the sparrow suitability score using the BIOCLIM model, which has been widely used since its introduction in 1984 (Booth et al. 2014). The model combines data on the presence of a species, which we obtain from eBird records, and local bioclimatic variables such as soil type, elevation, temperature, and precipitation.[9] The presence data and environmental data allow BIOCLIM to construct the convex hull of environmental conditions that appear to be beneficial for the presence of the species, which then gets projected back into geographic space to calculate suitability scores. The higher the score, the more likely the

[9] eBird is an online database of bird observations providing real-time data about bird distribution and abundance. Because eBird relies on self-reported observations of birds by citizen scientists instead of a scientifically designed monitoring protocol, we cannot simply use the mean number of sparrow records in eBird to infer habitat suitability. Habitat suitability models, such as BIOCLIM, are designed to overcome the inherent sampling biases in such species presence data.

area is a suitable niche for the species. For example, observing polar bears in the the Arctic landscapes would result in a high suitability score in Alaska, but not California. Similarly, observing beavers in wetlands would result in a high suitability score in Florida but not in Arizona. We plot the mean sparrow suitability score we obtain from the BIOCLIM model in Figure 2, and use it to assign county-level exposure to the treatment—the eradication of the sparrows.

Figure 2: Spatial Distribution of the BIOCLIM-Derived Sparrow Suitability Score



Notes: We obtain sparrow suitability for each county using the BIOCLIM Habitat Suitability Model (HSM). See text for more details.

It is important to note that suitability scores characterize the theoretical ecological niche a species can occupy—how well a species can survive in that environment—but other factors such as dispersion, competition with other species, and predators affect the ability of a species to occupy the niche.[10] In the case of birds and contiguous habitats, dispersion is not considered to be a limiting factor to their occupancy. For sparrows, food availability and environmental conditions are of higher importance than competition with other birds and the presence of predators (Repasky and Schluter 1994).

3.1.2 Crop Suitability Score

For the main crop types that we focus on in this paper (rice, wheat, and sweet potatoes), we also obtain corresponding crop suitability scores from version 4.0 of the Food and Agriculture Organization Global Agro-Ecological Zones database (Fischer et al. 2021). We choose the no-irrigation suitability scores, and use alternative measures for robustness checks that we detail in the results section.

A potential threat to our research design is that sparrow suitability might be correlated with crop suitability, in which case our estimates might also partially capture the potentially larger impacts of the GLF in regions with higher crop suitability. We address this concern in several different ways. First, in all our main regressions, we directly control for the interactions between crop suitability scores and year dummies, which isolates the impacts of sparrow eradication from potential heterogeneous responses to the GLF by regions with different levels of crop suitability. Second, we explicitly examine the relationships between sparrow suitability and crop suitability scores. In Online Appendix Figure A2, we show that they turn out to be not highly correlated with each other—conditional on crop suitability, there is still substantial variation left in sparrow suitability.

Furthermore, in Online Appendix Table A3, we investigate which environmental conditions can most strongly predict each type of suitability score. We find that the variables that are the strongest predictors for sparrow suitability do not act as strong predictors for crop

[10] Dispersion is important as it allows a species to arrive and occupy the niche. This is not considered a binding constraints for flight-capable birds. Competition with other species can prevent a species from occupying its theoretical niche. We do not know of species who can competitively exclude sparrows.

suitabilities, which explains the lack of strong correlation between their suitability scores.

3.2 Agricultural Production

Our baseline county-level crop data is from China's county gazetteers—the historical archives compiled by local gentries, which comprehensively document local socio-economic conditions and significant events separately from the official statistics.

In the 1950s and 1960s, China's official socio-economic statistics were collected through a top-down system, in which the central government elicited statistics from the provincial governments, who in turn elicited numbers from the county governments. Under the planned economy system, the numbers collected from this top-down system can be systematically distorted as the county and provincial governments were trying to meet the national targets. It is widely believed that these manipulated official economic numbers misguided policymakers, which contributed to the famine (Yang 2012).

In contrast, the county gazetteer data we digitize is from historical archives compiled and published in the 1990s.[11] Each county designates a county gazetteer committee consisting of local experts to organize historical archives, document important events (e.g., natural disasters, political events), and validate the county's statistics at their best endeavors.

A main advantage of the gazetteer data is its higher reliability compared to official statistics at the time. There are two reasons for this. First, gazetteers were published under no political pressure, as they only reported historical data; for example, publication in 1992 typically only includes data from 1949 to 1985; thus, the data released in the gazetteers are unlikely to be intentionally distorted by the local government officials. Second, the gazetteer committee corrected some data errors and made the statistics as precise as possible, particularly regarding the data reported during the radical political events, such as the Great Leap Forward and the Cultural Revolution. As discussed in Section 3.5, this is also consis-

[11] There have been two waves of gazetteer publication since the establishment of the People of Republic China: the first-wave gazetteer publication was in the 1990s, covering historical archives from 1949 to 1985 or later years depending on the actual publication date. The second-wave gazetteer publication happened in the 2010s, further updating the data till the late 2000s.

tent with the fact that the county gazetteer data indicate larger crop yield declines during the famine, relative to the provincial data, even after the provincial statistics got adjusted retrospectively by the government for misreporting.

Our data was digitized from two sections of each gazetteer: total agricultural output and total arable land from the *Economy* section and the crop-specific cultivated area and output by crop from the *Agriculture* section. First, we restricted our sample to areas titled "Xian" (county) in 1990 to ensure these areas were mainly agricultural counties. Thus, all urban jurisdictions are excluded from our analysis, even if some of these cities also provided agricultural output data. Second, to be included in our sample, we require a county to provide annual data from 1954 to 1965 for either rice or wheat, the two dominant food crops grown in China. Our eventual sample consists of 610 rural counties; among them, 421 counties grow rice, mostly in southern China, and 495 counties grow wheat, mostly in northern China, where 309 counties reported growing both rice and wheat.

The county-level crop output data is an unbalanced panel. In the Online Appendix, Section A.2, we further discuss the potential data selection issue. Online Appendix Table A2 examines whether the rice and wheat reporting patterns are correlated with the suitability of the sparrow. We find no evidence that the timing of reporting or having non-missing values before and after the FPC is correlated with sparrow suitability. Consistent with the higher suitability scores observed in northern China, high-sparrow suitability counties are more likely to report wheat output and less likely to report rice output.

We also obtain province-level data from various sources. The provincial crop data from 1950 to 1980 is obtained from the National Bureau of Statistics of China. The provincial data does not necessarily match the county-level data in gazetteers, as each provincial government puts together aggregate official statistics with retrospective data revisions, rather than data based on raw archives from the county gazetteers.

3.3 Mortality and Population Data

We obtain demographic data to quantify the link between sparrow killing and the subsequent Great Famine. The county-level fertility and mortality rates are digitized from the county gazetteers by Li and Kasahara (2020), which we use as dependent variables to quantify mortality rates in the subsequent Great Famine. We complement county-level data with provincial-level population data from Meng et al. (2015). In Online Appendix Figure A3, we correlate the average mortality of province-level and county-level death rates. Death rates from these two data sources are strongly correlated at 53% in 1960, which is not meaningfully different than the correlation from 1954 to 1965 (57%). While, in general, county-level death rates can be double that of the provinces they are in, once we take population-weighted means of the county-level death rates in 1960, the coefficient from the regression of the province-level death rate on the population-weighted mean is 0.996, reflecting almost perfect agreement between the two.

3.4 Other Supplementary Data

We also collect additional data on reported sparrow killings, pesticide use, and procurement for food redistribution. Some provincial governments self-reported sparrow-killing data during the FPC, which we can use to validate that our sparrow suitability score does capture meaningful variations in sparrow eradication. The number of sparrows killed is usually reported in mainstream provincial newspapers, such as the Beijing Daily, which is the mouthpiece of the Beijing Municipal Party Committee. The FPC was an integral part of the Great Leap Forward, so some party newspapers provided detailed records of its progress, including reported sparrow killings in each province, with the caveat that bureaucrats might had incentives to systematically over-report these numbers.

With a sharp decline in biological pest control by sparrows, farmers could have increased their use of pesticides as a mitigation—substituting for the role of sparrows in agricultural production. However, supply of pesticides was limited at the time, and there was no market mechanism that could allocate them efficiently to where they were needed the most. Even if farmers were able to substitute for the loss of biological pest control, then our results can be interpreted as a lower bound for the effects of biological pest control loss. We collect additional data on the sales volume of chemical pesticides from provincial Agricultural Cooperative Society publications.[12] In Online Appendix Figure A4, we plot the total quantity of pesticide usage and the grain yield from 1954 to 1965. Pesticide usage first jumped in 1958—after the start of the FPC and before the significant drop in grain yield. Pesticide usage remained unusually high until 1961, after which both sparrow population and agricultural productivity started to recover.

Centrally controlled procurement of food is consequential in this setting, as pointed out by Meng et al. (2015). To examine the relationship between food procurement and sparrow suitability, we also obtain the annual county-level crop procurement data, as collected by Li and Kasahara (2020), and compute the share of the crop being procured as a metric for the fiscal burden faced by each county. These data allow us to examine how government procurement policy reacted to the negative productivity shocks during the GLF.

Ideally, we would also be able to measure the intensities of various types of pest outbreaks in different locations over time. However, despite rich qualitative media discussions on increased pest issues after the FPC, this information was not systematically recorded in the county gazetteers in the 1950s and 1960s. In fact, accurately tracking pest outbreaks remains challenging even in the context of 21st century high income countries. For example, farmers in the United States do not have access to real-time data on crop pest densities in their vicinity, and have to rely on simple pest traps to monitor conditions. Those are not centralized into a single database. Even in cases of highly harmful invasive species such as the spotted lanternfly (a planthopper species), data are at best available on their presence and whether populations have managed to establish in a county, but not on their popu-

[12] For example, the *Cooperative Society Publication of Liaoning Province* and the *Agricultural Economic Statistical Data of Zhejiang Province, 1949-1985*

lation levels.[13] Similarly, despite large investments by the Food Agriculture Organization, monitoring of locust outbreaks remains a challenge, where the detection of locust swarms has improved since 2000, yet the densities of those swarms remains largely unreported. In short, even with modern technology, collecting and reporting data on insect outbreaks is a challenge—making it unsurprising that we lack detailed data on crop pest outbreaks in China from 1958 to 1960.

3.5 Secular Trends & Summary Statistics

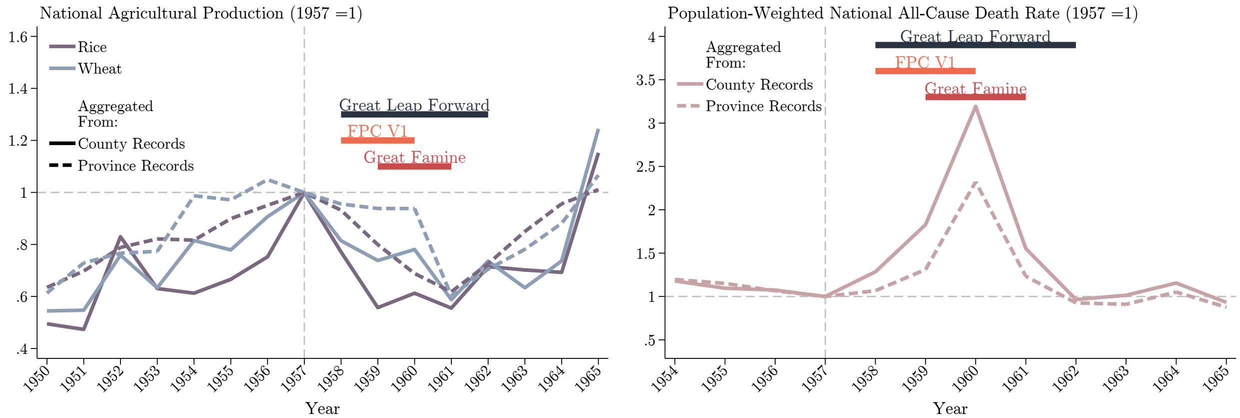
During our sample period of 1954 to 1965, China first saw consistent growth in grain production alongside reduction in all-cause death rate up until 1958, after which both trends were reversed. In Figure 3 panel (a), we plot the total production of rice and wheat, aggregated from either the county records or the provincial records. Similarly, in panel (b), we plot the population-weighted all-cause death rate, aggregated from either the county records or the provincial records. We normalize each time series relative to 1957, the year before the launch of the GLF and the FPC. We observe that by 1957, rice and wheat production had doubled relative to its 1950 baseline levels; however, those declined back to their 1951-1952 levels during 1959-1961. The fact that the (unofficial) county gazetteer data indicates larger yield declines is consistent with potential data manipulation in the official provincial statistics. China also saw a steady improvement in public health, as observed by the declining all-cause death rate from 1954 to 1957. During the peak of the Great Famine in 1960, mean mortality levels doubled or tripled relative to 1957 levels, according to the provincial or county records, respectively.

Even though our research design does not require that counties are fully balanced on observable and unobservable characteristics, it is helpful to examine the balance of key characteristics before and after the FPC. We summarize the key variables of sparrow suitability

[13] A noticeable exception is that only in the case of the spongy moth, an important forest defoliating insect, did the government invest in centralizing data on pest densities as part of its *Slow the Spread* efforts.

Figure 3: National Trends in Agricultural Production and Mortality

(a) Agricultural Production (b) Mortality



Notes: Aggregating data to the yearly level from either the provincial records or the county gazetteer data. We use the unbalanced panel to aggregate the data and normalize the time series for each variable relative to 1957. We highlight the duration of the Great Leap Forward, the Four Pest Campaign (FPC) in its first version, which included sparrows and the Great Famine. Panel (a) plots rice and wheat production from 1950 to 1965, and Panel (b) plots the population-weighted national all-cause death rate from 1954 to 1965.

score and population levels across below- and above-median suitability score in Table 1. As expected, the mean suitability score is much higher, by an order of magnitude, in the above median suitability score counties. Mean population levels from 1954 to 1957 are slightly higher in low-sparrow suitability counties, but similar in magnitude. We also compare baseline levels, from 1954 to 1957, of rice output, wheat output, procurement rate, and all-cause mortality. There are lower levels of rice production and higher levels of wheat production in the above-median suitability counties. The procurement rate in the above-median suitability counties is three percentage points lower, relative to a base of about 22-25%.

We observe a sharp widening in the mortality differential between the above- and below-median suitability counties between the two time periods of interest. The above-median suitability counties have 0.51 deaths per 1,000 people more than the below-median counties, for which we can reject the null hypothesis of a zero difference at the 5% significance level. That difference in the death rate increases six-fold, from 0.53 to 3.24, during the 1958 to 1961 period, which we can reject the null hypothesis of zero difference at the 1% significance level. During 1958-1961, we also observe a widening gap in rice yield and a shrinking gap in wheat yield, both consistent with agricultural production in the high-suitability counties being impacted more during the famine.

Table 1.
Differences in Observables Before & During the Four Pest Campaign

	(1)	(2)	(3)	(4)
	Group Means		Δ:(2)-(1)	N
Sparrow Suitability	*Low*	*High*		
Sparrow Suitability Score	.0392	.195	.156	691
	(.0262)	(.0773)	(.00418)	
Population, 1954-1957[1]	3.03	2.82	-.213	8,292
	(2.99)	(2.27)	(.0599)	
Rice Output, 1954-1957[2]	6,043	5,580	-464	901
	(11,918)	(10,028)	(737)	
Wheat Output, 1954-1957[2]	903	1,473	570	1,100
	(2,144)	(1,797)	(125)	
Procurement Rate, 1954-1957[2]	.255	.215	-.0397	1,878
	(.123)	(.0977)	(.00535)	
All-Cause Death Rate, 1954-1957[3]	11.8	12.3	.532	2,364
	(4.5)	(4.71)	(.191)	
Rice Output, 1958-1961[2]	5,281	4,152	-1,129	873
	(10,924)	(6,052)	(600)	
Wheat Output, 1958-1961[2]	770	1,224	454	1,054
	(1,673)	(1,385)	(98.8)	
Procurement Rate, 1958-1961[2]	.324	.292	-.0314	1,903
	(.148)	(.124)	(.00645)	
All-Cause Death Rate, 1958-1961[3]	17.9	21.2	3.24	2,338
	(15)	(19.6)	(.714)	

Notes: Counties with non-missing rice or wheat data in both pre- and post-1958.
Robust standard errors in parentheses.
1: In 100,000s.
2: In 10,000s kg.
3: Per-1,000 People.

4 The Sudden Extirpation of Sparrows as a Natural Experiment

In this section we first present descriptive evidence at the level of the province, summarizing the correlations between sparrow suitability, reported sparrow-killing levels, and outcomes such as: grain production, pesticide use, and all-cause mortality. We then proceed to describe the use of the sparrow suitability score in our econometric framework using the county-level data.

4.1 Descriptive Evidence on Sparrow Killings & Key Outcomes

To motivate the subsequent econometric analysis, in this section, we document a series of province-level correlational patterns, which help shed light on the relationships between sparrow suitability, sparrow eradication, and the Great Famine.

We first note that in addition to the variation in sparrow suitability (Figure 2), different provinces also reported vastly different numbers of total sparrows killed (Figure 4a). An important step in evaluating the province-level data, and our own calculations of the sparrow suitability score, is to compare the correlation between sparrow killings and suitability. In Figure 4b, we report a noisy, yet positive, correlation between the sparrow suitability score and the reported number of sparrows killed, normalized by area. The fact that we observe a low number of reported sparrow killings per square km where the suitability score is low is reassuring—provinces did not all report a uniformly high level of sparrow killings that was independent of habitat suitability for sparrows. Similarly, we observe that, at least on average, provinces that reported a high number of sparrows killed are also those for which we calculate a high sparrow suitability score. Combined, we find that the correlation in Figure 4b helps validate that the sparrow suitability metric acts as a useful proxy for baseline levels of sparrow populations. In addition, higher sparrow killings are correlated with lower grain production, higher pesticide use, and higher death rates in the immediate post-sparrow eradication campaign (1959 to 1961) relative to the preceding years (1955 to 1957) (Figures 4c-4e).[14] It is worth noting that if misreporting was severe in this context, we might have expected to see a positive—instead of negative—correlation between grain production and sparrow killings, as provinces would have had incentives to exaggerate reporting of both, leading to a spurious correlation.

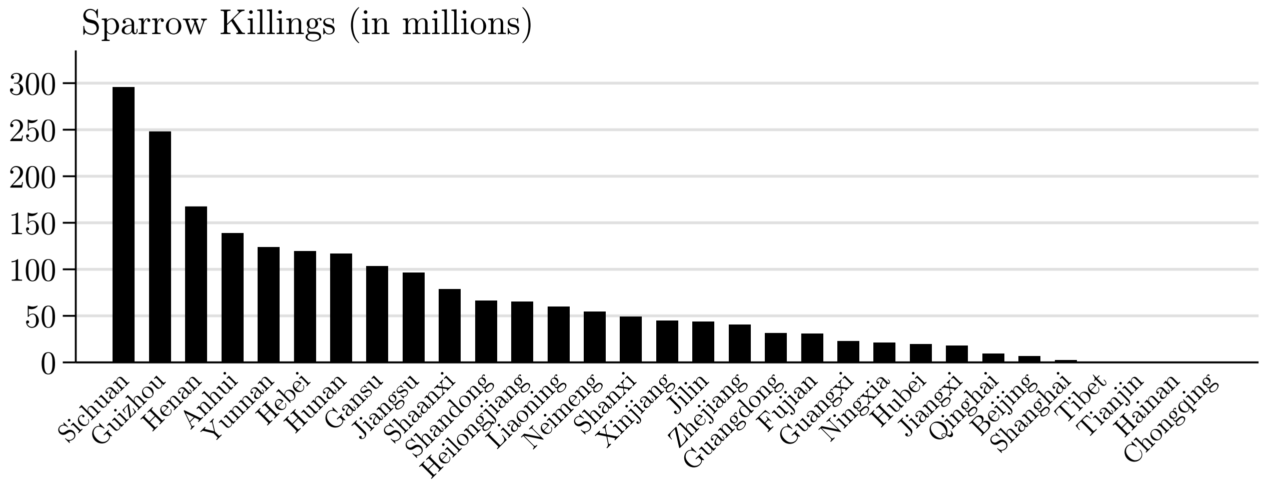
The province-level correlations help provide suggestive evidence that aligns with the hypothesis put forward by environmental historians: the campaign to eradicate sparrows contributed to the Great Famine. We avoid interpreting the empirical findings we discuss above as causal evidence because, especially at the level of the province, a key cause for concern is that local governments could have had other political motivations, which could have caused them to enthusiastically implement not only the sparrow eradication campaign, but also many other potentially harmful policy campaigns in this era. Those additional Great Leap Forward policies could also have contributed to the conditions that led to and exacerbated the famine. If the adoption of those additional policies was systematically correlated with the effort put into sparrow eradication, that would confound the relationship between the outcomes of interest and sparrow eradication.

Our baseline research design instead leverages the local exposure to the eradication shock—the combination of the baseline suitability and the sudden local extinction event—with the local agricultural production and mortality data. The empirical strategy, discussed below, uses more fine-scaled spatial variation at the level of the county to compare within geographic clusters, between counties with higher and lower sparrow suitability scores. This comparison will better allow us to separately identify the role of sparrow eradication, holding constant other ongoing policies at the time.

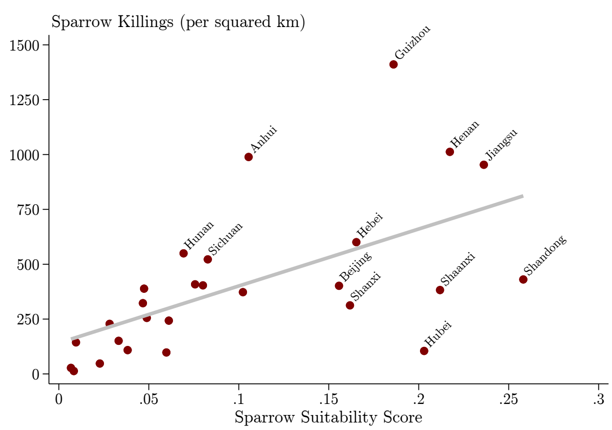
[14] We treat 1958 as a buffer year and omit it from the calculations in Figures 4c-4e.

Figure 4: Province-Level Correlations Between Sparrow Killings & Outcomes

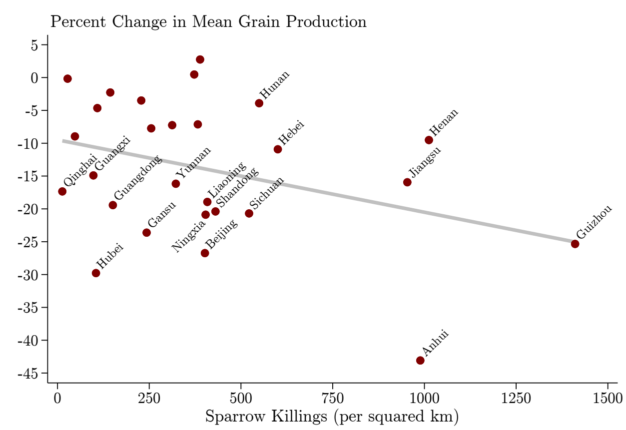
(a) Number of Reported Sparrow Killings by Province



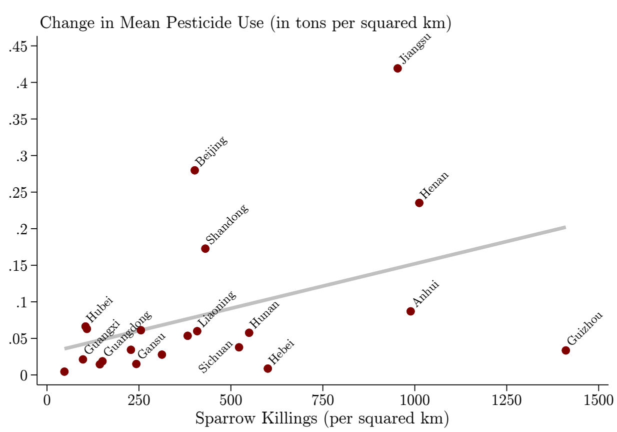
(b) Sparrow Killings VS. Sparrow Suitability



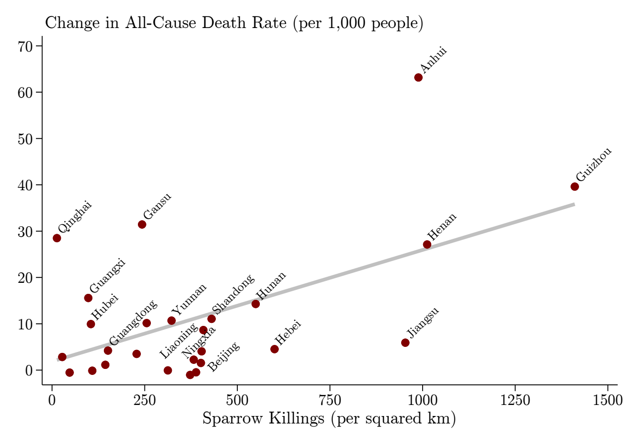
(c) Grain Production VS. Sparrow Killings



(d) Pesticide Use VS. Sparrow Killings



(e) All-Cause Mortality VS. Sparrow Killings



Notes: Summary of descriptive statistics of province-level statistics. Changes in panels (c)-(e) are for 1959-1961 relative to 1955-1957. Panel (d) excludes Shanghai for easier visual inspection as it has an outlier value of (372.7, 1.4).

4.2 Econometric Specification

Our main empirical analyses are conducted at the county-year level. We implement a difference-in-differences design, exploiting variation in each county's innate suitability for sparrow habitation, and compare how high- vs. low-suitability counties differed in agricultural and demographic outcomes, before and after the initiation of the FPC.

Specifically, for each county c, we calculate its sparrow suitability index $Suitability_c$, following the procedure discussed in Section 3. We then estimate the following specification:

$$Y_{ct} = \sum_{\tau \neq 1957} \beta_\tau Suitability_c \times \mathbb{1}\{t = \tau\} + \phi_c + \lambda_t + \varepsilon_{ct} \tag{1}$$

where Y_{ct} is the outcome of interest in county c in year t. We interact the sparrow suitability index, $Suitability_c$—either as a dummy for having an above median score, or as the continuous score—with year dummies. The parameters of interest are the β_τ coefficients that capture the dynamic response of the outcome to the impulse of the sparrow eradication, relative to 1957, which is the omitted category.

We account for time-invariant factors and pooled shocks by including ϕ_c and λ_t, which are county and year fixed effects, respectively. County fixed effects absorb factors that affect baseline agricultural productivity such as soil conditions, local crop pest composition, and climatology. Year fixed effects absorb pooled shocks such as extreme weather events, technological improvements, and structural transformation trends. In robustness tests, we allow the year fixed effects to vary at sub-national levels. Any unobserved heterogeneity is captured by the error term, ε_{ct}. The standard errors are clustered at the county level. The Online Appendix, Section A.6, further discusses spatial correlation (Figures A5-A7) and reports standard errors adjusted for spatial correlation—verifying that we are not underestimating the standard errors by clustering at the county level.

Our identifying assumption is that, in the absence of the FPC, local sparrow suitability index should have been orthogonal to the trajectories of agricultural production and demographic change. Therefore, in the event studies for the outcomes of interest, we expect β_τ to be statistically indistinguishable from zero before the onset of the FPC.

Even with parallel trends prior to the FPC, one additional potential confounder is that sparrow suitability might be systematically correlated with certain regional features, such as political zealousness in enforcing central policies, or levels of social capital, that could trigger differential responses to the national campaigns during the Great Leap Forward, and thereby generating breaks in trends after 1958. To investigate this possibility, we will directly examine the correlations between the sparrow suitability index and a set of province-level variables that capture other GLF policies that were ongoing during the FPC.

5 Economic & Demographic Consequences of Sparrow Eradication

In this section, we follow the baseline econometric specifications, as laid out in Equation 1, to investigate the economic impacts of sparrow eradication. In Section 5.1, we document the impacts of sparrow eradication on agricultural output. In Section 5.2, we examine the farmers' responses to sparrow eradication. In Section 5.3, we show how the government procurement policies responded to the sparrow-induced agricultural productivity loss. In Section 5.4, we examine the impacts on mortality and fertility. In Section 5.5, we combine the estimation results in a series of back-of-the-envelope calculations to quantify the contribution of the sparrow eradication to the agricultural loss and mortality.

5.1 Grain Output Declined Following the FPC

In Figure 5, we plot the event study coefficients we obtaine from estimating Equation 1, for the outputs of two key grain crops: rice and wheat. For rice, we do not observe a systematically different evolution of production in the years leading up to the FPC between sparrow-suitable and non-suitable counties. For wheat, we observe a nosily estimated minor growth in wheat production in sparrow-suitable counties prior to 1958. For both outcomes, we fail to see a downward pre-trend in treatment relative to control counties, which gives us additional confidence in the validity of our research design. In contrast, after 1958, when the sparrow eradication began, we see salient drops in rice and wheat output, which later gradually recovered in the post-1961 era. We observe a sharp decline in total grain production (rice or wheat) when defining treatment as the continuous sparrow suitability score, or when defining it in a binary manner—above-median sparrow suitability.

Taken together, these empirical patterns are consistent with our interpretation that counties more suitable for sparrow habitation were affected more by the eradication of sparrows. As a result, these counties became more vulnerable to locusts, planthoppers, and other pest outbreaks, which negatively affected their agricultural production. By removing sparrows from the FPC, and allowing them to repopulate after 1961, agricultural production in these affected counties gradually returned to their baseline levels.

The event study results are somewhat imprecisely estimated, with several of the 95% confidence intervals including zero; however, when we pool the treatment effects for 1958 to 1961, and 1962 to 1965, we recover more precisely estimated treatment effects. In Table 2, we summarize the patterns observed in Figure 5.[15] When we use the continuous suitability score (CSS), we see that counties with higher sparrow suitability scores experienced a large and significant drop in rice and wheat output during the FPC, compared to 1954 to 1957 (Panel A, columns 1 to 6).

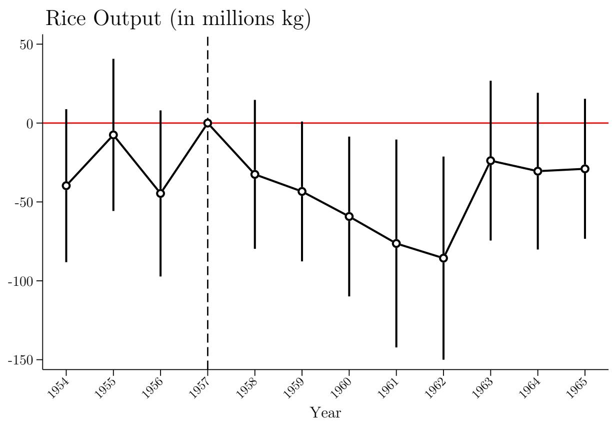
To place the magnitudes in context, a one standard deviation increase in CSS results in a 3,129 or 1,145 metric tons decline in total rice or wheat output from 1958 to 1961 (Panel A, columns 1 and 4). Relative to the mean levels in the sample, these reflect declines of 5.3% and 8.7%, respectively. Alternatively, the difference in rice or wheat output between counties that have CSS values at the 75th percentile versus the 25th percentile is 4,886 or 1,787 metric tons, respectively. In addition, if we compare the counties that have a CSS that

[15] Online Appendix Table A4 reports the results weighted by baseline population.

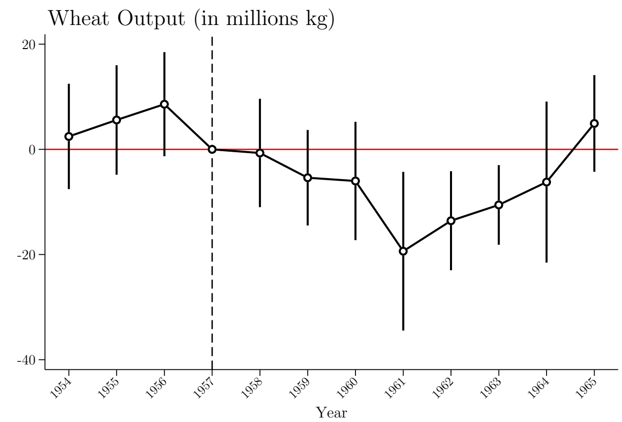
Figure 5: Effects on Rice and Wheat Output at County Level

Continuous Sparrow Suitability

(a) Rice Production

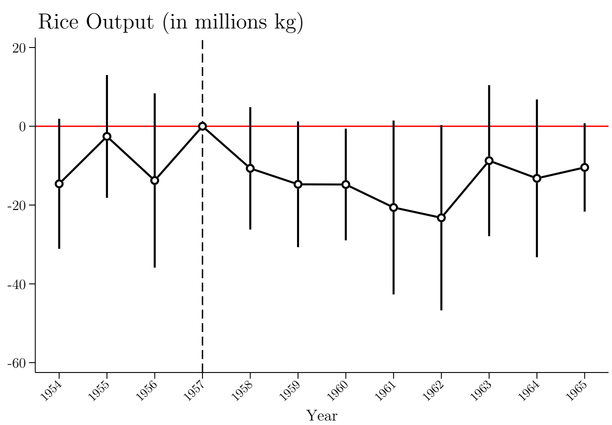


(b) Wheat Production

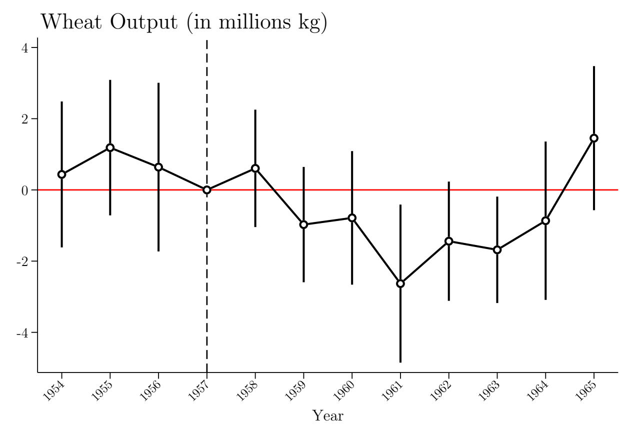


High Sparrow Suitability

(c) Rice Production



(d) Wheat Production



Notes: Coefficients and 95% CIs for the estimation specification in Equation (1). Panels (a) and (b) interact the continuous sparrow suitability score with year dummies, while panels (c) and (d) interact the dummy for above-median sparrow suitability (high sparrow suitability) with the year dummies. Each regression includes county and year fixed effects. Samples include all unbalanced counties with at least one year of non-missing data for rice and wheat before and after the onset of the FPC. Standard errors are clustered at the county level.

is above the median—hereafter, High Sparrow Suitability (HSS)—we find that rice or wheat declined in the HSS counties by 8,130 or 1,460 metric tons relative to their below-median counterparts (Panel B, columns 1 and 4). For both the CSS and HSS, we find that output was still meaningfully lower from 1962 to 1965, relative to 1954 to 1957, as the recovery of output towards baseline levels occurred around 1964 and 1965.

We continue to recover coefficients of similar magnitude and precision when we control for the dynamic impacts of baseline population—average population between 1954 and 1957 interacted with year fixed effects (columns 2 and 5). The results are also robust to including crop suitability interacted with year fixed effects (columns 3 and 6), indicating that the findings are not confounded by the sparrow suitability index picking up variations in the crop suitability indices.

One potential concern is that the campaign targeted four pests, yet we are focusing our attention on just one—sparrows. We do so for three reasons. First, sparrows were the primary target during our sample period, which is why the FPC is also referred to by many as the "sparrow eradication campaign." Second, sparrows were the only species included with agricultural production as the justification, while the other species were included due to public health reasons. If the eradication of flies, mosquitoes, and rats did improve public health, we would expect that to increase agricultural productivity. Similarly, even though rats were targeted for their role in spreading infectious diseases, rats can also cause agricultural damage by feeding on grain crops. Yet their eradication, if successful, would have led to higher agricultural production, and not lower production as we observe in the high-sparrow suitable areas. Third, controlling for the suitability of the other pests is complicated by the fact that all the pests targeted by the campaign are generalist species and can thrive in many habitats. This means that the same environmental conditions that predict high suitability for sparrows, tend to do so for the other pests as well. In addition, in the case of sparrows, there is one dominant species, the house sparrow, but in the case of the other pests, there are five fly species, five mosquito species, and two rat species—resulting in 12 additional covariates that are highly correlated with sparrow suitability.

Table 2
Effects on Rice and Wheat Output

	Rice Output			Wheat Output		
Panel A. Continous Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
CSS×1958-1961	-32.12**	-24.09**	-40.27***	-11.75***	-8.98**	-10.83***
	(14.79)	(11.39)	(13.71)	(3.65)	(3.54)	(3.63)
CSS×1962-1965	-21.61	-30.92**	-21.19	-9.68***	-8.87***	-9.69***
	(15.20)	(12.95)	(15.70)	(3.44)	(3.22)	(3.43)
R^2	0.89	0.90	0.89	0.90	0.88	0.90
Dep. Var. Mean	59.54	55.28	59.54	13.22	11.41	13.22
N	3,473	2,712	3,473	4,081	3,290	4,081
Clusters	421	336	421	495	407	495
Panel B. High Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
HSS×1958-1961	-8.13**	-9.05***	-7.77**	-1.46**	-1.07	-1.29*
	(3.45)	(2.93)	(3.31)	(0.70)	(0.79)	(0.70)
HSS×1962-1965	-7.01*	-9.34**	-7.06*	-1.03*	-1.60***	-1.07*
	(4.06)	(4.22)	(4.12)	(0.61)	(0.60)	(0.61)
R^2	0.89	0.90	0.89	0.90	0.88	0.90
Dep. Var. Mean	59.54	55.28	59.54	13.22	11.41	13.22
N	3,473	2,712	3,473	4,081	3,290	4,081
Clusters	421	336	421	495	407	495
Baseline Population-by-Year FE	N	Y	N	N	Y	N
Crop Suitability-by-Year FE	N	N	Y	N	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. Each regression includes county and year fixed effects. Standard errors are clustered at the county level.

5.2 Farmers' Adjustments

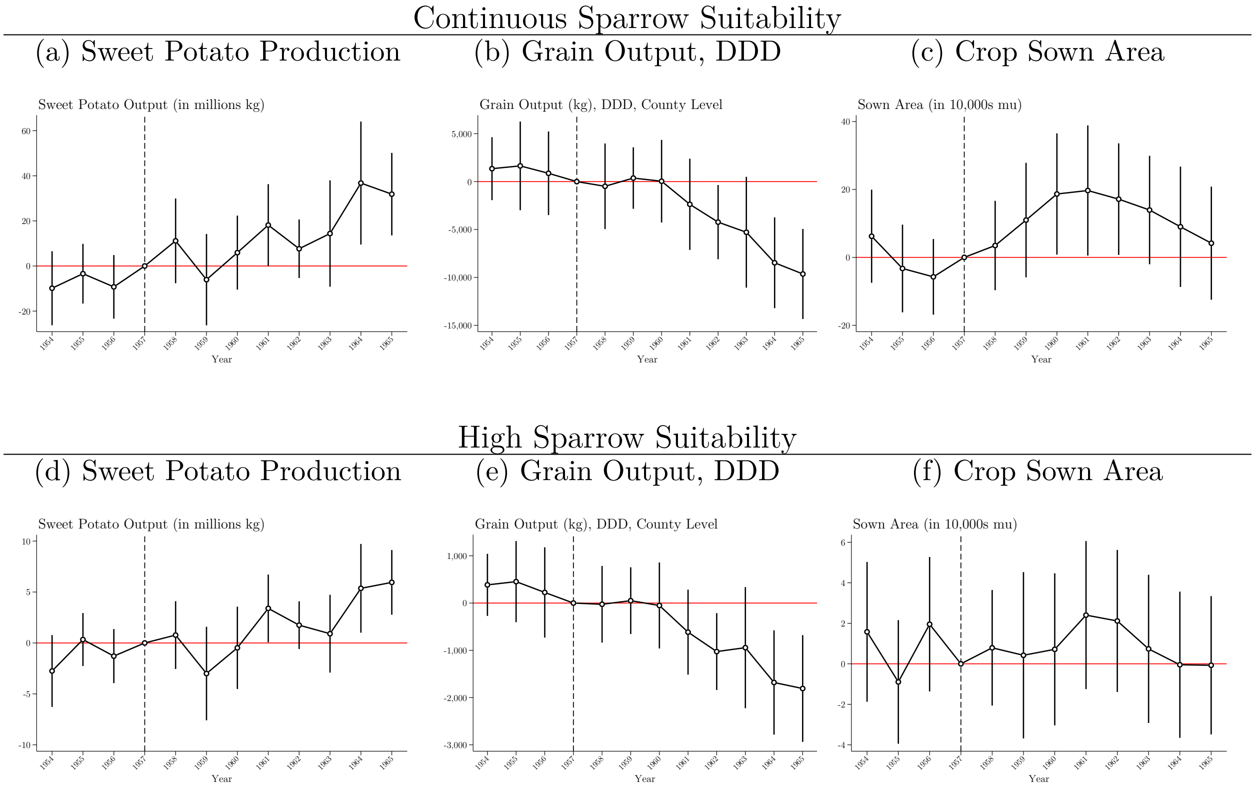
Farmers were limited in their ability to make adjustments in response to a potential increase in crop pest pressure for several reasons. First, most crop planting decisions were centrally planned, especially for grains such as rice and wheat. One notable exception to this was that after 1960, farmers were allowed to plant sweet potatoes for subsistence purposes (Meng et al. 2015). Second, other beneficial inputs such as pesticides and fertilizers were centrally distributed as opposed to purchased by farmers—preventing farmers from flexibly increasing inputs. Finally, migration and labor allocations were rigidly managed through the Hukou system (Yang 2012).

We begin examining potential adaptation by estimating whether there was a differential adoption of sweet potatoes in the counties that are more suitable for sparrows. It is important to note that grain crops such as rice and wheat are above-ground crops, while sweet potatoes are (root) below-ground crops. This feature makes sweet potatoes potentially less susceptible to an above-ground crop pest infestation—in particular locust outbreaks that were the main threat to agricultural production throughout Chinese history—the type that sparrows is believed to have played a key role in preventing (Mullié 2009; Sharma and Sharma 2017). It is documented in historical accounts that after 1960, the Chinese central government started allowing farmers to grow sweet potatoes on "private plots (*Zi Liu Di*)," in order to cope with the famine (Yang 2012).

In Figures 6a and 6d, we report the coefficients from the estimation of Equation (1) for total sweet potato production, and find *opposite* effects to rice and wheat. The event study coefficients demonstrate a reassuring flat pre-trend, and then a large and persistent *increase* in crop output after 1960—when sweet potato planting was allowed for self-consumption. This indicates that counties more suitable for sparrow habitation experienced significant spikes in the production of sweet potatoes following the FPC, which persisted even as rice and wheat crops returned to baseline levels. It is important to note, however, that our sample size for counties with sweet potato data is smaller—206 counties relative to 421 and 495 counties for rice and wheat.

These observed empirical patterns are consistent with the different susceptibility of the below- versus above-ground features we described above. We interpret these findings as

Figure 6: Effects on Sweet Potato Output and Crop Sown Area at County Level



Notes: Coefficients and 95% CIs for the estimation specification in Equation (1). Panels (a)-(c) interact the continuous sparrow suitability score with year dummies, while panels (d)-(f) interact the dummy for above-median sparrow suitability (high sparrow suitability) with the year dummies. Each regression includes county and year fixed effects. Samples include all unbalanced counties with at least one year of non-missing data for rice and wheat before and after the onset of the FPC. Standard errors are clustered at the county level.

suggestive evidence that, in the absence of the biological provision of pest control functions, historically provided by sparrows, farmers of rice and wheat crops would become more willing to switch or increase their sweet potato cultivation to hedge themselves against future pest outbreaks. Such a switch in crop choice in the more sparrow-suitable counties appears persistent even after the removal of sparrows from the FPC, which can be rationalized by either a fixed cost of crop switching or shock-induced learning (about the benefits of growing sweet potatoes).[16]

The cultivation of sweet potatoes is a time-varying outcome that could account for other

[16] Sweet potatoes were not introduced to China until the mid-seventeenth century, when farmers had been growing rice and wheat for centuries and did not fully adopt this new crop (Jia 2014). A negative shock to rice and wheat yields such as the FPC could have induced farmers to learn more about the returns to growing sweet potatoes.

factors that affect rice and wheat production—for example, drought conditions. We estimate a triple-differences specification by using a sample of rice, wheat, and sweet potato, where the comparison between rice/wheat vs. sweet potato provides the third dimension of "difference." In Figures 6b and 6e, we report the coefficients for the triple-interaction of sparrow suitability (continuous or dummy for above-median), rice or wheat crops, and year dummies. Effectively, this specification benchmarks the decline in rice and wheat against the growth in sweet potatoes, across counties with different levels of sparrow suitability score, before and after the FPC. The results again reveal that, after the start of sparrow eradication, counties more affected by sparrow eradication shifted from relying on rice and wheat to relying on sweet potatoes, creating a clear divergence in crop choices that persisted even after the end of the FPC.

One potential way farmers could have increased production is to increase the amount of land area under cultivation, especially given that "private plots (*Zi Liu Di*)" for sweet potatoes became allowed at the time. However, one challenge to that could have been that labor reallocation from rural villages led to the abandonment of agricultural lands, leading to reduced total agricultural output. If sparrow-suitable counties systematically reduced the sown area more than non-suitable counties then this presents a threat to our identification strategy as it offers an alternative explanation to the decline in output. In Figures 6c and 6f, we report imprecisely estimated *increases* in sown area in the sparrow-suitable counties. We interpret this result as the data on sown area not being consistent with the notion that grain output fell in sparrow-suitable counties because of a sharp reduction in cultivated land for agricultural production. In other words, using sown area as a proxy for rural labor, we do not find evidence that supports a differential reallocation of rural labor away from sparrow-suitable counties relative to non-suitable counties.

In Table 3, we summarize the graphical patterns documented in Figure 6, following the same specifications used in Table 2. Our estimates indicate that a one standard deviation increase in the sparrow suitability score resulted in an increase of 1,263 and 2,732 metric tons of sweet potato production during the periods of 1958-1961 and 1962-1965 (Panel A, column 1). The fact that sparrow-suitable counties keep producing more sweet potatoes in the long run, combined with the fact that rice or wheat production in these counties returned to baseline by 1965, suggests that the passive adoption of sweet potatoes during a time of crisis might have long-run benefits to these counties, who suffered most during the famine. As expected, in Panel B of Table 3, we fail to recover an estimate for sweet potato production increasing in the HSS counties from 1958 to 1961, but we recover meaningful and precisely estimated spikes in production from 1962 to 1965. Finally, when using either the CSS or HSS, we always fail to detect statistically significant changes in crop sown area, and can reject meaningful declines in sown area.

5.3 Government Responses

As documented by Meng et al. (2015), during the GLF, in addition to declines in agricultural output, the rigid procurement standard also played a key role in generating regional food shortages and thereby causing the famine. Guided by this insight, we formally examine whether the government was able to adjust procurement requirements in the regions that were more affected by the FPC, which helps shed light on whether, and through what potential mechanisms, the FPC would play a role in the formation of the Great Famine.

Our analysis demonstrates that the rigid crop procurement rule further exacerbated the negative agricultural production shock. We report the coefficients for the event study estimation for the procurement rate and amount in Figure 7, where we observe a spike during the years of the FPC with sharp reversal in 1961. When high-suitability counties experienced a negative output shock after sparrow eradication, they woefully got assigned even higher procurement amounts, which was likely driven by the central government's working assumption for the FPC—that sparrow eradication would boost agricultural productivity, rather than reducing it (Zhao and Su 2011). For example, in 1960, when China's Vice Premier Tan Zhenlin discussed the FPC—despite a long list of prominent scientists arguing other-

Table 3
Effects on Sweet Potato Output and Crop Sown Area

	Sweet Potato Output			Crop Sown Area		
Panel A. Continous Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
CSS×1958-1961	12.97*	-0.87	6.19	14.03*	10.26	13.85*
	(7.75)	(5.72)	(7.50)	(8.18)	(7.64)	(7.93)
CSS×1962-1965	28.05***	11.02***	20.11**	11.59	7.45	11.55
	(10.27)	(3.92)	(8.48)	(8.39)	(7.43)	(8.16)
R^2	0.85	0.87	0.86	0.98	0.98	0.98
Dep. Var. Mean	17.02	14.11	17.02	85.15	82.89	85.15
N	1,588	1,219	1,588	3,741	3,345	3,741
Clusters	206	164	206	459	417	459
Panel B. High Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
HSS×1958-1961	1.09	-1.26	-0.29	0.49	0.12	0.39
	(1.45)	(1.36)	(1.50)	(1.79)	(1.56)	(1.77)
HSS×1962-1965	4.46***	2.07**	2.88**	0.10	-0.55	0.05
	(1.60)	(0.87)	(1.28)	(1.93)	(1.63)	(1.91)
R^2	0.85	0.88	0.86	0.98	0.98	0.98
Dep. Var. Mean	17.02	14.11	17.02	85.15	82.89	85.15
N	1,588	1,219	1,588	3,741	3,345	3,741
Clusters	206	164	206	459	417	459
Baseline Population-by-Year FE	N	Y	N	N	Y	N
Crop Suitability-by-Year FE	N	N	Y	N	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. Each regression includes county and year fixed effects. Standard errors are clustered at the county level.

wise—he remarked, "*the achievement of the FPC is more than clear; sparrows have mostly been eradicated, crop yield has been growing steadily, we have already greatly alleviated the negative impacts of sparrows on agricultural production.*"[17] This maladaptation further reduced local available food supplies, which were now being procured and redistributed, in the exact location that already experienced a negative production shock.

Since crop yield and procurement amount moved in such opposite directions, the effective procurement rate (procurement divided by output) went up substantially for the high-suitability counties during the FPC, which echoes the patterns documented by Meng et al. (2015), in which more productive counties saw larger declines in food availability. After 1960, both the procurement amount and the effective procurement rate started to catch up with the lower yields in high-suitability counties, consistent with the historical background documented in the Great Famine literature—the Chinese government realized the severity of the famine after 1960, and adjusted its procurement policies accordingly (Yang 2012).

Taking stock, our results indicate that the eradication of sparrows reduced crop yields in counties with high sparrow suitability scores between 1958 and 1961, while grain procurement in these areas did not adjust accordingly until 1961. As a result, 1960 was likely a particularly difficult year for the high-suitability counties—yield had already fallen significantly, while procurement amount further went up. We examine this hypothesis explicitly in the following section.

5.4 Mortality and Fertility Rates

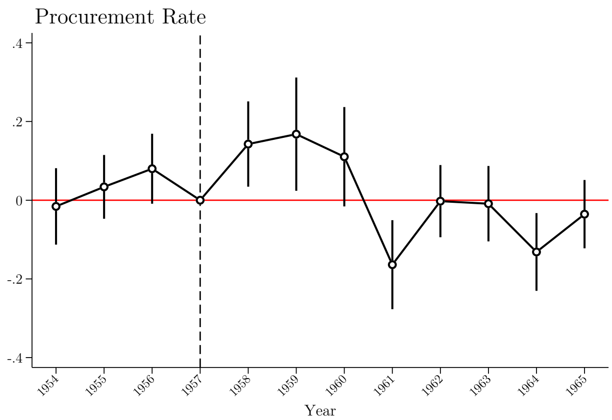
In this section, we investigate the demographic impacts of the eradication of sparrows. Our key hypothesis is that because sparrow-suitable counties experienced both a decline in agricultural production, and, at the same time, were required to deliver more of their diminished food surplus for purposes of redistribution, they were likely to experience a higher degree of food shortages. If so, this should reflect in more severe mortality outcomes in these coun-

[17] Source: https://www.gov.cn/test/2006-02/27/content_212502.htm. Accessed June 6, 2025.

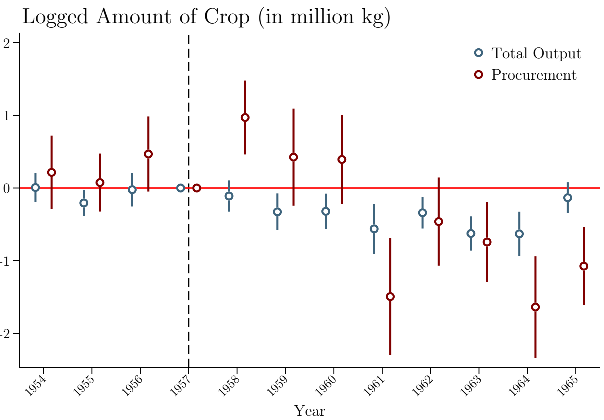
Figure 7: Examining the Role of the Procurement Policy

Continuous Sparrow Suitability

(a) Procurement Rate

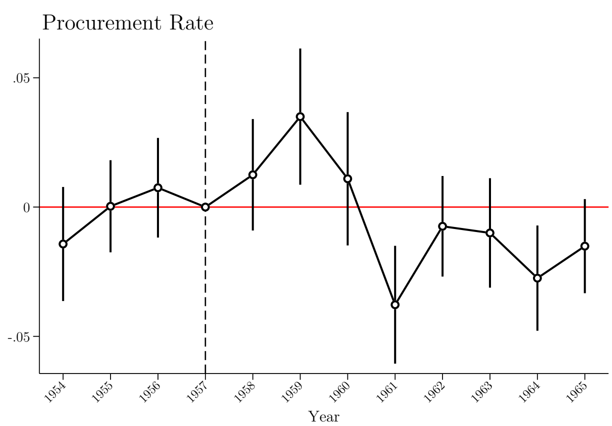


(b) Numerator and Denominator

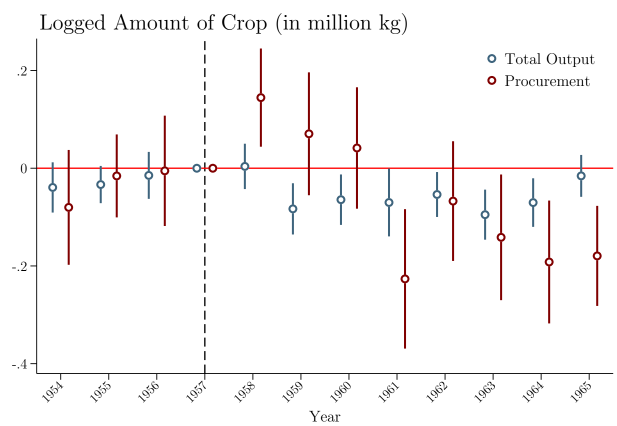


High Sparrow Suitability

(c) Procurement Rate



(d) Numerator and Denominator



Notes: Coefficients and 95% CIs for the estimation specification in Equation (1). Panels (a) and (b) interact the continuous sparrow suitability score with year dummies, while panels (c) and (d) interact the dummy for above-median sparrow suitability (high sparrow suitability) with the year dummies. In panels (a) and (c), we plot the procurement rate (amount procured for redistribution relative to total local production), while in panels (b) and (d), we separately examine the logged amount in the numerator or denominator in the procurement rate. Each regression includes county and year fixed effects. Samples include all unbalanced counties with at least one year of non-missing data for rice and wheat before and after the onset of the FPC. Standard errors are clustered at the county level.

ties. Throughout the demographic analysis, all regressions are weighted by the pre-1957 population of each county.[18]

There was no systematic difference in mortality or fertility trends between sparrow-suitable or non-suitable counties before the FPC, but during the peak of the Great Famine, sparrow-suitable counties experienced a meaningful differential shock to these outcomes. In Figure 8, we plot the event study coefficients from Equation (1) for either the all-cause death rate or the birth rate, per 1,000 people. For the all-cause death rate, we observe no difference in how sparrow-suitable counties were trending relative to the sparrow-unsuitable counties in the pre-FPC years—when using either the continuous or dummy version of the treatment variable (Figure 8a or 8c). For both versions of the treatment variable, we observe a sharp spike in mortality in 1960, the peak of the Great Famine. The timing of this effect is highly consistent with the relative timelines of agricultural shock and delayed procurement adjustment, as discussed in Section 5.3. When using the above-median sparrow suitability treatment definition (Figure 8c), we observe that the high sparrow suitability counties started to diverge from the low sparrow suitability counties in 1958.

The magnitudes of the mortality effects are meaningful, even against the backdrop of the calamity of the Great Famine. For example, in 1960, a one standard deviation difference in the sparrow suitability score resulted in 3.3 additional deaths per 1,000 people. Alternatively, the difference in mortality in 1960 between a county with a sparrow suitability score at the 75th to the 25th percentile level is 5.1 additional deaths per 1,000 people. The high sparrow suitability counties (above-median suitability) had 13.14 additional deaths per 1,000 people in 1960, relative to the low sparrow suitability counties. These reflect relative differences of 9.6%, 15%, and 38.9%, respectively, relative to the mean all-cause death rate in 1960 of 33.9 deaths per 1,000 people.[19]

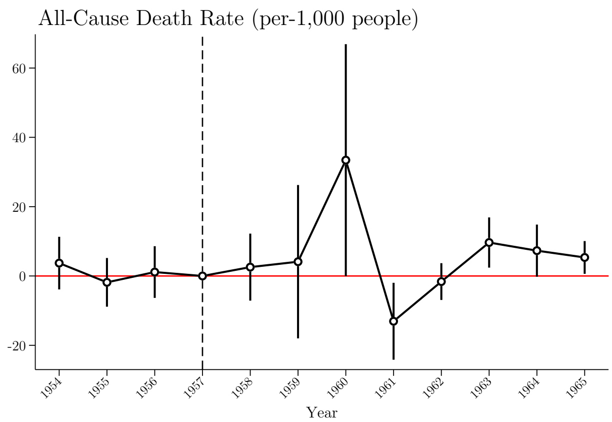
[18] To allow for comparison between the previous unweighted results and results reported here, we present population-weighted results in Table 4, and unweighted results in Online Appendix Table A5.

[19] The mean all-cause death rate in 1960 is masking considerable heterogeneity. The 10th, 25th, 75th, and 90th percentile values for the all-cause death rate in 1960 were: 9.7, 13.6, 52.7, and 70.4 deaths per 1,000 people.

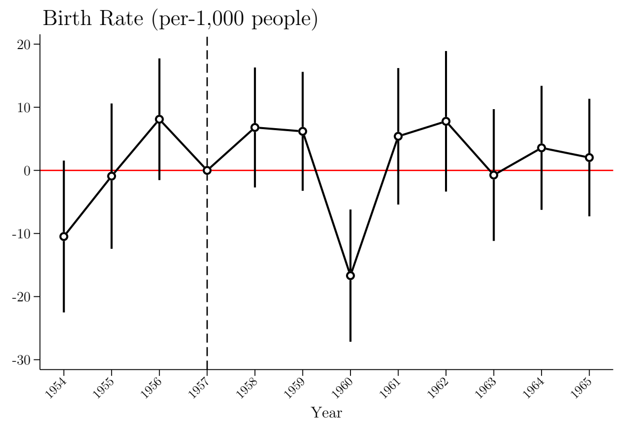
Figure 8: Effects on Population at County Level

Continuous Sparrow Suitability

(a) Mortality

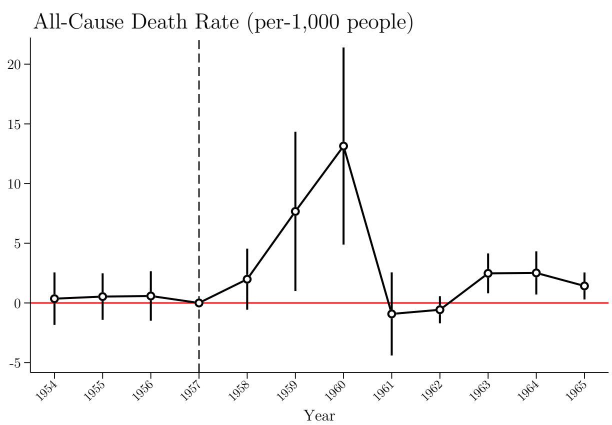


(b) Fertility

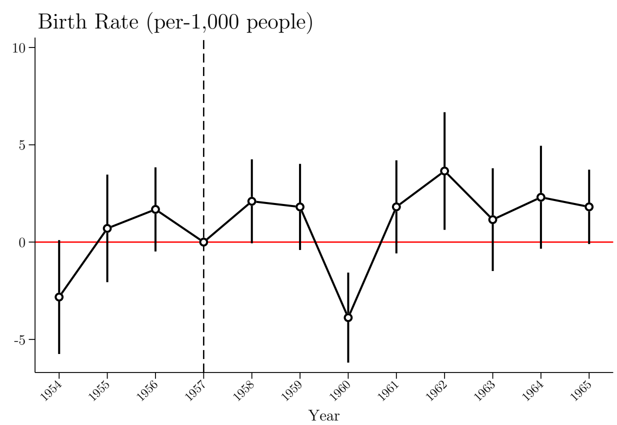


High Sparrow Suitability

(c) Mortality



(d) Fertility



Notes: Coefficients and 95% CIs for the estimation specification in Equation (1). Panels (a) and (b) interact the continuous sparrow suitability score with year dummies, while panels (c) and (d) interact the dummy for above-median sparrow suitability (high sparrow suitability) with the year dummies. Each regression includes county and year fixed effects. Samples include all unbalanced counties with at least one year of non-missing data for rice and wheat before and after the onset of the FPC. Standard errors are clustered at the county level.

Higher mortality is one demographic dimension through which counties could have experienced the severe negative effects of the Great Famine, while fertility is another important dimension we examine. In Figures 8b and 8d, we repeat the same exercise for fertility rate, motivated by previous findings in the literature showing that the Great Famine consisted of not only death counts but also foregone births in the corresponding cohorts (Ashton et al. 1992). As expected, the pattern appears to be the mirror image of that in mortality results: the birth rate is strongly negatively correlated with the sparrow suitability score in 1960, but not in the years before or after.

In Table 4, we summarize the patterns we report in Figure 8.[20] Because the events of the Great Famine were so heavily concentrated during the peak in 1960, we recover a positive but imprecisely estimated coefficient when we pool 1958 to 1961 together, using the CSS (Panel A, columns 1 to 3). When we use the HSS, we recover precisely estimated increases in mortality over the 1958-1961 period of 5.1 additional deaths per 1,000 people (Panel B, column 1). While our pooled estimates for fertility from 1958 to 1961 smooth out the sharp negative effect in 1960 we observe in Figures 8b and 8d, we observe a precisely estimated *increase* in the birth rate following the FPC, during 1962 to 1965. We find that the birth rate was 2.2 births per 1,000 people higher in the HSS counties (Panel B, column 4). This is consistent with delayed fertility decisions and with fertility choices that seek to compensate for mortality shocks (Nobles et al. 2015; Eckstein et al. 1984).

It is worth noting that while sparrow-suitable counties experienced the largest reductions in rice production in 1960-1961, and in wheat production in 1961, the main demographic consequences were heavily concentrated in 1960, which echoes Meng et al. (2015) by highlighting the central role of procurement rules in driving the famine. In fact, we observe that sparrow-suitable counties experienced the biggest differential change to the procurement rate in 1960 (Figures 7a and 7c). To put it in another way, it is unlikely that the eradication of sparrows alone would have caused all the documented demographic changes, had there not

[20] Online Appendix Table A5 reports the same sets of regression with equal-weighted rather than population-weighted.

Table 4
Effects on Death and Birth Rate

	Death Rate			Birth Rate		
Panel A. Continous Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
CSS×1958-1961	5.49	6.14	0.46	0.52	-0.16	-0.21
	(7.89)	(8.06)	(7.58)	(3.61)	(3.48)	(3.70)
CSS×1962-1965	4.28*	2.91	3.05	3.12	2.76	-0.10
	(2.25)	(2.22)	(2.30)	(4.02)	(4.05)	(3.68)
R^2	0.45	0.46	0.48	0.68	0.68	0.70
Dep. Var. Mean	14.65	14.65	14.65	31.63	31.63	31.63
N	3,699	3,699	3,699	3,654	3,654	3,654
Clusters	486	486	486	482	482	482
Panel B. High Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
HSS×1958-1961	5.10**	5.44**	4.17*	0.31	0.14	0.14
	(2.18)	(2.37)	(2.17)	(0.79)	(0.80)	(0.81)
HSS×1962-1965	1.00*	0.73	0.74	2.16**	2.15**	1.58*
	(0.51)	(0.49)	(0.54)	(0.91)	(0.97)	(0.86)
R^2	0.46	0.46	0.48	0.68	0.68	0.70
Dep. Var. Mean	14.65	14.65	14.65	31.63	31.63	31.63
N	3,699	3,699	3,699	3,654	3,654	3,654
Clusters	486	486	486	482	482	482
Baseline Population-by-Year FE	N	Y	N	N	Y	N
Crop Suitability-by-Year FE	N	N	Y	N	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. Each regression is weighted by the mean population between 1954 and 1957. Each regression includes county and year fixed effects. Standard errors are clustered at the county level.

been such misguided procurement rules prior to 1960.

5.5 Back-of-the-Envelope Calculation

In this section, we evaluate the aggregate contribution of the FPC to the Great Famine. Linking the estimates for agricultural and demographic impacts, and imposing linearity assumptions on these effects, we can conduct back-of-the-envelope calculations on the extent to which the eradication of sparrows contributed to the Great Famine.

Specifically, according to our agricultural estimates, 23,169,473 (3,844,525) tons of lost rice (wheat) can be attributed to the eradication of sparrows, which is 8.72% of the baseline national crop yield, and accounts for 19.64% of the lost output during the Great Famine.[21] According to our demographic estimates, sparrow eradication led to the loss of 1,954,169 lives, and reduced fertility counts by 397,368.[22] This is equivalent to 0.307% of the total national population, and 6.49% of the total death count during the Great Famine.

In Online Appendix Tables A6 and A7, we redo these calculations using different versions of baseline point estimates and under different functional form assumptions, and present the most "aggressive" vs. "conservative" findings. As the results suggest, while the calculated impacts of sparrow eradication do vary across specifications and functional forms, the main quantitative message remains robust—sparrow eradication was accountable for a substantial amount of agricultural output loss and excessive deaths during the Great Famine.

[21] We calculate the lost crop caused by sparrow killing as the sum of products across counties of the suitability scores, which is weighted by the percentage of a certain crop production out of the total output of all crops, multiplied by the event study coefficients for 1959, 1960, and 1961. We calculate the total lost crop as the difference in the sum of the estimated crop output between 1959 and 1961 and the actual crop output between 1959 and 1961.

[22] We calculate the total loss of lives in a similar way to the crop losses. We take the sum of products of the suitability scores times the all-cause death rate event study coefficients for 1959, 1960, and 1961, multiplied by the county's population. We then divide that sum by the total number of deaths across all counties. We repeat this process for fertility.

6 Robustness Checks and Ecological Validation

In Section 6.1, we assess the robustness of our baseline findings. In Section 6.2, we benchmark the econometric results against simulations of a simple ecological model of predator–prey population dynamics.

6.1 Robustness & Threats to Internal Validity

We examine the robustness of our baseline findings to a variety of changes to the regression specification, or additional sample restrictions. One potential concern is the representativeness of our baseline county sample. Since official statistics were widely known to be severely exaggerated in that period (Chen and Kung 2011), we rely on decentralized information independently documented in the county gazetteers, which is believed to be more accurate (Alesina et al. 2020). However, the county gazetteers were only available intermittently in 898 counties, reflecting 58.6% of the total number of agricultural counties at the time, raising questions about possible sample selection issues across regions and over time. We address these concerns in two ways.

First, as discussed in Section 4, when regressing official agricultural output numbers against official numbers of sparrow killings at the provincial level, this balanced panel shows a pattern consistent with our county-level analysis: provinces reported to have killed more sparrows during the FPC also experienced sudden losses in agricultural output during this period. This aggregated balanced panel thus helps alleviate concerns that the county-level results are driven by its incomplete coverage. While it is certainly possible that the provincial official statistics may have been manipulated, it is worth noting that such politically-motivated misreporting would likely be systematically inflated for both crop yields and sparrow killings, thereby generating a spurious positive correlation between the two, rather than the negative relationship observed in our data.

Second, in addition to aggregating the analysis to the provincial level, we also repeat the county-level analysis with only a balanced panel.[23] In Online Appendix Table A8, we compare estimates from the baseline specification in Equation (1) using the unbalanced panel, to the estimates we obtain when restricting the sample to be balanced between 1955 and 1962. We fail to find meaningful differences in the baseline empirical patterns. This is reassuring that our findings are indeed driven by the treatment effect of sparrow eradication, instead of potentially endogenous entry and exit of counties in our baseline sample. The results from the balanced sample complement the analysis in Online Appendix Table A2, where we do not find evidence that the timing of failing to report a value for rice or wheat is correlated with sparrow suitability.

Environmental data are often spatially clustered, and since the sparrow suitability score is a function of different environmental variables, we expect it to be spatially clustered as well (see Figure 2). One concern that arises from such spatial clustering is that the standard errors are spatially clustered, and that by clustering at the county level, we might be systematically overestimating the precision of our estimates. In Online Appendix Section A.6, we first document the distance distribution between counties, then demonstrate that when allowing standard errors to be correlated across neighboring counties, the precision of the results holds.

Another concern with our use of environmental data is that we use data from more recent years when estimating the sparrow suitability score. Because of climate change, it is possible that environmental conditions today are meaningfully different than what they were around 1960. This could threaten our identification strategy if climate change had a larger effect in sparrow-suitable areas, as it would introduce non-classical measurement error to our key treatment variable. In Online Appendix Section A.7, we examine the scope of this concern. We first document that the temperature distribution has shifted to the right over time, but verify that changes in mean annual temperatures are uncorrelated with the sparrow suitability score we calculate.

[23] To avoid dropping too many counties from the sample, for the robustness checks with balanced panels, we focus on the sample period between 1955 and 1962.

One might also worry about potential outliers in the historical data, especially given that the county gazetteers data was largely voluntarily documented by the local gentry class, without a streamlined process of quality checking. To alleviate such concerns, in Online Appendix Tables A10 and A11, we re-run the baseline regressions using truncated samples at [1%,99%], [2.5%,97.5%], and [5%,95%], respectively. Compared to the baseline untruncated sample, the key empirical patterns remain highly robust, indicating that the main results are not driven by outliers.

To further verify that the main results are not sensitive to the choice of fixed effects in the specification, especially the temporal controls, we report several variations to the baseline regression specification in Equation (1). In Online Appendix Tables A12-A25, we report—for all the outcomes, using either the CSS or HSS—the baseline event-study coefficients, along with results that include the baseline population-by-year, and the crop suitability-by-year controls. To this, we add results that also allow the year fixed effects to vary by one of three regions (east, middle, or west). In a more demanding check, we include province, of which there are 31 of, linear time trends. This change leads to similar patterns in terms of the sign of the dynamics, despite sometimes resulting in less precisely estimated coefficients.

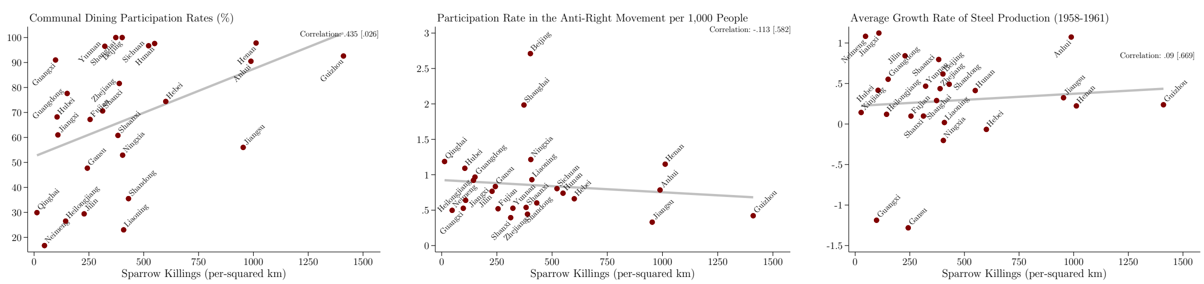
As additional time-varying controls, in Online Appendix Tables A12-A25, we also add the province-level cross-sectional covariates on communal dining, participation in the anti-rightist movement, cattle killings, and steel production growth, which we interact with year fixed effects. All four have been used in previous papers on the GLF and the Great Famine to examine the varying degree of adherence to GLF policies (Lin 1990; Lin and Yang 2000; Meng et al. 2015; Chen and Lan 2017). We also summarize the province-level correlation of these variables with the reported sparrow killings in Figure 9, where we fail to detect meaningful correlations.[24] By including the interactions of these province-level proxies for GLF "zealousness," we are allowing different dynamics at the province level to absorb more

[24] While communal dining (Figure 9a, shows a linear fit with a positive slope, it is heavily driven by just three outlier provinces. Removing just one of the three provinces in the top-right corner of the figure, greatly suppresses the positive slope of the linear fit line.

of the variation in agricultural production, as well as other outcomes. As we include more of these covariates, however, we reduce the sample size because not all of these variables are reported for all of the provinces. In the most demanding specification, where we include baseline population-by-year, crop suitability-by-year, GLF covariates-by-year, and province linear time trends, we are left with a little over half of the original sample, yet we still recover meaningful and precisely estimated treatment effects based on sparrow suitability.

Figure 9: Cross-Sectional Provincial Correlations With GLF Policies

(a) Communal Dining (b) Anti-Right Movement (c) Steel Production Growth



Notes: Province-level correlations of proxies for "zealousness" with respect to pursing other Great Leap Forward policies, and sparrow killings.

6.2 Benchmarking Agricultural Losses

To better interpret our findings on the decline in grain production, we use a predator–prey model to derive back-of-the-envelope estimates. The Lotka–Volterra model is one of the most commonly used frameworks in ecology for describing the population dynamics of two interacting species (Wangersky 1978). Our goal is not to make precise predictions of population levels but rather to highlight how a change in one species' population can lag behind a change in the other and to illustrate the potential magnitude of their oscillations over time. Figure 10a plots the dynamics of both populations, initialized at steady state and subjected to a negative shock to the predator population. In Online Appendix Section A.8, we present the equations and steady-state of the system.

Using this model, we simulate how crop damage varies following a decline in biological pest control. We consider multiple baseline values for both the sparrow and pest populations, as well as the damage coefficient quantifying pest impacts on crops. Baseline population levels are determined by the four key model parameters: the pest birth rate, the predation rate by natural enemies (biological pest control), the predator death rate, and the conversion factor from consumed prey to new predators. In each simulation, these four parameters are sampled from uniform distributions. We also sample the pest damage coefficient from values commonly reported in the literature. These are the five system parameters.

We vary the relative reduction in biological pest control following the sparrow eradication across simulations. As noted earlier, sparrows were not the sole agents of pest control, and the campaign's targeting was imperfect: other species continued providing control, while sparrow-like birds may also have been affected. We simulate predator population shocks of 1 – 20 percent, performing 100 iterations per shock. In each iteration, we randomly sample the five system parameters. We then infer the relative change in crop damage from the resulting deviation in pest population levels from the steady state.

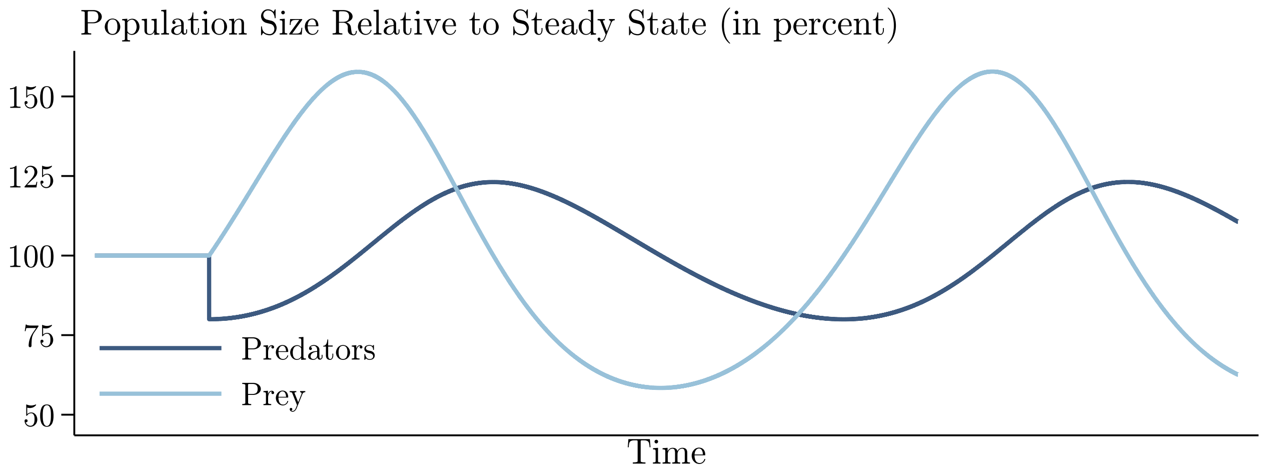
Simulation results highlight a wide range of possible crop-damage increases—up to 40 percent. In Figure 10b, we plot each trajectory of crop-pest damage following a shock to biological pest control. Although the simulation abstracts away from many important system dimensions, we find that the observed relative declines in rice and wheat fall well within the simulated damage increases. In other words, the simulations illustrate that biological pest control did not have to collapse completely after sparrows were eradicated. Even moderate losses of pest control, combined with varying degrees of pest-damage coefficients, can produce large, meaningful declines in output.

It is important to caveat the results from this simulation as it is an illustrative exercise. We place less emphasis on the exact numbers we obtain, as those are sensitive to the chosen ranges of parameter values, and the model provides a highly simplified system of only two species. That being said, we argue that the simulation offers two useful insights: (i) the reduction in biological pest control leads to larger crop pest damages due to the insects that do not get eaten, but more importantly, because the insect population increases non-linearly;

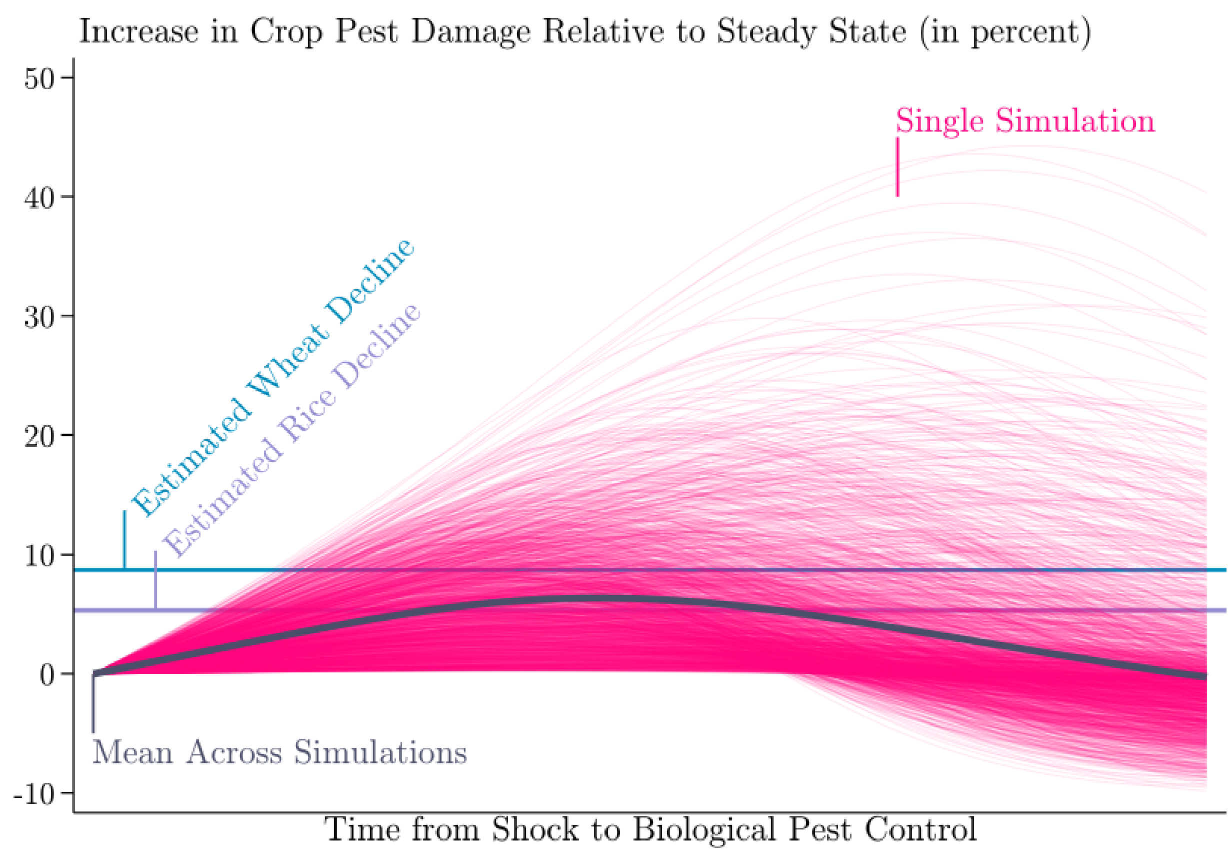
and (ii) the simulation results highlight that under a combination of parameter values, the increase in crop damages can be substantially higher, even higher by an order of magnitude than what we estimate in our analysis.

Figure 10: Benchmarking Agricultural Losses Using a Predator-Prey Simulation

(a) Schematic Predator-Prey Model Dynamics



(b) Change in Agricultural Losses Due to Crop Pests



Notes: In Panel (a), we plot the schematic dynamics of a predator-prey model. Starting with the populations of both at steady state, we sharply reduce the predator population by 20 percent. This sets in motion a cycle of changes in the population size that repeats itself unless the system is disrupted again. In Panel (b), we summarize 2,000 simulations of such a model, where the prey are the crop pests and the predators are sparrows and other species that can provide biological pest control. In the simulations, we draw at random a damage coefficient that converts the crop pest population to agricultural losses. We plot the change in the the damages from crop pests relative to the steady state as it evolves over time following the shock to the biological pest control population. We also plot our estimated declines in rice and wheat in sparrow suitable to unsuitable counties, which fall very close to the mean loss across all simulations.

7 Conclusions

Our findings confirm that counties in China with high sparrow habitation suitability experienced a marked reduction in grain production and a surge in all-cause mortality during the Great Famine, following the Four Pests Campaign of 1958–1960. This outcome offers robust empirical support for the long-held environmental history hypothesis that eradicating sparrows—a decision pursued despite widespread scientific warnings—played a significant role in exacerbating famine conditions. More broadly, it underscores how ignoring scientific advice in favor of political expediency can lead to disastrous policy outcomes. Notably, parallels to China's more recent "COVID Zero" strategy have appeared in public discourse under the moniker "Sparrow Zero," underscoring that large-scale interventions enacted without gradual experimentation and adequate scientific scrutiny risk triggering unintended, and potentially catastrophic, consequences.

From an environmental standpoint, our findings underscore the importance of preserving ecosystem stability in the face of ongoing challenges like habitat loss, climate change, and over-exploitation. Although modern governments rarely enact extermination programs on the scale of the Four Pests Campaign, many species remain at risk of local or functional extinction. Our results demonstrate that, given the intricate interdependencies within ecosystems, even localized losses of key species can severely disrupt production functions essential to human well-being. Consequently, striking a balance between societal needs and ecological sustainability requires that policymakers heed scientific insights—ensuring that short-sighted measures do not inadvertently undermine the very ecosystems upon which human survival depends.

> "You call them thieves and pillagers; but know,
> They are the winged wardens of your farms,
> Who from the cornfields drive the insidious foe,
> And from your harvests keep a hundred harms;"
>
> *-Longfellow's Birds of Killingworth*

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Online Appendix

A Additional Results Appendix

A.1 Validating BIOCLIM Suitability Scores Predict Species Abundance

In the paper, we use the the BIOCLIM model to generate the sparrow suitability score, and then use it to define treatment and exposure to the eradication of sparrows. This relies on the assumption that the suitability score provides a strong proxy for the abundance of sparrows before the FPC. In other words, we assume that the sparrow suitability score is correlated with baseline population levels of sparrows. We cannot test this assumption holds because we lack any data on sparrow population counts, which is precisely why we use a habitat suitability model in the first place. That being said, the correlation between the reported number of sparrows killed per squared km and the sparrow suitability score (Figure 4a) does provide reassuring suggestive evidence that the suitability score is correlated with another variable that we think is proportional to baseline population levels.

Here we report additional results from a different setting where we do get to observe *both* data on population levels that were collected using a repeated scientific protocol, and use the BIOCLIM model to generate suitability scores. We use data from the Breeding Bird Survey (BBS) in the United States, from 1999 to 2019, where trained individuals travel along pre-determined routes and collect counts on different bird species. We use these counts for different bird species as inputs to the BIOCLIM habitat suitability model and generate suitability scores. To avoid a mechanical relationship between the population data and the suitability scores we exclude one state at a time, and generate suitability scores for each of the bird species using only data from outside of that state. We repeat this process for all the lower 48 states in the United States, and each of the 518 bird species in the BBS data. Because different species might have different magnitudes of abundance, we construct z-scores for each bird species using the data from all the counties in the contiguous United States.

The standardized measures of bird population levels are strongly correlated with the out-of-sample BIOCLIM suitability scores we generate. In Figure A1, we use a local polynomial regression to summarize the relationship between BBS mean bird counts (standardized across species), and the BIOCLIM suitability scores for 3,108 counties and 518 bird species. There is a clear positive relationship where higher suitability scores are correlated with higher mean population levels. We observe this correlation for all bird species, for only the nine species in the Passer genus, to which the house sparrow belongs to, and when we focus solely on the house sparrow species.

We interpret this as strong support for the assumption that suitability scores from the BIOCLIM model provide a proxy for baseline population levels. These patterns hold even if we assume that missing county-species values are capturing true zero values for the mean population count. When we assume those are true zeros, we observe a sharp increase in mean bird counts as suitability scores increase from zero to non-zero values, and then a tapering of the correlation.

We further demonstrate that the relationship between the BIOCLIM suitability scores and abundance is not only strongly correlated, but also precisely estimated. In Table A1, we report estimation results for a regression of the standardized abundance on either the continuous suitability scores, or different quantiles of it. We cluster the standard errors at both the county and species levels. For the quantiles, we calculate them for the cases of a non-zero suitability score. This makes the omitted category in each regression the same: suitability scores of zero. The coefficients point to the same fundamental result: Higher suitability scores are precisely and meaningfully correlated with higher standardized abundance values.

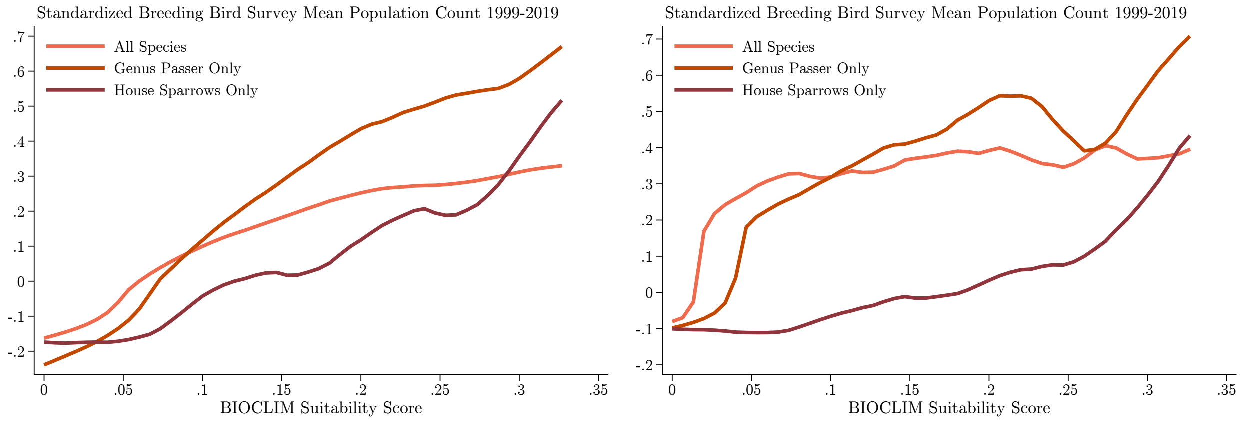
Table A1
Regression Results for the Breeding
Bird Survey & BIOCLIM Validation Exercise

	All Bird Species ($n = 518$)			Passer Genus Only ($n = 9$)		
	(1)	(2)	(3)	(4)	(5)	(6)
CSS	4.36***			5.29***		
	(0.22)			(1.04)		
Tercile (1)		0.21***			0.12	
		(0.01)			(0.06)	
Tercile (2)		0.59***			0.59***	
		(0.02)			(0.10)	
Tercile (3)		0.97***			1.04***	
		(0.03)			(0.13)	
Quintile (1)			0.15***			0.05
			(0.01)			(0.06)
Quintile (2)			0.34***			0.30**
			(0.02)			(0.09)
Quintile (3)			0.60***			0.58***
			(0.03)			(0.09)
Quintile (4)			0.85***			0.85***
			(0.03)			(0.11)
Quintile (5)			1.05***			1.18***
			(0.04)			(0.15)
R^2	0.083	0.106	0.109	0.196	0.219	0.225
N	1,596,360	1,596,360	1,596,360	27,594	27,594	27,594

Notes: Estimation results for a regression of the standarized abundance data on either the continuous suitability score, or quantiles of the suitability score (using the out-of-sample suitability score). We winsorize the suitability score at the 99th percentile. Each regression includes county and species fixed effects. Standard errors are twoway clustered at the county and species level. Columns 1 to 3 include all bird species in the sample, and columns 4 to 6 only include species in the Passer genus, to which the house sparrow belongs to. The sample contains all counties in the contiguous United States.
* 0.10 ** 0.05 *** 0.01

Figure A1: Correlation of Bird Population Counts & BIOCLIM Suitability Scores

(a) Not Assuming Missing Values Are Zeros (b) Assuming Missing Values Are Zeros



Notes: Local polynomial regression, averaging 518 bird species, across 3,108 counties in the lower 48 states in the United States. We truncate the suitability score at the 99th percentile. In panel (a), we treat missing values as missing, while in panel (b), we treat them as true zero population counts. While the magnitudes change, the broad pattern of positive correlation between standardized population counts and suitability scores holds. See text for more details.

A.2 Examining Data Reporting & Correlation With Sparrow Suitability

As we mention in the data section of the main text, after we drop large counties from the data, we have 492 out of the 704 counties (70%) that report at least rice or wheat in both 1954 to 1957 and 1958 to 1965. However, most counties fail to report rice or wheat data every year. Here, we examine whether the missing data patterns are correlated with the sparrow suitability score. We reports results for linear probability models where the outcomes are either: (i) non-missing value in year t for rice or wheat, (ii) ever reporting rice or wheat, or (iii) having data for either rice or wheat in both pre- and post-FPC periods. In Table A2, we report results using both the continuous sparrow suitability score and the above-median suitability dummy variable. We find that the timing of missing data is not correlated with sparrow suitability; however, high sparrow suitability counties are less likely to report rice output and are more likely to report wheat output. Finally, we fail to detect any correlation between having non-missing rice or wheat data in both pre- post-FPC periods and sparrow suitability.

Table A2: Summarizing Rice & Wheat Data Reporting Patterns

Non-Missing	At t				Ever				Pre/Post	
	Rice		Wheat		Rice		Wheat		Rice or Wheat	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Suitability	-0.006		0.109		-0.761		0.529		-0.060	
	(0.211)		(0.181)		(0.186)		(0.186)		(0.178)	
Suitability (H)		0.003		0.015		-0.126		0.098		-0.007
		(0.039)		(0.036)		(0.038)		(0.037)		(0.035)
$\overline{Y}$	0.65	0.65	0.66	0.66	0.51	0.51	0.61	0.61	0.70	0.70
R^2	0.05	0.05	0.04	0.04	0.02	0.02	0.01	0.01	0.00	0.00
N	4,272	4,272	5,184	5,184	704	704	704	704	704	704
Clusters	356	356	432	432	704	704	704	704	704	704

Notes: Estimation results for linear probability models as a function of sparrow suitability (continuous score of above-median score). In columns 1 to 4, the outcome is whether the crop (rice or wheat) is not missing in a specific year. In columns 5 to 8, the outcome is whether the county ever has a non-missing value. In columns 9 and 10, the outcome is whether the county has non-missing data for rice *or* wheat in the pre- *and* post-FPC periods (during 1954-1957 and 1958-1965).

A.3 Examining Correlations Between Crop & Sparrow Suitabilities

In the main text, we describe how our research design compares sparrow suitable to unsuitable places using the sparrow suitability score we derive from the BIOCLIM model. Because the BIOCLIM model relies on environmental conditions that could also predict crop suitability, there is a concern that the sparrow suitability is highly correlated with, for example, rice and wheat suitability. If that is the case, then our analysis might simply capture that the more agriculturally productive regions were also those that had high sparrow suitability. If the sparrow eradication had no effect on the decline in agricultural production, then our results might be due to the correlation between sparrow and crop suitability.

To address this concern in the main analysis, we report results that control for rice and wheat suitabilities that we interact with a linear time trend. This effectively allows counties with higher or lower baseline crop suitabilities to experience different evolution of agricultural production that might be unrelated to the eradication of sparrows. In those regressions, inclusion of those controls does not meaningfully change the results. Here we provide additional analysis that documents that sparrow suitability and crop suitabilities are far from being perfectly correlated.

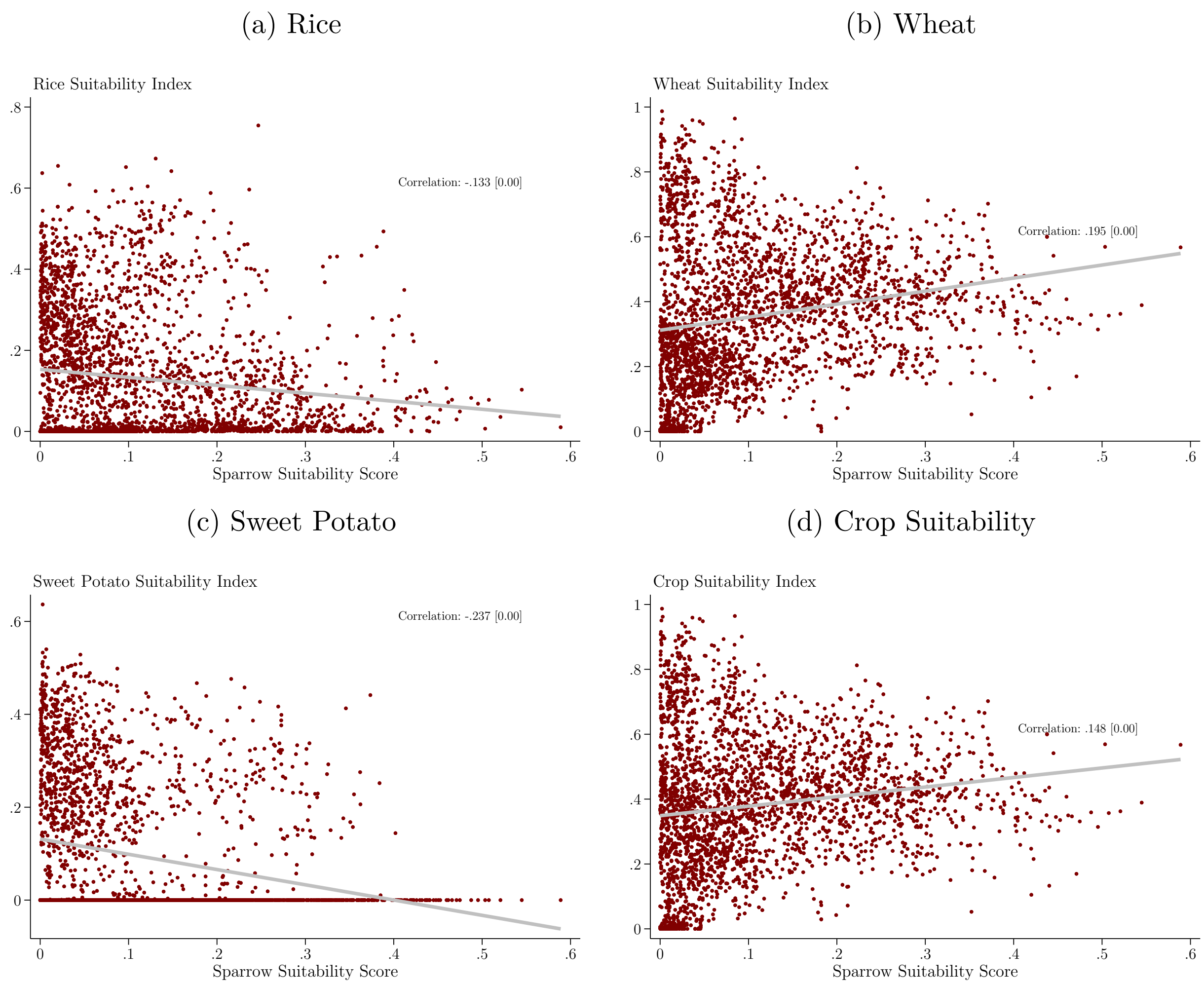
We use FAO GAEZ data on the crop suitability for rice, wheat, sweet potato, and all crops measured per county, and find no meaningful correlation in the data. In Figure A2, we plot four scatter plots for the four crop suitability score and sparrow suitability. Overall, there is no clear pattern that suggests a systematic relationship between crop and sparrow suitabilities. Even in cases where the linear fit exhibits a positive slope, it is driven by outlier observations in places with very high sparrow suitability. In Section A.12, we verify that the results in the main text hold even when we exclude outlier values from the sample.

In addition to the scatter plots in Figure A2, we also run a regression where the outcome is either the sparrow suitability, or one of the crop suitabilities. We regress each suitability score on a set of different weather variables such as evaporation, precipitation, available sunlight, temperature, and wind speed, all at the monthly level, as well as the share of specific soil types.[25] In Table A3, we report only the coefficients that are precisely estimated to be an important predictor for sparrow suitability.

The key takeaway from this analysis, is that many of the environmental predictors of sparrow suitability fail to predict crop suitability. Some variables are important for sparrow suitability and the different crop suitabilities, however, the results do not demonstrate that the same set of environmental variables equally predict all the suitability scores. We conclude

[25] CLp and PDj are variables that capture the share of soil types "Petric Calcisols" and "Stagnic Podzoluvisols," respectively. Petric Calcisol soils have a high calcium concentration, and are considered relatively fertile. Stagnic Podzoluvisols soils have a relatively low nutrient concentration, and are considered to be mostly suitable for livestock grazing. They can be used to grow crops, but often require fertilizer inputs.

Figure A2: County-Level Correlations Between Sparrow and Crop Suitability



Notes: This figure plots the correlation between sparrow suitability and crop suitability scores at the county level. Panel (a) reports rice suitability, Panel (b) reports wheat suitability, Panel (c) plots sweet potato suitability, and Panel (d) plots the overall crop suitability score.

that there is no strong support in the data for the notion that we are misinterpreting the effect of larger declines in counties with higher crop suitability as the effect of larger reductions in sparrows in more suitable counties.

Table A3: Determinants of Suitability (Only Sparrow Significant Predictors)

	(1)	(2)	(3)	(4)	(5)
	Sparrow	Crop	Rice	Wheat	Sweet Potato
	b/se	b/se	b/se	b/se	b/se
CLp Ratio	1.760*	0.341	0.517	0.661	-0.839
	(1.030)	(1.293)	(0.856)	(1.252)	(0.871)
PDj Ratio	-40.98*	-26.94	38.84*	-37.37	-17.30
	(21.409)	(30.535)	(20.229)	(29.564)	(20.575)
Evaporation M2	-0.0891***	0.0383	0.121***	0.0418	0.0212
	(0.022)	(0.032)	(0.021)	(0.031)	(0.021)
Evaporation M4	0.0680***	-0.0390	0.0485***	-0.0361	0.0659***
	(0.018)	(0.026)	(0.017)	(0.025)	(0.017)
Evaporation M5	-0.0555***	0.00526	0.00476	0.00374	-0.0194
	(0.015)	(0.021)	(0.014)	(0.021)	(0.014)
Evaporation M6	-0.0216**	-0.0106	0.00799	-0.00686	0.0199**
	(0.010)	(0.014)	(0.009)	(0.013)	(0.009)
Evaporation M11	0.175***	0.137***	-0.0944***	0.175***	-0.126***
	(0.036)	(0.051)	(0.034)	(0.050)	(0.035)
Evaporation M12	-0.130***	-0.127**	0.196***	-0.186***	0.251***
	(0.041)	(0.059)	(0.039)	(0.057)	(0.040)
Precipitation M1	-0.0715***	0.00677	-0.0170	-0.00005	0.0312
	(0.025)	(0.035)	(0.023)	(0.034)	(0.024)
Precipitation M2	-0.0898***	0.0538**	0.148***	0.0638**	0.0542***
	(0.019)	(0.026)	(0.017)	(0.026)	(0.018)
Precipitation M3	0.0340***	-0.0528***	-0.106***	-0.0603***	-0.0417***
	(0.012)	(0.016)	(0.011)	(0.016)	(0.011)
Precipitation M4	0.0337***	-0.0260***	-0.00596	-0.0172**	-0.0281***
	(0.006)	(0.008)	(0.005)	(0.008)	(0.005)
Precipitation M5	-0.0113**	0.00735	0.0138***	-0.00632	0.0270***
	(0.006)	(0.008)	(0.005)	(0.008)	(0.005)
Precipitation M7	0.00908***	-0.00776	0.0197***	-0.00855*	0.0108***
	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)
Precipitation M8	-0.00998***	0.00576	-0.00396	0.00337	-0.00157
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)
Precipitation M9	-0.0101***	-0.0122**	-0.0212***	-0.00744	0.00164
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)
Precipitation M10	0.0154***	0.0205**	0.00460	0.00598	0.00799
	(0.006)	(0.008)	(0.005)	(0.008)	(0.005)
Precipitation M11	0.0216*	0.0619***	0.0173	0.0382**	0.00744
	(0.012)	(0.017)	(0.011)	(0.016)	(0.011)
Precipitation M12	-0.0785***	-0.00387	0.135***	0.0124	0.0678***
	(0.021)	(0.030)	(0.020)	(0.029)	(0.020)
Sunshine M2	0.0901***	-0.124***	-0.0199	-0.106***	-0.0747***
	(0.016)	(0.023)	(0.015)	(0.022)	(0.015)
Sunshine M3	-0.0822***	0.143***	0.0572***	0.127***	0.0540***
	(0.017)	(0.024)	(0.016)	(0.023)	(0.016)
Sunshine M7	-0.0209*	0.0922***	0.0253**	0.0771***	0.125***
	(0.011)	(0.016)	(0.011)	(0.016)	(0.011)
Temperature M3	-0.0563***	0.0133	0.0107	0.00404	0.0298**
	(0.014)	(0.020)	(0.014)	(0.020)	(0.014)

Temperature M6	0.0234*	0.0582***	-0.0300**	0.0571***	0.0381***
	(0.014)	(0.020)	(0.013)	(0.019)	(0.013)
Temperature M7	0.0617***	-0.142***	-0.00760	-0.113***	-0.133***
	(0.020)	(0.028)	(0.019)	(0.027)	(0.019)
Temperature M8	-0.0594***	0.190***	0.0486***	0.161***	0.132***
	(0.018)	(0.026)	(0.017)	(0.025)	(0.017)
Temperature M10	-0.0527***	0.00810	0.00110	0.0189	0.00998
	(0.015)	(0.021)	(0.014)	(0.020)	(0.014)
Temperature M11	0.0476***	0.00204	0.0326***	-0.00140	-0.000148
	(0.012)	(0.017)	(0.011)	(0.017)	(0.012)
Wind Speed M1	-0.0731***	-0.0500	-0.144***	0.0115	-0.0936***
	(0.023)	(0.033)	(0.022)	(0.032)	(0.022)
Wind Speed M2	0.0642**	0.00832	0.0540**	-0.0503	0.184***
	(0.026)	(0.037)	(0.025)	(0.036)	(0.025)
Wind Speed M3	-0.0600**	0.0141	0.0425*	0.0463	-0.172***
	(0.027)	(0.039)	(0.026)	(0.038)	(0.026)
Wind Speed M4	0.0941***	0.0342	-0.112***	0.0617	-0.0203
	(0.031)	(0.043)	(0.029)	(0.042)	(0.029)
Wind Speed M5	-0.101***	0.0160	0.0596**	-0.0317	0.152***
	(0.031)	(0.045)	(0.030)	(0.043)	(0.030)
Wind Speed M6	0.181***	-0.0323	-0.106***	0.0163	-0.113***
	(0.026)	(0.038)	(0.025)	(0.036)	(0.025)
Wind Speed M7	-0.0970***	0.0855**	0.216***	0.0575*	0.0746***
	(0.024)	(0.035)	(0.023)	(0.034)	(0.023)
Wind Speed M8	0.0562*	-0.104**	-0.182***	-0.102**	-0.0713**
	(0.031)	(0.045)	(0.030)	(0.043)	(0.030)
Wind Speed M9	-0.0619**	-0.118***	0.125***	-0.114***	-0.0143
	(0.031)	(0.044)	(0.029)	(0.043)	(0.030)
Wind Speed M11	-0.164***	0.0991**	-0.0232	0.120***	0.0202
	(0.027)	(0.038)	(0.025)	(0.037)	(0.026)
Wind Speed M12	0.127***	-0.0685	0.105***	-0.105**	-0.0310
	(0.030)	(0.042)	(0.028)	(0.041)	(0.028)
R-squared	0.720	0.856	0.887	0.874	0.866
Obs.	2847	2852	2852	2852	2852

Notes: This table reports coefficient estimates from cross-sectional OLS regressions of various habitat suitability scores on a rich set of environmental covariates. Each column corresponds to a different dependent variable. This table keeps only coefficients that significantly predict sparrow suitability. For full table including all parameters used for the construction of suitability indexes, see: https://drive.google.com/file/d/1hi8uh9MOHRacRfWc2ib9HqHhH5gJ_UxE/view?usp=share_link

A.4 Examining Correlation Between Province & County Mortality

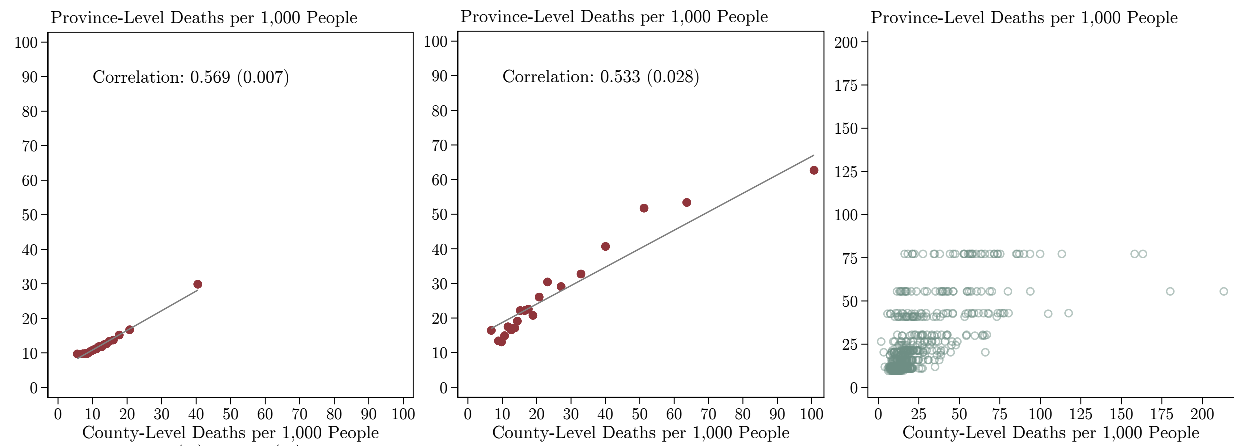
In the main text, we use recent data sources on mortality at the county level. We report how death rates spiked differentially in sparrow-suitable counties, above the mean increase that occurred during the Great Famine. Previous research studied mortality during this time period using province-level records from the provincial statistics. Here we compare the correlation between the province and county mortality data.

Death rates from the province-level records are highly, but not perfectly, correlated with mean population-weighted death rates that we aggregate from the county level to the province level. The main takeaway from this comparison is that death rates from the two sources are, as we would expect, strongly correlated and there do not appear to be signs of contradictions between the two administrative levels.

In Figure A3, we plot the correlation between the two province-level measures for the full span of the sample, 1945 to 1965, as well as for 1960, the peak year of mortality during the Great Famine (Panels a and b). The correlation are high, 0.569 and 0.533, and are precisely estimated. The two measures are more similar when we calculate the mean over the 1954-1965 period, but they diverge more from each other when we focus on 1960. In 1960, on average, death rates from province-level records are higher than the population-weighted mean aggregated from the county-level records. The difference is larger when the death rate from the county records is higher. For completeness, we also plot the scatter plot of province-level death rates against the individual county-level death rates (in 1960) in Panel (c). In this plot, each line of dots reflects a single province-level death rate and the dots on the line are the county-level death rates. The conversion from Panel (c) to (b) also applies population weights to obtain the province-level death rates from aggregating the county-level death rates.

Figure A3: Summarizing Correlations Between Province & County Mortality

(a) 1954-1965 (b) 1960 (c) 1960



Notes: Panels (a) and (b) plot binscatters of the province-level death rate versus the population-weighted means of county-level death rates that we aggregate to the province level, for the period of 1954-1965, and 1960 only. Panel (c) plots the full distribution of province death rates versus county death rates in 1960. Correlation numbers report the slope and standard error from a regression of province-level on county-level death rates (with no fixed effects or adjustment to standard errors).

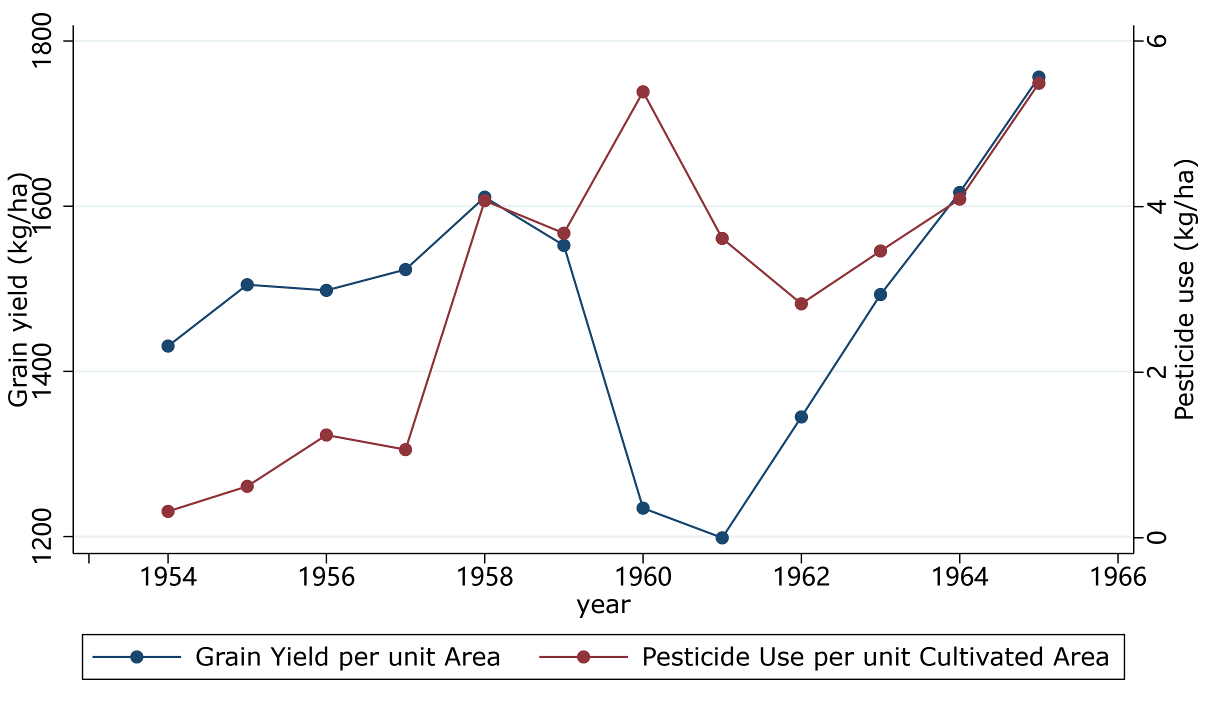
A.5 National Trends in Grain Production & Pesticide Use

In the main text, we report how grain production and mortality were evolving around 1958 (see Figure 3. Here we report how pesticide use was evolving around 1958. In Figure A4, we plot the aggregated time series for total grain yield, as well as total pesticide use, also normalized by cultivated area. Using the total grain amount, from the provincial records, offers a comparison to the more detailed wheat and grain data from the county gazetteers. It also provides a point of reference for the pesticide use time series.

During these years, pesticide inputs were allocated as part of the central planning process, and not through a market. This means that if farmers experienced a sharp change in pest pressure they could not respond immediately by increasing their pesticide use.

The key takeaway from comparing grain yields and pesticide use over time is that we do not see a pesticide use responding to the sharp decline in yields. We observe the decline in agricultural production, where grain yields dropped from a level of close 160 kg/ha to 120 kg/ha. From 1958 to 1961—the time period when we report the largest differences in agricultural production and mortality between sparrow suitable and unsuitable counties—we do not observe overall pesticide use increasing. This could be because the supply of pesticides was severely constrained or that the central government was unaware of the report of higher pest pressure. After 1961, the peak year of the Great Famine, we observe nearly a doubling in the amount of pesticide use, from 3 kg/ha to close to 6 kg/ha by 1965.

Figure A4: National Trends in Agricultural Production & Pesticide Use



(a) National Trend: Grain Yield and Pesticide Use

Notes: This figure plots China's aggregate grain yield per unit area and chemical pesticide usage per unit area from 1954 to 1965. The solid line (left axis) shows grain yield (kilograms of grain produced per hectare of cultivated land), and the dashed line (right axis) shows total pesticide application (kilograms of active ingredients per hectare of cultivated land). Both series are normalized by cultivated area to account for changes in planted acreage.

A.6 Examining the Scope of Spatial Correlation of the Standard Errors

In the main text, our baseline approach is to always cluster at the unit of observation—the county. While we cluster at the county level to address serial correlation of the standard errors, spatial correlation remains a concern. Here we report that the standard errors are not sensitive to allowing them to be flexibly correlated using different distance thresholds. We begin by summarizing the centroid distances between neighboring counties. Using the observed distance distribution, we re-estimate the key regressions from the main text while allowing for spatial clustering up to different distance thresholds (Conley 1999).

The distribution of distances between counties is heavily skewed. Most counties (above 90 percent) are within 100 km of each other. In Figures A5a and A5b, we plot the full distribution and the truncated at the 99th percentile value distribution of the distances. These distance distributions suggest that most counties will have their first degree neighbor (their adjacent county) within 50 km, their second degree neighbor within 100 km, and their third degree neighbor within 150 km. Based on these values and their distributions, we evaluate how the precision of the main estimates changes when we allow for spatial clustering up to a threshold of 250 km in increments of 10 km.

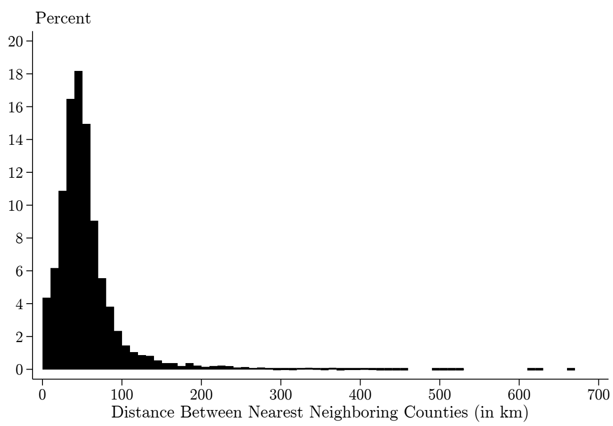
We examine how spatial clustering affects the precision of our estimation for the outcomes of rice and wheat production, sown area, sweet potato production, and the death and birth rates. For each outcome, we use the baseline models (columns 1 and 4, Panels A and B) in Tables 2, 3, and 4. To summarize the changes across six outcomes, two regression specifications (continuous suitability score and high suitability score dummy), and two coefficients per each outcome and specification (one for the 1958-1961 period and one for the 1962-1965 period), we plot the histograms of the relative changes in standard errors and p-values across 24 coefficients when spatially clustering up to 100 km (capturing the nearest neighbors of more than 90 percent of the sample) in Figures A5c and A5d.

More often than not, precision of the coefficients increases when spatially clustering the standard errors. Standard errors are often smaller, with 75.4 percent of them shrinking in value (left of the red-dashed line in Figure A5d. Even though p-values exhibit a larger spread, 71.7 percent of p-values are lower than in the case of no spatial clustering (left of the red-dashed line in Figure A5d.

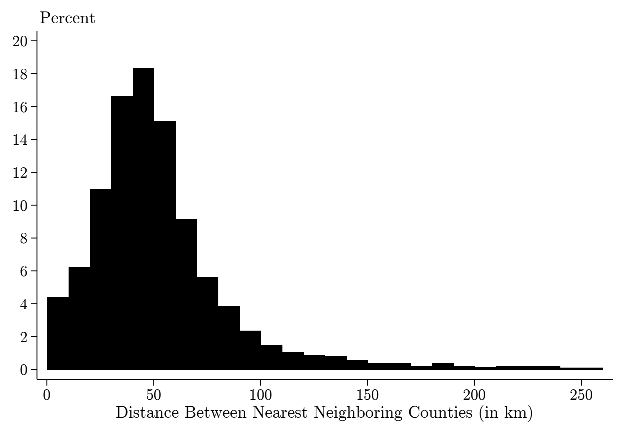
We provide more details about how the precision of each coefficient changes in Figures

Figure A5: Distance Distributions Between Counties & Relative Change to Precision When Spatially Clustering Standard Errors

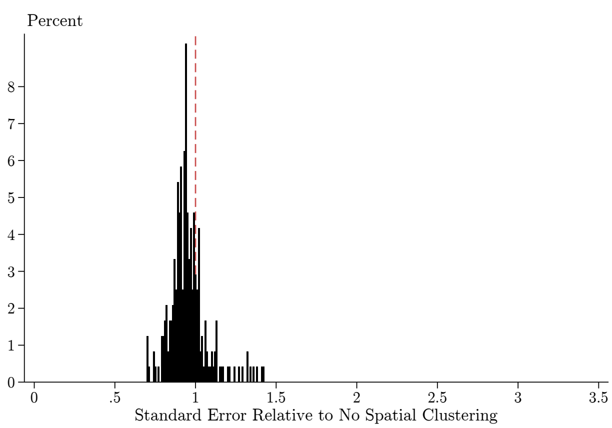
(a) County Distance Distribution



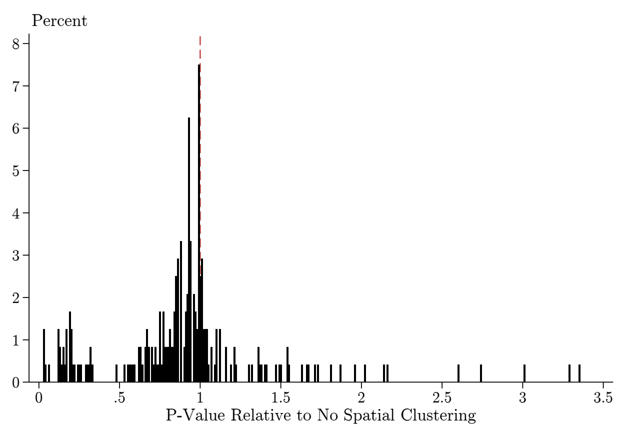
(b) Truncated County Distance Distribution



(c) Changes to Standard Errors



(d) Changes to P-Values

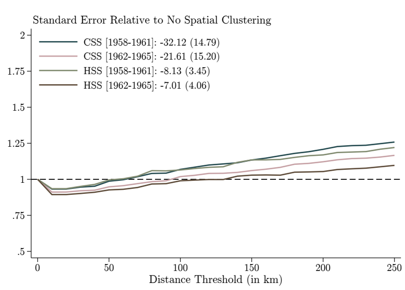


Notes: Panels (a) and (b) plot the distribution of distances between counties and their nearest neighbors. In Panel (a), we plot the distribution for the entire sample, while in Panel (b), we truncate the distribution at the 99th percentile value. In Panel (c), we plot the value distribution of standard errors, across several coefficients, when spatially clustering the standard errors up to 100 km, while normalizing each standard error by the value obtain when not spatially clustering. See text for more details. In Panel (d), we plot a similar distribution as in (c) but for p-values.

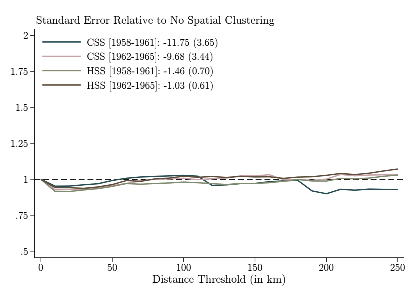
A6 and A7. In general, coefficients that are precisely estimated when we do not spatially cluster the standard errors remain precisely estimated, especially up to distance thresholds of up to 100 km. In Figure A6, we observe that clustering up to distances that allow a county to be spatially correlated with their first and second degree neighbors (see Figure A5a) tends to result in either smaller or roughly equal standard errors. In Figure A7, we report how the spatial clustering at difference thresholds affects the precision by plotting the p-values, instead of the standard error normalized by no spatial clustering. We observe that coefficients where we could reject the null hypothesis of zero difference at a 5 percent significance level remain well below that threshold. In short, spatially clustering the standard errors, especially up to distances that capture reasonable neighboring degrees such as up to 100 km, has little to no impact on the precision of the estimated coefficients.

Figure A6: Changes to Standard Errors When Spatially Clustering at Different Distance Thresholds

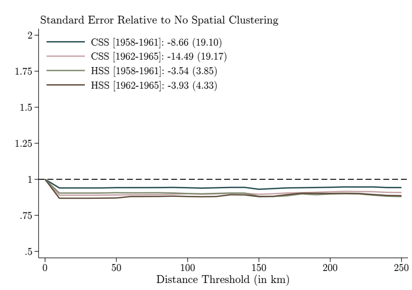
(a) Rice



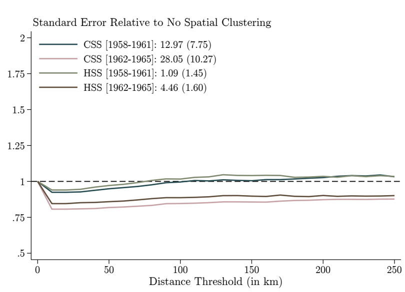
(b) Wheat



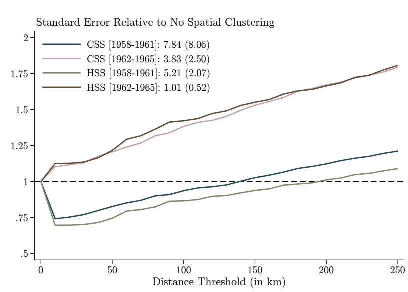
(c) Sown Area



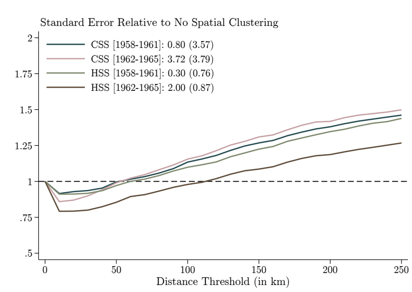
(d) Sweet Potato



(e) Death Rate



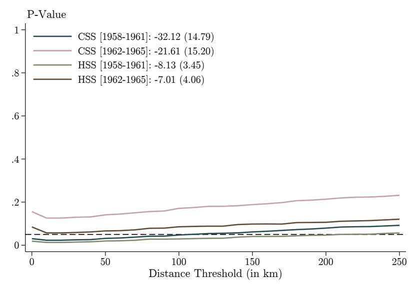
(f) Birth Rate



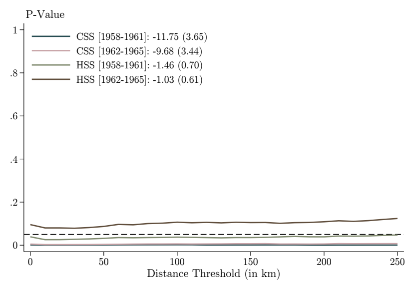
Notes: Each panel plots the p-value for each of the outcomes we report in the tables in the main text Each line plots how the standard error of a single coefficient changes when spatially clustering across longer distance thresholds, relative to the baseline of no spatial clustering. For each coefficient, we also report (in the legend) the coefficient's value and standard error from the baseline model.

Figure A7: Changes to P-Values When Spatially Clustering at Different Distance Thresholds

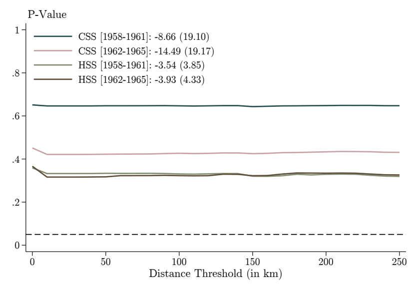
(a) Rice



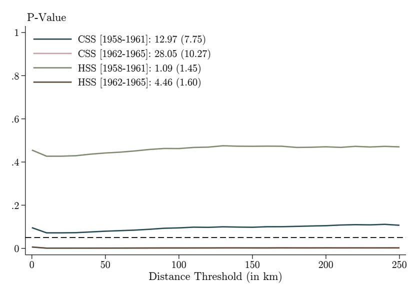
(b) Wheat



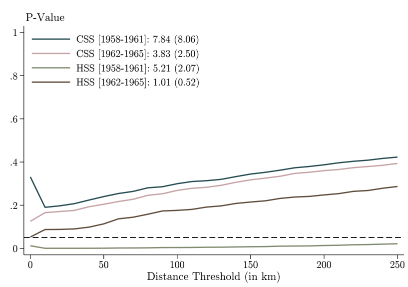
(c) Sown Area



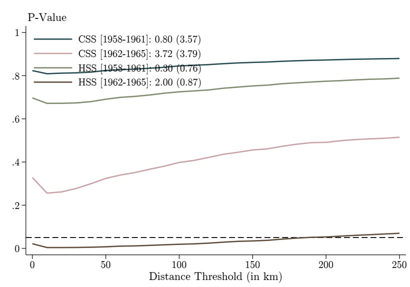
(d) Sweet Potato



(e) Death Rate



(f) Birth Rate



Notes: Each panel plots the p-value for each of the outcomes we report in the tables in the main text. Each line plots how the p-value of a single coefficient changes when spatially clustering across longer distance thresholds. For each coefficient, we also report (in the legend) the coefficient's value and standard error from the baseline model.

A.7 Examining the Correlation Between Climate Change & Sparrow Suitability Score

In constructing the BIOCLIM suitability score, we use bioclimatic data that covers several decades. One concern is that the changes due to climate change are systematically correlated with the suitability score itself. This might bias the calculation of the sparrow suitability score. To examine the scope to which this is a concern, we use geocoded weather station data from the period of 1954 to 1965 (our main sample), and 2010 to 2022. We match each station to the county identifier using the same county borders as we use in the main analysis. In calculating the changes in temperature, we focus on the counties that produce either rice or wheat, as those are the counties in the main sample.

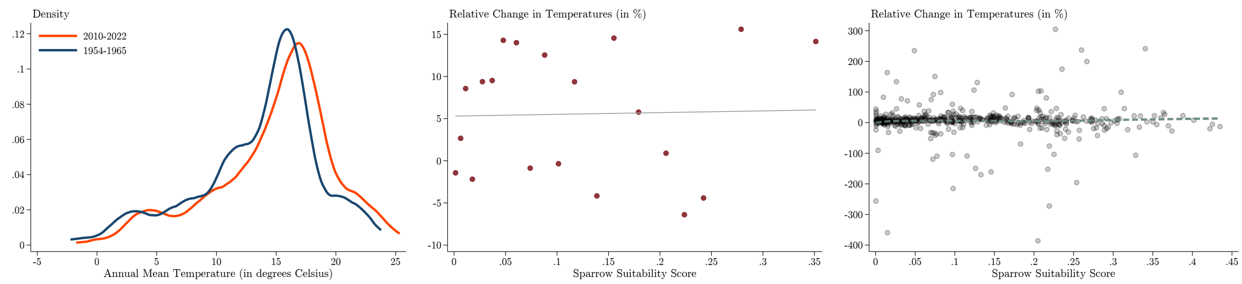
Our descriptive analysis finds that while, on average, counties have experienced a meaningful warming between the two time periods, the change in temperature is not correlated with the sparrow suitability score. In Figure A8a, we plot the kernel densities for the two temperature distributions, in 2010-2022 and 1954-1965. There is a clear shift of the temperature distribution to the right in the latter period, in agreement with climate change trends. In Figures A8b and A8c, we calculate for each county the relative change in temperature and plot it against the sparrow suitability score, truncating the relative temperature change at the 1st and 99th percentile values. Using either approach, we fail to observe a suggestive correlation between the relative change in temperature and the sparrow suitability score. We interpret these descriptive figures as evidence that climate change does not pose a risk of systematically biasing our sparrow suitability score.

A.8 Lotka-Volterra Model for Predator-Prey Dynamics

In the main text, we discuss results from a simulation of predator-prey dynamics where the crop pests are the prey and the different species that provide biological pest control are the predators. To do so, we use simple model that links the two population together: The

Figure A8: Verifying No Correlation Between Climate Change & Sparrow Suitability

(a) Temperature Distributions (b) Binscatter (c) LOWESS Smoother



Notes: Summarizing the changes in temperature distributions between 2010-2022 and 1954-1965 (Panel a), and the lack of systematic correlation between the relative temperature changes in the counties to the calculated sparrow suitability score (Panels b and c).

Lotka-Volterra model.

The mode is governed by two equations that define how the population levels of the predator and prey change over time. The predator benefits from a larger prey population, and goes extinct without any prey to feed on. The prey population constantly grows as it experiences predation pressure. At its most simple form, the model abstracts away from carrying capacities that limit the population levels of each species, but those can be easily integrated into the model. Explicitly, following the notation in Wangersky (1978), the change in prey, x, and predator, y, populations follows the following differential equtions:

$$\frac{dx}{dt} = rx - \alpha xy$$
$$\frac{dy}{dt} = \beta xy - Dy$$

Where the four parameters of the model are: (i) r, the intrinsic growth rate of the crop pests (ii) α, the predation rate of the biological control predators; (iii), β, the conversion parameter from prey to new predators; and (iv) D, the mortality rate of the biological control predators. In equilibrium, the populations are no longer changing. Setting both equations to zero and solving for the non-zero steady state values of x and y yields:

$$x^* = \frac{D}{\beta}$$

$$y^* = \frac{r}{\alpha}$$

In the simulation, we draw values from uniform distributions for the r, α, β, and D parameters on ranges of 1.01-1.1, 0.01-0.075, 0.0025-0.01, 0.025-0.25, respectively. If possible, the choice of parameters should follow either observational data or experimental data. None are available for our specific setting of China, around 1960. Instead, we follow similar choices and values used in other applications of the Lotka-Volterra model (Maurer 1984; Larsen 2012). From each simulation, we normalize the predator and prey populations relative to their steady state values. We multiply the change in the prey population of crop pests by a damage coefficient. For the crop damage coefficient, we draw from a uniform distribution ranging from 10 to 25 percent. We choose these values based on review papers that summarize different losses of agricultural production due to insects (Pimentel et al. 1991; Oerke 2006; Savary et al. 2019). In each iteration, we start from the steady state values that are a function of the four base parameters. We then perturb the system by reducing the predator population level from its steady state value by 1 or 20 percent. For each one percent increment in the magnitude of the shock, we run the simulation 100 times. At the end, we have 2,000 simulation runs that capture different potential values for the population dynamics, crop damage coefficients, and different assumptions about the magnitude of the loss in biological pest control following the eradication of the sparrows.

A.9 Results for Weighted and Unweighted Regressions

In the main text, we report results from unweighted regressions for agricultural production and operations, and results from population-weighted regressions for demographic outcomes. Each choice is sensible for the specific outcome. There is no clear reason to use population weights for rice production, the amount of sown land, the procurement rate, etc. Similarly, when using outcomes of birth rates and death rates, and unweighted regression is highly sensitive to noise and unstable rates that can originate from counties with small population levels. The challenge remains of how to interpret the two sets of results, unweighted and weighted. Our approach effectively treats the two sets of results as separate empirical exercises that allow us to establish key facts that link the eradication of sparrows to the conditions that gave rise to the Great Famine.

For completeness, we report in Tables A4 and A5 versions of the main results in Tables 2 and 4 that switch from unweighted to population weighted for the rice and wheat results, and from population-weighted to unweighted for the death and birth rates.

Qualitatively, we recover the same sign of the effects, and at similar magnitudes. The key differences between the unweighted and population-weighted results are in the precision of the estimates. In the unweighted rice and wheat results, we have precisely estimated declines for rice when using the high suitability score dummy, but not the continuous suitability score, during the 1958-1961 period. In the case of wheat, this pattern reverses. We recover precisely estimated declines using the continuous suitability score but not the high suitability dummy during the 1958-1961 period. Because weighting agricultural production by population does not have a clear interpretation, we focus on the fact that the signs are negative—rice and wheat production declined in sparrow suitable counties during the FPC—and of similar magnitudes as in the unweighted regressions. In other words, the population-weighted results do not contradict the findings in the unweighted analysis.

For death rates and birth rates, we continue to observe higher mortality but lower fertility in the sparrow suitable counties during the 1958-1961 period. However, for that time period, the results are only precisely estimated in the case of the high suitability dummy. As in the case of the rice and wheat population-weighted regression, we recover the same signs and similar magnitudes in the unweighted demographic outcomes regressions. In other words, even when allowing unstable rates from low population counties to have the same weight as high population counties, we still observe large increases in mortality, which are as precisely estimated as in the population-weighted regressions.

A.10 Detailed Back-of-the-Envelope Calculations

In the main text, we interpret our estimates in the context of the Great Famine by using the coefficients in a back-of-the-envelope calculation (BOEC). That calculation requires several assumptions that can influence its magnitude. In Tables A6 and A7, we provide additional calculations that rely on different assumptions. Below, we explain the main calculation and alternative specifications in greater detail.

Linking our agricultural and demographic estimates under simple linearity assumptions, we first construct a counterfactual "no-sparrow-shock" scenario for 1959–1961 yields. For each county, we project what rice and wheat output would have been in 1959–1961 by either (i) linearly extrapolating the 1954–1957 trend or (ii) applying the county's average 1954–1957 growth rate to 1958–1961. Summing across all counties gives us counterfactual national rice and wheat totals; subtracting the actual 1959–1961 outputs yields the *total observed shortfall* during the Great Famine.

To isolate the loss attributable specifically to sparrow eradication, we multiply each county's sparrow-suitability score $Suitability_c$ by the corresponding event-study coefficients β_τ for rice (or wheat) during 1959–1961. Weighting by each county's share of total crop production converts $\beta_{59-61} \times Suitability_c$ into *tons of lost output.* Summing over all counties yields approximately Rice $\text{loss}_{\text{sparrow}} = 23{,}169{,}473$ tons, Wheat $\text{loss}_{\text{sparrow}} = 3{,}844{,}525$ tons.

Dividing these estimates by baseline (1954–1957 average) suggests an 8.72% reduction in total crop yield, and dividing by the total observed shortfall shows that sparrow eradication accounts for 19.64% of agricultural loss during the Great Famine.

In parallel, our demographic regressions show that for each county c, the sum of the all-cause-death-rate coefficients during 1959–1961 (δ_{59-61}) times the county's suitability score $Suitability_c$ produces a forecasted *excess death rate* per 1,000 people. Multiplying ($\delta_{59-61}\, Suitability_c$)

Table A4
Effects on Rice and Wheat Output, Weighted by Baseline Population

	Rice Output			Wheat Output		
Panel A. Continous Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
CSS×1958-1961	-29.91	-39.44	-28.35	-10.29**	-11.75**	-10.91**
	(28.62)	(26.61)	(20.31)	(4.58)	(4.63)	(4.61)
CSS×1962-1965	-52.42*	-45.34*	-53.04	-10.17**	-12.21***	-10.57***
	(31.75)	(25.27)	(32.51)	(3.96)	(3.89)	(3.99)
R^2	0.91	0.91	0.91	0.86	0.87	0.87
Dep. Var. Mean	55.28	55.28	55.28	11.41	11.41	11.41
N	2,712	2,712	2,712	3,290	3,290	3,290
Clusters	336	336	336	407	407	407
Panel B. High Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
HSS×1958-1961	-9.29*	-12.45**	-5.57	-1.15	-1.34	-1.27
	(5.59)	(5.44)	(5.07)	(0.87)	(0.93)	(0.88)
HSS×1962-1965	-13.25	-11.76	-13.16	-2.20**	-2.54***	-2.32***
	(8.08)	(7.39)	(8.22)	(0.86)	(0.91)	(0.87)
R^2	0.91	0.91	0.91	0.86	0.87	0.87
Dep. Var. Mean	55.28	55.28	55.28	11.41	11.41	11.41
N	2,712	2,712	2,712	3,290	3,290	3,290
Clusters	336	336	336	407	407	407
Baseline Population-by-Year FE	N	Y	N	N	Y	N
Crop Suitability-by-Year FE	N	N	Y	N	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table corresponds to the main analysis of death rates and birth rates (see Table 4 in the paper), but here the regressions are unweighted (each county carries equal weight, instead of weighting by population). Panel A presents results using the continuous sparrow suitability score, and Panel B presents the results using the high-suitability indicator, for the two outcomes: all-cause death rate and birth rate (measured per 1,000 people). Each specification includes county and year fixed effects, with standard errors clustered by county.

Table A5
Effects on Death and Birth Rate, Unweighted

	Death Rate			Birth Rate		
Panel A. Continous Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
CSS×1958-1961	3.18	4.80	0.17	-0.67	-1.99	-1.39
	(6.20)	(6.24)	(5.77)	(3.34)	(3.27)	(3.38)
CSS×1962-1965	4.29**	3.82**	2.61	0.73	0.92	-0.58
	(1.89)	(1.80)	(1.87)	(3.79)	(3.82)	(3.49)
R^2	0.43	0.45	0.47	0.67	0.67	0.69
Dep. Var. Mean	14.62	14.65	14.62	31.68	31.63	31.68
N	3,733	3,699	3,733	3,688	3,654	3,688
Clusters	492	486	492	488	482	488
Panel B. High Suitability Score						
	(1)	(2)	(3)	(4)	(5)	(6)
HSS×1958-1961	4.28***	4.52***	3.36**	-0.30	-0.48	-0.45
	(1.57)	(1.58)	(1.49)	(0.72)	(0.71)	(0.73)
HSS×1962-1965	1.17***	1.13***	0.75*	1.82**	1.83**	1.39*
	(0.39)	(0.38)	(0.39)	(0.77)	(0.78)	(0.71)
R^2	0.44	0.45	0.47	0.67	0.68	0.69
Dep. Var. Mean	14.62	14.65	14.62	31.68	31.63	31.68
N	3,733	3,699	3,733	3,688	3,654	3,688
Clusters	492	486	492	488	482	488
Baseline Population-by-Year FE	N	Y	N	N	Y	N
Crop Suitability-by-Year FE	N	N	Y	N	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table reproduces the main rice and wheat output regressions (as in Table 2 of the main text) using population-weighted estimations. Each observation (county-year) is weighted by the county's average population in 1954–1957, to give more influence to more populous counties. Panel A uses the continuous sparrow suitability score as the treatment variable, and Panel B uses the high-suitability dummy (HSS). Within each panel, columns (1)–(3) report results for rice output under different control sets, and columns (4)–(6) report analogous results for wheat output (mirroring the specifications of Table 2). All regressions include county fixed effects and year fixed effects, and standard errors are clustered at the county level.

by the 1960 county population (divided by 1,000) and summing over all counties yields 1,954,169 excess deaths, and 397,368 fewer births. These numbers correspond to 0.307% of the national population and 6.49% of the total Famine-period death count.[26]

Appendix Tables A6 and A7 report "conservative" versus "aggressive" estimates, varying baseline point estimates and functional-form assumptions. For example, in the agricultural calculations, using both the largest and the smallest coefficients from a given regression, we perform calculations under different assumptions: (a) extrapolating pre–Great Famine levels versus trends; (b) including or excluding rice/wheat weights based on their caloric values; and (c) accounting for only the dominant crop in each county versus using the relative share of each crop. Although point estimates for sparrow-induced losses move somewhat across specifications, the fundamental conclusion holds: sparrow eradication was responsible for a substantial fraction of agricultural shortfalls and excess deaths during the Great Famine.

[26] Excess deaths = $\sum_c (\delta_{59-61}\, Suitability_c \times \text{population}_c/1{,}000)$. Analogous calculation for fertility uses fertility-rate coefficients.

Table A6: Back-of-the-Envelope Calculation: Crop

Grain Type	**Calculate County Number**	**Most Aggressive Results**			
		Extrapolate by Growth		**Linear Extrapolation**	
		Weighted by Calorie	**Not Weighted**	**Weighted by Calorie**	**Not Weighted**
Rice	By Percentage	24.12%(12.21%)		24.66%(12.21%)	
	By Dominant Crop	25.94%(13.14%)		26.53%(13.14%)	
Wheat	By Percentage	26.62%(6.52%)		12.26%(6.52%)	
	By Dominant Crop	24.54%(6.01%)		11.30%(6.01%)	
Crop	By Percentage	24.60%(10.81%)	24.57%(10.91%)	21.43%(10.81%)	21.66%(10.91%)
	By Dominant Crop	25.90%(11.38%)	25.90%(11.50%)	22.56%(11.38%)	22.83%(11.50%)

Grain Type	**Calculate County Number**	**Most Conservative Results**			
		Extrapolate by Growth		**Linear Extrapolation**	
		Weighted by Calorie	**Not Weighted**	**Weighted by Calorie**	**Not Weighted**
Rice	By Percentage	14.44%(7.31%)		14.77%(7.31%)	
	By Dominant Crop	15.53%(7.86%)		15.88%(7.86%)	
Wheat	By Percentage	15.07%(3.69%)		6.94%(3.69%)	
	By Dominant Crop	13.89%(3.40%)		6.39%(3.40%)	
Crop	By Percentage	14.61%(6.42%)	14.60%(6.48%)	12.73%(6.42%)	12.87%(6.48%)
	By Dominant Crop	15.40%(6.76%)	15.41%(6.84%)	13.41%(6.76%)	13.58%(6.84%)

Notes: This table shows the back-of-envelope calculation of the effects on crop production caused by sparrow killing. Number in each box represents the ratio of crop loss caused by sparrow killing to the total crop loss during GLF and the number in the parenthesis is the ratio to the baseline total crop production. Calculation Method: Rice(Wheat) loss caused by sparrow killing is calculated by multiplying national average sparrow suitability, number of corresponding counties and the sum of coefficients between 1959 and 1961 together. The total rice(wheat) loss is calculated by either extrapolating output before 1958 linearly or using the average growth rate between 1954 and 1957 as the potential growth rate after 1958. And the baseline total rice(wheat) production is just the average production between 1954 and 1957.

Table A7: Back-of-the-Envelope Calculation: Population

	Index	**Highest Results**	
		Weighted by Population	**Not Weighted**
Population Loss	Ratio to Total Death	6.71%	3.98%
	Ratio to Total Actual Population	.31%	.18%
	Ratio to Total Estimated Population Loss	4.67%	2.77%
	Ratio to Total Estimated Population	.29%	.17%

	Index	**Lowest Results**	
		Weighted by Population	**Not Weighted**
Population Loss	Ratio to Total Death	1.96%	1.83%
	Ratio to Total Actual Population	.09%	.08%
	Ratio to Total Estimated Population Loss	1.36%	1.27%
	Ratio to Total Estimated Population	.08%	.08%

Notes: This table shows the back-of-the-envelope calculation of the effects on population caused by sparrow killing. Provincial population loss caused by sparrow killing is calculated by multiplying the sparrow suitability of each province and the sum of the coefficients between 1959 and 1961, which is weighted by provincial population of each year. Then total population loss is obtained by adding up all the provincial population loss. The estimated population between 1959 and 1961 is calculated by using the average growth rate between 1954 and 1957 as the potential growth rate after 1958. Then the estimated population loss is the difference between estimated population and actual population.

A.11 Comparing Results from Balanced and Unbalanced Panels

In the main text, we report results that use an unbalanced panel. In Table A2, we demonstrate that the timing of the missingness of the data is not correlated with the sparrow suitability score. For completeness, in Table A8, we report annual coefficients for a truncated sample, spanning 1955 to 1962. The shorter sample allows us to retain more units in the balanced sample, while still focusing on the period of interest, 1958-1961. When restricting the sample to use data from only the counties that report the outcome of interest in each year, we leave out about half of the counties in the data. The results remain similar in magnitude and precision, except in the case of sweet potato production, where we no longer have a precisely estimated increase in cultivation and production following 1960 when farmers were allowed to grow them for personal consumption. The sweet potato sample was already about half the size of the sample for rice and wheat (about 400 counties), and balancing the sweet potato data leaves us with only 102 counties—making our analysis of this outcome in the balanced panel likely severely underpowered.

For the population outcomes of mortality and fertility, we similarly lose about half of the counties when we balance the sample, but recover the same pattern of higher death rates and lower birth rates in sparrow suitable counties, especially in 1960. The one notable difference between the unbalanced and balanced results is that when we use the continuous suitability score, the coefficient for the death rate in 1960 is no longer precisely estimated. However, the coefficient for death rate in 1960, when using the high suitability dummy, remains precisely estimated. In short, balancing the data lowers the precision of a small number of coefficients, yet we still recover the same signs and magnitude of the effects.

Table A8
Effects on Agriculture with Balanced Sample

	Rice		Wheat		Sweet Potato		Procurement Rate	
Panel A. Continous Suitability Score								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CSS×1955	-5.15	16.69	5.28	8.12	-1.07	-5.58	0.03	-0.05
	(24.45)	(21.05)	(5.53)	(5.40)	(6.64)	(5.61)	(0.04)	(0.04)
CSS×1956	-40.09	-10.07	9.83*	10.94***	-8.78	-13.63**	0.08*	0.01
	(26.88)	(10.29)	(5.22)	(4.03)	(7.06)	(5.48)	(0.05)	(0.04)
CSS×1958	-30.44	-8.10	-0.61	4.35	12.33	11.45	0.14**	0.11*
	(23.70)	(20.68)	(5.38)	(5.25)	(10.10)	(10.84)	(0.06)	(0.06)
CSS×1959	-41.06*	-27.80	-5.54	-3.69	-4.35	-3.49	0.16**	0.11
	(22.40)	(18.94)	(4.76)	(4.52)	(10.55)	(11.94)	(0.07)	(0.08)
CSS×1960	-56.96**	-54.78**	-6.14	-5.33	8.11	14.71	0.10	0.04
	(25.68)	(26.35)	(5.80)	(5.93)	(8.25)	(9.97)	(0.07)	(0.07)
CSS×1961	-74.64**	-62.19**	-20.08***	-19.12**	19.09**	20.87	-0.17***	-0.22***
	(33.05)	(30.60)	(7.60)	(8.66)	(9.53)	(12.84)	(0.06)	(0.06)
CSS×1962	-77.32**	-56.09**	-12.38***	-9.82**	8.43	12.06	-0.00	-0.07
	(32.05)	(23.56)	(4.74)	(4.96)	(6.93)	(8.75)	(0.05)	(0.06)
R^2	0.88	0.95	0.91	0.90	0.88	0.89	0.76	0.73
Dep. Var. Mean	56.33	56.70	12.86	13.69	17.13	18.00	0.27	0.26
N	2,324	1,832	2,713	2,128	1,051	816	2,248	1,608
Clusters	396	229	458	266	184	102	391	201
Panel B. High Suitability Score								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HSS×1955	-2.12	7.02**	1.01	1.28	0.92	-0.83	-0.00	-0.02**
	(8.08)	(3.08)	(1.00)	(1.01)	(1.57)	(1.08)	(0.01)	(0.01)
HSS×1956	-13.00	-0.77	0.70	0.89	-1.36	-2.42**	0.01	-0.01
	(11.37)	(2.55)	(1.26)	(1.14)	(1.35)	(1.10)	(0.01)	(0.01)
HSS×1958	-10.52	-1.55	0.55	1.15	0.95	0.75	0.01	0.00
	(8.11)	(3.25)	(0.86)	(0.80)	(1.76)	(1.90)	(0.01)	(0.01)
HSS×1959	-14.61*	-7.17*	-1.05	-0.80	-2.64	-3.10	0.03**	0.03*
	(8.25)	(4.10)	(0.85)	(0.78)	(2.34)	(2.60)	(0.01)	(0.01)
HSS×1960	-14.51**	-9.23*	-0.94	-1.03	-0.07	1.19	0.01	0.00
	(7.36)	(5.15)	(0.97)	(1.00)	(1.82)	(1.97)	(0.01)	(0.02)
HSS×1961	-20.45*	-10.83*	-2.74**	-2.50**	3.59**	3.04	-0.04***	-0.05***
	(11.26)	(5.94)	(1.11)	(1.24)	(1.72)	(2.15)	(0.01)	(0.01)
HSS×1962	-21.13*	-9.47**	-1.31	-1.09	1.91	1.48	-0.01	-0.02
	(11.95)	(4.52)	(0.86)	(0.90)	(1.21)	(1.60)	(0.01)	(0.01)
R^2	0.88	0.95	0.91	0.90	0.88	0.89	0.76	0.73
Dep. Var. Mean	56.33	56.70	12.86	13.69	17.13	18.00	0.27	0.26
N	2,324	1,832	2,713	2,128	1,051	816	2,248	1,608
Clusters	396	229	458	266	184	102	391	201
Balanced	N	Y	N	Y	N	Y	N	Y

Notes: Estimation results from Equation 1 for the main sample spanning 1955 to 1962. This table re-estimates the effects of sparrow eradication on agricultural outcomes using a balanced panel of counties. All regressions include county fixed effects and year fixed effects. Standard errors clustered at the county level.

Table A9
Effects on Population with Balanced Sample

	Mortality		Fertility	
Panel A. Continous Suitability Score				
	(1)	(2)	(3)	(4)
CSS×1955	-2.03	-0.78	-1.48	-7.12
	(4.14)	(2.80)	(6.03)	(6.77)
CSS×1956	0.33	3.19	7.56	4.88
	(4.22)	(4.26)	(4.88)	(4.50)
CSS×1958	2.85	-2.22	6.59	4.28
	(5.22)	(5.66)	(4.77)	(4.88)
CSS×1959	3.75	-4.03	5.16	4.97
	(11.45)	(13.39)	(4.66)	(5.30)
CSS×1960	32.71*	29.68	-18.06***	-20.69***
	(17.06)	(18.24)	(5.24)	(5.56)
CSS×1961	-12.94**	-12.32*	4.52	0.92
	(5.78)	(6.90)	(5.37)	(6.53)
CSS×1962	-2.58	-1.35	7.80	10.73*
	(2.88)	(3.27)	(5.74)	(6.06)
R^2	0.51	0.47	0.65	0.62
Dep. Var. Mean	16.00	16.87	27.21	26.00
N	2,431	1,608	2,389	1,480
Clusters	436	201	430	185
Panel B. High Suitability Score				
	(1)	(2)	(3)	(4)
HSS×1955	0.82	-0.00	0.49	-1.38
	(1.26)	(0.64)	(1.55)	(1.88)
HSS×1956	0.85	0.30	1.52	0.36
	(1.31)	(1.05)	(1.10)	(1.07)
HSS×1958	2.36	0.71	1.96*	0.86
	(1.47)	(1.49)	(1.07)	(1.13)
HSS×1959	8.01**	6.37	1.55	1.23
	(3.44)	(3.91)	(1.05)	(1.21)
HSS×1960	13.05***	9.35**	-4.21***	-4.86***
	(4.22)	(3.92)	(1.19)	(1.39)
HSS×1961	-0.56	-1.39	1.55	0.06
	(1.88)	(2.15)	(1.20)	(1.53)
HSS×1962	-0.77	-0.15	3.60**	3.64***
	(0.62)	(0.72)	(1.52)	(1.34)
R^2	0.52	0.48	0.66	0.63
Dep. Var. Mean	16.00	16.87	27.21	26.00
N	2,431	1,608	2,389	1,480
Clusters	436	201	430	185
Balanced	N	Y	N	Y

Notes: Same as in Table A8, but using death and birth rates as outcomes. Observations are population-weighted.

A.12 Additional Sensitivity Checks for the Main Regressions

We report here a set of additional regression results. First, we report the same event-study specification as in Equation (1) for the main outcomes we report in the paper, only we change the sample by truncating it at different cutoffs. In each table, for each outcome, we also include the full sample to allow for easier comparison. Then, we truncate at percentile values of 1 and 99, 2.5 and 97.5, or 5 and 95. The change in the number of counties is small as we use higher cutoff values—anywhere from about 20 to 30 counties, depending on the outcome. As was the case with some of the robustness checks we discussed earlier, we continue to recover the same sign for the main effects, at similar magnitudes, but at times, with lower precision when using the continuous suitability score, but less so when using the high suitability dummy. The truncated regression results are reported in Tables A10 and A11. We report those results for the agricultural outcomes, but not the population outcomes, because we are mostly worried about the inclusion of outliers in the agricultural data.

Next, we provide detailed regression results for the event-study analysis where we include more controls, and more stringent temporal fixed effects and/or time trends. These results expand on the variation we cover in the main text. Throughout this set of estimation results, as we include more controls such as weather controls, variables that proxy for the GLF intensity, steel production growth, and baseline population interacted with year fixed effects, we end up with a smaller sample. For example, in the case of rice output, including all of the additional controls reduces the number of counties in the sample from 421 to 260. As we add more control variables, and include more stringent time controls, we are reducing the residual variation that is left to isolate the effect of sparrow suitability, and sacrificing statistical power as we shrink the number of counties by more than a third. These results are reported in Tables A12-A25.

Table A10
Effects on Agriculture with Winsorized Sample

	Rice				Wheat				Sweet Potato				Procurement Rate			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
CSS×1954	-39.69	-31.57*	-29.73*	-14.39	2.45	5.71	4.42	3.79	-9.86	-13.52*	-16.46**	-12.49	-0.02	-0.03	-0.04	-0.02
	(24.66)	(18.33)	(16.35)	(10.06)	(5.10)	(5.07)	(3.47)	(3.33)	(8.33)	(8.01)	(8.08)	(7.74)	(0.05)	(0.05)	(0.04)	(0.04)
CSS×1955	-7.51	0.10	-21.88	-2.84	5.59	5.85*	6.26**	3.63	-3.41	-3.81	0.09	1.09	0.03	-0.00	-0.00	-0.02
	(24.52)	(18.86)	(13.56)	(9.74)	(5.30)	(2.99)	(2.98)	(2.74)	(6.72)	(6.51)	(5.70)	(5.77)	(0.04)	(0.04)	(0.04)	(0.04)
CSS×1956	-44.61*	-22.33**	-16.02*	-0.87	8.58*	13.32***	13.43***	7.81**	-9.26	-7.77	-3.13	-1.33	0.08*	0.05	0.06	0.04
	(26.78)	(9.52)	(8.74)	(7.63)	(5.04)	(3.73)	(3.77)	(3.02)	(7.16)	(6.61)	(6.05)	(6.09)	(0.05)	(0.04)	(0.04)	(0.04)
CSS×1958	-32.53	-19.80	-28.45*	-9.43	-0.69	3.83	-0.54	-0.27	11.14	19.53***	18.20**	21.38***	0.14***	0.18***	0.21***	0.21***
	(24.02)	(17.62)	(15.68)	(8.11)	(5.24)	(4.70)	(2.71)	(2.79)	(9.53)	(7.18)	(7.44)	(7.59)	(0.06)	(0.05)	(0.04)	(0.04)
CSS×1959	-43.36*	-32.58**	-35.52**	-16.60	-5.40	-1.43	-2.15	-3.78	-6.06	0.26	1.54	3.94	0.17**	0.17***	0.19***	0.14**
	(22.55)	(16.01)	(14.38)	(10.20)	(4.62)	(3.68)	(2.69)	(2.62)	(10.27)	(6.29)	(6.15)	(6.38)	(0.07)	(0.07)	(0.06)	(0.06)
CSS×1960	-59.23**	-59.51***	-60.93***	-40.40***	-6.01	-2.62	1.16	1.20	5.93	4.95	2.72	3.73	0.11*	0.11*	0.13**	0.12**
	(25.77)	(21.44)	(19.28)	(13.04)	(5.72)	(4.70)	(3.18)	(2.91)	(8.33)	(8.18)	(7.36)	(7.01)	(0.06)	(0.06)	(0.06)	(0.05)
CSS×1961	-76.33**	-62.52**	-66.85***	-39.77**	-19.37**	-15.58**	-9.87*	-11.64***	18.15*	11.60	11.00	4.38	-0.16***	-0.18***	-0.14***	-0.08
	(33.51)	(25.90)	(24.22)	(16.82)	(7.68)	(7.08)	(5.80)	(3.20)	(9.21)	(8.82)	(8.47)	(7.05)	(0.06)	(0.06)	(0.05)	(0.05)
CSS×1962	-85.63***	-63.61***	-62.43***	-32.44***	-13.57***	-10.71***	-5.33	-5.10**	7.65	4.57	2.97	3.98	-0.00	-0.03	-0.03	-0.03
	(32.75)	(19.20)	(17.66)	(11.54)	(4.79)	(3.65)	(3.38)	(2.46)	(6.58)	(5.52)	(5.53)	(5.57)	(0.05)	(0.04)	(0.04)	(0.04)
CSS×1963	-23.83	-11.18	-21.02	-2.28	-10.57***	-6.63**	-5.77**	-4.77**	14.39	4.07	4.39	6.55	-0.01	-0.04	-0.05	-0.06
	(25.77)	(17.24)	(14.28)	(11.18)	(3.85)	(2.66)	(2.72)	(2.39)	(11.97)	(6.11)	(6.09)	(6.12)	(0.05)	(0.05)	(0.04)	(0.04)
CSS×1964	-30.49	-5.61	-33.78**	-15.39*	-6.22	-4.34	-8.02**	-10.88***	36.78***	24.34***	24.78***	24.00***	-0.13***	-0.17***	-0.15***	-0.17***
	(25.27)	(14.21)	(14.35)	(9.24)	(7.79)	(7.34)	(3.55)	(2.42)	(13.84)	(8.32)	(8.11)	(7.80)	(0.05)	(0.05)	(0.04)	(0.04)
CSS×1965	-29.00	-17.82	-50.52***	-30.95***	4.93	7.26*	7.35**	3.10	31.87***	28.25***	24.74***	23.15***	-0.04	-0.05	-0.04	-0.04
	(22.57)	(19.59)	(14.10)	(8.69)	(4.68)	(3.77)	(3.39)	(2.55)	(9.28)	(7.84)	(5.71)	(5.57)	(0.04)	(0.04)	(0.04)	(0.04)
R^2	0.89	0.90	0.89	0.90	0.90	0.87	0.88	0.89	0.86	0.89	0.89	0.89	0.75	0.75	0.75	0.73
Dep. Var. Mean	59.54	52.09	47.76	44.15	13.22	11.95	10.90	9.86	17.02	16.33	15.50	14.40	0.25	0.25	0.25	0.25
N	3,473	3,403	3,297	3,117	4,081	3,996	3,874	3,656	1,588	1,557	1,505	1,424	3,388	3,320	3,214	3,042
Clusters	421	416	408	395	495	489	482	462	206	204	199	193	440	440	435	426
Winsorized	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table checks the robustness of the agricultural impact estimates by progressively trimming outliers in the data. We focus on four key outcomes—rice output, wheat output, sweet potato output, and grain procurement rate—and re-estimate the sparrow effect under different winsorization thresholds for these variables. In columns (1)–(4), the data are winsorized at 0

Table A11
Effects on Agriculture with Winsorized Sample

	Rice				Wheat				Sweet Potato				Procurement Rate			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
HSS×1954	-14.61*	-8.53**	-7.40**	-4.85*	0.43	0.71	0.70	0.12	-2.75	-2.73*	-3.27**	-2.89*	-0.01	-0.01	-0.02	-0.01
	(8.40)	(3.76)	(3.47)	(2.66)	(1.04)	(0.97)	(0.62)	(0.55)	(1.79)	(1.52)	(1.53)	(1.50)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1955	-2.58	2.54	-0.80	1.93	1.19	1.67**	1.42**	0.41	0.34	-0.30	0.44	0.44	0.00	-0.01	-0.01	-0.01
	(7.93)	(2.99)	(2.38)	(2.02)	(0.97)	(0.83)	(0.63)	(0.48)	(1.32)	(1.16)	(1.08)	(1.08)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1956	-13.76	-3.88*	-2.34	0.10	0.64	2.02**	1.74**	0.99	-1.29	-1.14	-0.21	-0.21	0.01	0.00	0.00	0.00
	(11.25)	(2.15)	(2.17)	(1.71)	(1.21)	(0.82)	(0.78)	(0.62)	(1.35)	(1.28)	(1.16)	(1.13)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1958	-10.68	-3.77	-5.12**	-2.79*	0.61	1.28*	0.72	0.33	0.77	2.66*	2.46*	3.17**	0.01	0.02**	0.03***	0.03***
	(7.90)	(2.66)	(2.60)	(1.62)	(0.84)	(0.71)	(0.52)	(0.52)	(1.69)	(1.35)	(1.38)	(1.40)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1959	-14.73*	-8.05**	-8.75***	-5.78**	-0.97	-0.29	-0.00	-0.27	-3.00	-1.31	-1.04	-0.56	0.03***	0.03**	0.04***	0.03***
	(8.12)	(3.36)	(3.11)	(2.43)	(0.82)	(0.67)	(0.60)	(0.59)	(2.33)	(1.56)	(1.46)	(1.45)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1960	-14.79**	-11.17***	-11.33***	-9.78***	-0.79	-0.24	0.47	0.48	-0.48	0.17	-0.38	-0.11	0.01	0.01	0.01	0.01
	(7.21)	(4.10)	(3.53)	(3.16)	(0.95)	(0.81)	(0.60)	(0.55)	(2.05)	(1.63)	(1.49)	(1.30)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1961	-20.62*	-11.85**	-12.13***	-9.45**	-2.63**	-2.45***	-1.82**	-1.68**	3.39**	2.13	1.88	0.73	-0.04***	-0.04***	-0.03***	-0.02**
	(11.23)	(4.93)	(4.26)	(3.66)	(1.13)	(0.93)	(0.82)	(0.66)	(1.69)	(1.61)	(1.47)	(1.34)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1962	-23.23*	-12.65***	-11.53***	-7.97***	-1.44*	-1.27*	-0.61	-0.64	1.75	1.26	0.95	1.50	-0.01	-0.01	-0.01	-0.01
	(11.96)	(3.82)	(3.05)	(2.43)	(0.85)	(0.69)	(0.68)	(0.51)	(1.19)	(1.04)	(1.07)	(1.05)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1963	-8.73	-1.09	-3.19	-0.10	-1.68**	-0.92	-0.97*	-0.66	0.91	0.07	0.27	0.92	-0.01	-0.02	-0.02*	-0.02**
	(9.75)	(4.19)	(3.47)	(2.47)	(0.76)	(0.60)	(0.57)	(0.49)	(1.94)	(1.36)	(1.37)	(1.34)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1964	-13.22	-3.28	-6.25*	-3.83*	-0.86	-0.79	-1.30*	-1.69***	5.36**	3.75**	4.10**	3.72**	-0.03***	-0.03***	-0.03***	-0.03***
	(10.19)	(3.57)	(3.25)	(2.29)	(1.13)	(0.98)	(0.70)	(0.52)	(2.21)	(1.68)	(1.69)	(1.54)	(0.01)	(0.01)	(0.01)	(0.01)
HSS×1965	-10.45*	-6.87*	-11.02***	-7.80***	1.45	1.78**	1.95***	1.05**	5.95***	5.04***	4.52***	4.31***	-0.02	-0.02*	-0.02*	-0.02*
	(5.70)	(3.60)	(3.22)	(2.00)	(1.03)	(0.77)	(0.67)	(0.48)	(1.61)	(1.32)	(1.18)	(1.18)	(0.01)	(0.01)	(0.01)	(0.01)
R^2	0.89	0.90	0.89	0.90	0.90	0.87	0.88	0.89	0.86	0.89	0.89	0.89	0.75	0.75	0.75	0.73
Dep. Var. Mean	59.54	52.09	47.76	44.15	13.22	11.95	10.90	9.86	17.02	16.33	15.50	14.40	0.25	0.25	0.25	0.25
N	3,473	3,403	3,297	3,117	4,081	3,996	3,874	3,656	1,588	1,557	1,505	1,424	3,388	3,320	3,214	3,042
Clusters	421	416	408	395	495	489	482	462	206	204	199	193	440	440	435	426
Winsorized	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95	0-100	1-99	2.5-97.5	5-95

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table is the counterpart to Table A8, presenting the results for the high sparrow-suitability indicator in more detail (separated for clarity). It contains the same analyses of rice, wheat, sweet potato, and procurement outcomes under various winsorization levels, but here each coefficient represents the effect of being an above-median sparrow suitability county (HSS), rather than a one-unit increase in the suitability score. All regressions include county and year fixed effects with county-clustered errors.

Table A12
Effects on Rice Output, Detailed

	Rice Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	-39.69	-48.90*	-52.11*	-20.54	-125.43**	-22.47	-51.96*	-40.45*	9.93	-39.70	16.32
	(24.66)	(26.77)	(28.33)	(21.37)	(54.35)	(24.75)	(29.36)	(23.35)	(49.15)	(42.91)	(59.90)
CSS×1955	-7.51	-15.89	-7.09	1.72	8.49	9.37	-10.36	-6.14	24.16	-10.14	25.98
	(24.52)	(26.81)	(27.35)	(23.82)	(56.61)	(26.07)	(29.31)	(24.30)	(46.92)	(45.11)	(57.57)
CSS×1956	-44.61*	-47.87*	-52.84	-29.30	-69.87	-45.01	-51.33	-41.28	10.53	-44.32	5.24
	(26.78)	(27.85)	(32.52)	(25.00)	(50.99)	(34.31)	(32.86)	(26.29)	(38.83)	(51.60)	(39.93)
CSS×1958	-32.53	-26.74	-35.55	-1.91	-63.83	-15.72	-40.20	-33.37	27.90	-3.29	24.32
	(24.02)	(23.11)	(27.46)	(19.88)	(45.87)	(25.07)	(28.59)	(24.12)	(35.10)	(36.50)	(31.22)
CSS×1959	-43.36*	-32.58	-31.09	-29.86	-78.30**	-19.74	-56.05**	-41.26*	-33.36	-39.35	-51.40*
	(22.55)	(22.63)	(25.82)	(19.45)	(37.87)	(25.68)	(26.08)	(22.69)	(32.24)	(35.28)	(27.75)
CSS×1960	-59.23**	-45.56	-42.98	-46.35**	-107.27**	-24.94	-74.57***	-58.94**	-58.00**	-54.51**	-80.17***
	(25.77)	(28.81)	(29.97)	(18.55)	(41.84)	(28.76)	(26.97)	(25.84)	(27.14)	(26.34)	(26.02)
CSS×1961	-76.33**	-58.11	-63.30*	-58.61**	-127.89***	-46.62	-93.52***	-77.10**	-89.63**	-77.67*	-103.85***
	(33.51)	(36.94)	(38.00)	(28.32)	(48.31)	(38.20)	(35.89)	(33.65)	(43.26)	(43.81)	(37.33)
CSS×1962	-85.63***	-59.82*	-83.34**	-62.71**	-132.61**	-64.03	-104.83***	-84.65***	-62.18	-69.53	-82.68**
	(32.75)	(36.07)	(38.46)	(28.63)	(52.75)	(38.85)	(39.17)	(32.04)	(44.13)	(45.81)	(36.62)
CSS×1963	-23.83	4.49	-8.79	-16.65	-69.78	-5.60	-29.30	-25.08	9.77	3.27	0.75
	(25.77)	(26.73)	(29.33)	(25.78)	(42.31)	(32.56)	(31.41)	(24.27)	(38.75)	(33.48)	(35.96)
CSS×1964	-30.49	0.94	-22.43	-31.42	-68.04	-34.97	-34.74	-33.66	-29.76	-24.24	-39.71
	(25.27)	(23.15)	(28.73)	(25.64)	(42.43)	(31.68)	(31.29)	(25.05)	(39.43)	(33.32)	(35.00)
CSS×1965	-29.00	13.53	-21.76	-48.56***	-53.47	-46.22**	-21.24	-30.66	-50.02*	-28.59	-59.43*
	(22.57)	(22.69)	(20.38)	(16.65)	(36.42)	(19.97)	(23.91)	(22.86)	(25.51)	(18.61)	(33.70)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.89	0.89	0.89	0.90	0.88	0.89	0.89	0.89	0.89	0.91	0.89
Dep. Var. Mean	59.54339	59.54339	59.54339	55.28177	61.30209	61.0959	59.54339	59.54339	58.39933	54.61808	58.39933
N	3,473	3,473	3,473	2,712	2,180	3,050	3,473	3,473	1,720	2,565	1,720
Clusters	421	421	421	336	319	379	421	421	260	321	260

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table conducts a series of robustness checks for the impact of sparrow eradication on rice output. Using the continuous sparrow suitability measure as the treatment, columns (1)–(11) report estimates from variants of our baseline regression with different sets of controls and fixed effects included (as indicated in the bottom panel of the table). In column (1), we include only county and year fixed effects (the baseline specification); by column (4) we add baseline population-by-year fixed effects; by column (7) we add controls for other GLF policies (e.g., steel production targets, commune dining, etc.); by column (10) we incorporate region-by-year fixed effects or provincial trends, and so on. All regressions include county fixed effects throughout (year fixed effects are omitted in those specifications where year-by-other interactions serve a similar purpose). Standard errors are clustered at the county level.

Table A13
Effects on Rice Output, Detailed

	Rice Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	-14.61*	-17.74**	-17.98*	-15.94*	-38.41**	-15.39	-14.11*	-14.72*	-20.61	-20.52*	-23.54*
	(8.40)	(8.59)	(9.99)	(9.41)	(17.06)	(10.08)	(8.20)	(8.03)	(12.59)	(11.61)	(13.18)
HSS×1955	-2.58	-4.70	-3.28	-5.02	-4.63	-1.50	-2.19	-2.28	-5.49	-6.96	-7.58
	(7.93)	(8.07)	(9.54)	(9.24)	(16.12)	(9.51)	(7.91)	(7.78)	(14.27)	(12.09)	(14.30)
HSS×1956	-13.76	-14.68	-16.61	-13.78	-26.20	-16.20	-13.09	-13.12	-11.77	-16.24	-14.96
	(11.25)	(11.38)	(13.68)	(13.03)	(23.38)	(14.06)	(10.90)	(11.08)	(17.72)	(16.82)	(17.67)
HSS×1958	-10.68	-9.02	-12.16	-8.50	-21.73	-10.83	-10.42	-10.70	-6.49	-7.82	-6.56
	(7.90)	(7.91)	(9.64)	(8.94)	(16.41)	(9.69)	(7.87)	(7.98)	(13.62)	(11.88)	(13.38)
HSS×1959	-14.73*	-11.60	-12.70	-16.62*	-26.86*	-12.06	-14.17*	-14.22*	-13.71	-12.32	-14.87
	(8.12)	(8.15)	(9.74)	(9.02)	(16.09)	(9.88)	(7.97)	(8.07)	(13.88)	(11.53)	(13.29)
HSS×1960	-14.79**	-10.54	-11.55	-17.87**	-30.11**	-10.73	-14.08**	-14.66**	-17.50	-12.88	-17.89
	(7.21)	(7.44)	(8.84)	(7.41)	(15.00)	(8.91)	(6.94)	(7.21)	(11.25)	(9.06)	(11.03)
HSS×1961	-20.62*	-15.03	-18.07	-24.71**	-38.74*	-17.61	-19.27*	-20.71*	-26.79	-20.14	-24.17
	(11.23)	(11.47)	(13.51)	(12.35)	(20.09)	(13.74)	(10.73)	(11.32)	(18.54)	(15.69)	(18.19)
HSS×1962	-23.23*	-15.82	-23.99	-22.63*	-39.18*	-22.45	-23.17*	-23.06*	-21.39	-17.35	-18.15
	(11.96)	(12.13)	(14.82)	(13.19)	(21.80)	(14.70)	(11.85)	(11.79)	(18.88)	(16.39)	(18.48)
HSS×1963	-8.73	-0.65	-7.16	-12.56	-23.01	-7.06	-8.76	-8.99	-10.02	-4.62	-3.31
	(9.75)	(9.58)	(11.68)	(11.18)	(18.27)	(12.09)	(9.71)	(9.42)	(13.94)	(12.83)	(13.72)
HSS×1964	-13.22	-3.46	-13.90	-17.77	-26.06	-15.20	-13.13	-13.72	-21.63	-11.46	-12.54
	(10.19)	(9.83)	(12.36)	(11.72)	(19.11)	(12.61)	(10.04)	(9.99)	(14.97)	(13.26)	(14.98)
HSS×1965	-10.45*	1.23	-9.53	-14.88**	-19.60	-12.30*	-9.49	-10.73*	-16.50*	-5.51	-7.77
	(5.70)	(5.00)	(6.05)	(6.01)	(12.17)	(6.75)	(5.77)	(5.67)	(8.77)	(6.18)	(9.29)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.89	0.89	0.90	0.90	0.88	0.89	0.90	0.89	0.89	0.91	0.89
Dep. Var. Mean	59.54339	59.54339	59.54339	55.28177	61.30209	61.0959	59.54339	59.54339	58.39933	54.61808	58.39933
N	3,473	3,473	3,473	2,712	2,180	3,050	3,473	3,473	1,720	2,565	1,720
Clusters	421	421	421	336	319	379	421	421	260	321	260

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table repeats the above robustness exercise for rice output using the high-suitability indicator as the treatment variable. It corresponds to Table A10, but instead of the continuous score we interact the high-suitability county dummy with the year indicators. The eleven columns include the same sequence of control combinations (baseline population controls, GLF policy variables, weather, region trends, etc.). Every specification includes county fixed effects (and, except where intentionally omitted, year fixed effects), with standard errors clustered by county.

Table A14
Effects on Wheat Output, Detailed

	Wheat Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	2.45	0.32	4.62	2.75	-0.75	7.69**	1.67	3.41	6.34	4.73	8.41
	(5.10)	(4.93)	(5.87)	(3.86)	(7.56)	(3.87)	(4.90)	(5.15)	(5.96)	(4.50)	(5.88)
CSS×1955	5.59	3.97	3.67	2.26	6.43	1.30	5.30	5.62	-4.27	-5.16	-2.02
	(5.30)	(5.07)	(4.98)	(4.10)	(8.96)	(4.11)	(5.32)	(5.49)	(7.17)	(4.64)	(7.11)
CSS×1956	8.58*	7.63	4.92	8.59	7.74	9.97*	7.94	9.21*	6.24	4.68	5.10
	(5.04)	(5.02)	(4.69)	(5.84)	(6.81)	(5.47)	(5.20)	(5.11)	(9.31)	(6.76)	(9.46)
CSS×1958	-0.69	-0.62	-3.28	1.31	-4.86	-1.38	0.06	0.45	-2.63	1.00	-3.82
	(5.24)	(5.32)	(4.61)	(5.79)	(7.85)	(5.73)	(5.23)	(5.25)	(9.13)	(6.50)	(9.20)
CSS×1959	-5.40	-4.99	-5.25	-5.79	-7.61	-7.07	-5.83	-5.83	-10.25*	-8.91**	-10.89**
	(4.62)	(4.89)	(4.31)	(3.88)	(6.33)	(4.39)	(4.60)	(4.60)	(5.26)	(4.00)	(5.53)
CSS×1960	-6.01	-5.19	-4.18	-5.65	-8.67	-5.60	-5.15	-5.95	-11.22*	-9.31*	-12.16**
	(5.72)	(6.13)	(5.73)	(5.22)	(6.94)	(5.04)	(5.60)	(5.72)	(5.93)	(5.37)	(6.00)
CSS×1961	-19.37**	-18.17**	-16.48**	-13.25*	-22.85**	-17.64**	-18.34**	-19.03**	-7.08	-11.26	-8.53
	(7.68)	(7.77)	(7.73)	(7.06)	(9.12)	(8.89)	(7.62)	(7.73)	(9.07)	(7.69)	(9.36)
CSS×1962	-13.57***	-11.97**	-13.73***	-12.71***	-15.95***	-14.70***	-12.99***	-13.03***	-11.88*	-13.40***	-13.61**
	(4.79)	(5.20)	(4.79)	(4.70)	(5.66)	(5.24)	(4.75)	(4.78)	(6.07)	(5.14)	(6.38)
CSS×1963	-10.57***	-8.52*	-9.51***	-10.52***	-12.72**	-9.99**	-10.45***	-9.22**	-8.48	-6.88	-11.28*
	(3.85)	(4.82)	(3.37)	(3.94)	(5.20)	(4.21)	(3.85)	(3.83)	(5.87)	(4.69)	(6.42)
CSS×1964	-6.22	-3.74	-5.44	-3.84	-9.03	-0.57	-5.85	-4.68	8.55	8.38	4.65
	(7.79)	(8.36)	(8.82)	(8.69)	(9.36)	(9.02)	(7.80)	(7.94)	(13.24)	(10.84)	(13.23)
CSS×1965	4.93	7.04	5.55	2.34	1.79	8.00*	2.77	5.48	-1.72	2.08	-4.64
	(4.68)	(5.58)	(4.62)	(4.51)	(6.10)	(4.77)	(4.92)	(4.77)	(6.91)	(5.63)	(7.37)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.90	0.90	0.91	0.88	0.89	0.90	0.90	0.90	0.86	0.89	0.86
Dep. Var. Mean	13.21826	13.21826	13.21826	11.41211	13.61061	12.91032	13.21826	13.21826	11.60349	11.41411	11.60349
N	4,081	4,081	4,081	3,290	2,856	3,720	4,081	4,081	2,248	3,177	2,248
Clusters	495	495	495	407	394	458	495	495	322	394	322

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table is analogous to Table A10 but for wheat output as the dependent variable. We use the continuous sparrow suitability score and estimate its interaction effects on wheat output across 1958–1965 under various specifications. Columns (1)–(11) introduce the same sets of additional controls stepwise (county fixed effects in all, and progressively adding population-by-year FE, crop suitability controls, weather controls, etc., as indicated in the table). Standard errors are clustered at the county level.

Table A15
Effects on Wheat Output, Detailed

	Wheat Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	0.43	-0.04	0.89	0.52	-0.42	1.70*	0.27	0.64	0.97	1.07	1.23
	(1.04)	(1.02)	(1.20)	(0.78)	(1.55)	(0.90)	(1.02)	(1.07)	(1.21)	(1.00)	(1.19)
HSS×1955	1.19	0.85	0.79	1.47	0.71	0.94	1.11	1.14	0.31	0.24	0.67
	(0.97)	(1.01)	(0.92)	(1.00)	(1.51)	(0.96)	(0.96)	(1.00)	(1.80)	(1.04)	(1.80)
HSS×1956	0.64	0.44	-0.28	0.49	0.62	0.84	0.50	0.75	-0.22	-0.52	-0.50
	(1.21)	(1.23)	(1.20)	(1.48)	(1.99)	(1.30)	(1.26)	(1.23)	(3.02)	(1.81)	(3.06)
HSS×1958	0.61	0.65	0.14	0.88	-0.11	0.62	0.76	0.79	0.09	0.76	-0.05
	(0.84)	(0.85)	(0.75)	(0.89)	(1.37)	(0.89)	(0.83)	(0.83)	(1.50)	(0.95)	(1.48)
HSS×1959	-0.97	-0.83	-0.82	-0.24	-1.72	-0.94	-1.08	-1.11	-1.15	-0.68	-1.00
	(0.82)	(0.84)	(0.80)	(0.77)	(1.25)	(0.90)	(0.81)	(0.82)	(1.20)	(0.80)	(1.26)
HSS×1960	-0.79	-0.52	-0.57	-0.39	-1.74	-0.45	-0.68	-0.79	-2.23*	-1.10	-2.30*
	(0.95)	(1.00)	(0.92)	(0.90)	(1.34)	(0.84)	(0.92)	(0.95)	(1.34)	(0.87)	(1.30)
HSS×1961	-2.63**	-2.27*	-1.96*	-2.26**	-3.72**	-2.51*	-2.45**	-2.61**	-1.45	-1.79	-1.52
	(1.13)	(1.16)	(1.10)	(1.13)	(1.54)	(1.34)	(1.11)	(1.14)	(1.58)	(1.24)	(1.63)
HSS×1962	-1.44*	-0.96	-1.26	-1.89**	-1.86	-1.60*	-1.33	-1.36	-1.79	-1.83**	-1.90
	(0.85)	(0.91)	(0.85)	(0.88)	(1.18)	(0.93)	(0.84)	(0.85)	(1.25)	(0.92)	(1.29)
HSS×1963	-1.68**	-1.07	-1.34*	-2.05**	-2.18*	-1.33*	-1.68**	-1.42*	-1.75	-1.10	-2.08
	(0.76)	(0.88)	(0.71)	(0.79)	(1.13)	(0.81)	(0.76)	(0.76)	(1.34)	(0.90)	(1.43)
HSS×1964	-0.86	-0.14	-0.77	-1.38	-1.29	0.26	-0.81	-0.62	1.16	1.14	0.70
	(1.13)	(1.15)	(1.17)	(1.12)	(1.59)	(1.31)	(1.11)	(1.13)	(1.81)	(1.28)	(1.68)
HSS×1965	1.45	2.15**	1.65	0.69	1.14	2.65**	0.92	1.55	0.25	1.13	-0.04
	(1.03)	(1.07)	(1.08)	(1.11)	(1.44)	(1.13)	(1.12)	(1.04)	(2.10)	(1.45)	(2.26)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.90	0.90	0.90	0.88	0.89	0.90	0.90	0.90	0.86	0.88	0.86
Dep. Var. Mean	13.21826	13.21826	13.21826	11.41211	13.61061	12.91032	13.21826	13.21826	11.60349	11.41411	11.60349
N	4,081	4,081	4,081	3,290	2,856	3,720	4,081	4,081	2,248	3,177	2,248
Clusters	495	495	495	407	394	458	495	495	322	394	322

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table provides the detailed wheat output results using the high-suitability dummy as the treatment, complementing Table A12. It runs the same eleven regression specifications (columns (1)–(11)) with various fixed effects and controls. All regressions include county fixed effects, and standard errors are clustered by county.

Table A16
Effects on Sweet Potato Output, Detailed

	Sweet Potato Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	-9.86	-5.11	-8.24	-2.74	-43.67**	-16.86*	-10.90	-9.52	-16.95	-3.82	-13.51
	(8.33)	(9.87)	(9.14)	(5.16)	(20.57)	(9.25)	(8.35)	(9.18)	(11.61)	(11.91)	(13.24)
CSS×1955	-3.41	-0.58	-3.60	2.84	-21.14	-8.37	-1.66	-3.61	-9.02	-8.89	-6.82
	(6.72)	(6.52)	(7.02)	(5.61)	(16.77)	(7.24)	(6.51)	(6.93)	(9.40)	(7.92)	(10.39)
CSS×1956	-9.26	-5.94	-7.68	0.25	-16.23	-8.39	-4.13	-9.12	-8.67	-3.69	-5.43
	(7.16)	(8.09)	(8.15)	(5.63)	(14.09)	(7.65)	(6.63)	(7.22)	(13.96)	(8.36)	(13.48)
CSS×1958	11.14	8.82	9.65	11.25*	7.07	5.10	12.68	11.88	-0.72	5.12	3.60
	(9.53)	(9.85)	(11.21)	(6.41)	(18.45)	(10.06)	(9.12)	(9.42)	(10.38)	(7.97)	(9.21)
CSS×1959	-6.06	-11.02	-5.21	-11.15*	-7.41	-7.44	-13.29	-6.70	-5.55	-12.67	0.71
	(10.27)	(11.16)	(11.69)	(6.64)	(14.12)	(10.97)	(11.49)	(10.53)	(8.32)	(8.02)	(9.77)
CSS×1960	5.93	-1.21	9.21	-9.36	-8.33	4.98	1.84	5.62	-9.37	-14.22	-5.17
	(8.33)	(9.90)	(9.24)	(8.67)	(11.49)	(9.03)	(8.91)	(8.31)	(10.68)	(10.18)	(11.19)
CSS×1961	18.15*	8.26	22.77**	3.81	7.25	16.82*	7.08	18.14*	-2.10	-5.30	-4.82
	(9.21)	(11.16)	(10.69)	(8.17)	(13.23)	(9.26)	(9.50)	(9.42)	(8.08)	(8.43)	(10.05)
CSS×1962	7.65	-4.92	7.56	1.45	1.98	3.21	1.83	7.87	-14.52*	-13.00*	-14.83
	(6.58)	(8.15)	(6.89)	(4.89)	(8.91)	(5.34)	(5.91)	(6.43)	(8.36)	(6.87)	(9.80)
CSS×1963	14.39	-0.27	14.68	-0.88	18.64	6.59	13.86	13.50	-9.10	-13.71	-12.23
	(11.97)	(13.86)	(13.89)	(5.64)	(17.87)	(11.68)	(9.91)	(11.88)	(12.38)	(9.13)	(11.87)
CSS×1964	36.78***	18.82	39.11***	17.61***	39.68**	30.67**	26.78**	35.87***	15.72*	5.90	6.19
	(13.84)	(15.21)	(14.76)	(6.30)	(19.97)	(12.50)	(12.00)	(13.68)	(9.30)	(8.16)	(10.98)
CSS×1965	31.87***	10.23	32.80***	22.20***	29.55**	21.42***	23.04***	32.62***	4.43	-0.11	-11.57
	(9.28)	(11.87)	(10.72)	(5.12)	(13.98)	(7.17)	(7.49)	(9.29)	(8.30)	(9.29)	(15.01)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.86	0.86	0.87	0.88	0.84	0.87	0.86	0.86	0.88	0.89	0.88
Dep. Var. Mean	17.02351	17.02351	17.20693	14.10802	15.35498	15.90042	17.02351	17.02351	12.33827	12.73427	12.33827
N	1,588	1,588	1,571	1,219	872	1,421	1,588	1,588	690	1,114	690
Clusters	206	206	206	164	142	188	206	206	116	153	116

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table is analogous to Table A10 but for sweet potato output as the dependent variable. We use the continuous sparrow suitability score and estimate its interaction effects on sweet potato output across 1958–1965 under various specifications. Columns (1)–(11) introduce the same sets of additional controls stepwise (county fixed effects in all, and progressively adding population-by-year FE, crop suitability controls, weather controls, etc., as indicated in the table). Standard errors are clustered at the county level.

Table A17
Effects on Sweet Potato Output, Detailed

	Sweet Potato Output										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	-2.75	-1.99	-2.53	-2.40	-6.41**	-3.69*	-3.11*	-2.57	-2.89	-2.84*	-3.02
	(1.79)	(1.77)	(2.10)	(1.68)	(3.03)	(1.87)	(1.62)	(1.85)	(2.99)	(1.52)	(3.10)
HSS×1955	0.34	0.78	0.52	0.90	-1.82	-0.47	0.66	0.23	-1.23	-1.26	-1.26
	(1.32)	(1.23)	(1.33)	(1.39)	(2.43)	(1.40)	(1.32)	(1.40)	(2.23)	(1.41)	(2.26)
HSS×1956	-1.29	-0.91	-0.87	0.19	-3.10	-1.36	-0.46	-1.41	-0.68	-0.57	-0.50
	(1.35)	(1.37)	(1.50)	(1.18)	(2.35)	(1.43)	(1.18)	(1.40)	(2.67)	(1.41)	(2.53)
HSS×1958	0.77	0.43	0.38	0.99	-1.57	-0.65	0.81	0.94	-1.28	-0.09	-0.29
	(1.69)	(1.74)	(1.76)	(1.37)	(2.97)	(1.71)	(1.53)	(1.68)	(2.19)	(1.59)	(1.99)
HSS×1959	-3.00	-3.72	-3.29	-3.84**	-4.21	-2.13	-4.58*	-3.13	-2.64	-2.60	-0.68
	(2.33)	(2.54)	(2.73)	(1.80)	(3.55)	(2.51)	(2.65)	(2.44)	(1.82)	(1.82)	(1.73)
HSS×1960	-0.48	-1.63	-0.23	-3.83	-4.04	0.24	-1.53	-0.67	-3.12	-3.66	-1.60
	(2.05)	(2.25)	(2.07)	(2.43)	(2.84)	(2.09)	(2.19)	(2.04)	(2.83)	(2.48)	(2.54)
HSS×1961	3.39**	1.79	4.05**	0.41	0.98	4.21**	1.23	3.36*	0.67	0.35	1.78
	(1.69)	(1.91)	(1.80)	(1.34)	(2.59)	(1.71)	(1.76)	(1.75)	(1.63)	(1.42)	(1.82)
HSS×1962	1.75	-0.22	1.66	0.09	0.53	1.42	0.66	1.61	-2.89	-1.26	-1.09
	(1.19)	(1.32)	(1.22)	(0.99)	(2.13)	(1.08)	(1.12)	(1.15)	(1.98)	(1.28)	(2.01)
HSS×1963	0.91	-1.40	0.62	-1.37	0.88	-0.58	0.47	0.60	-3.91	-2.82	-2.47
	(1.94)	(2.11)	(2.25)	(1.38)	(3.03)	(2.01)	(1.45)	(1.94)	(2.84)	(1.80)	(2.67)
HSS×1964	5.36**	2.51	5.64**	3.02*	5.92	4.63**	3.24	5.08**	3.94	2.19	4.45
	(2.21)	(2.19)	(2.44)	(1.73)	(3.72)	(2.19)	(1.97)	(2.17)	(3.16)	(2.06)	(2.97)
HSS×1965	5.95***	2.60	6.08***	4.53***	5.89**	4.28***	4.20***	6.05***	2.19	1.98	1.62
	(1.61)	(1.67)	(1.82)	(1.32)	(2.89)	(1.34)	(1.33)	(1.61)	(1.98)	(1.32)	(2.06)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.86	0.86	0.86	0.88	0.84	0.87	0.86	0.86	0.88	0.89	0.89
Dep. Var. Mean	17.02351	17.02351	17.20693	14.10802	15.35498	15.90042	17.02351	17.02351	12.33827	12.73427	12.33827
N	1,588	1,588	1,571	1,219	872	1,421	1,588	1,588	690	1,114	690
Clusters	206	206	206	164	142	188	206	206	116	153	116

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. This table provides the detailed sweet potato output results using the high-suitability dummy as the treatment, complementing Table A14. It runs the same eleven regression specifications (columns (1)–(11)) with various fixed effects and controls. All regressions include county fixed effects, and standard errors are clustered by county.

Table A18
Effects on Procurement Rate, Detailed

	Procurement Rate										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	-0.02	-0.05	-0.11**	-0.02	0.04	-0.03	-0.01	-0.02	0.02	-0.06	-0.04
	(0.05)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.07)
CSS×1955	0.03	0.01	-0.01	0.04	0.10*	0.02	0.04	0.04	0.12**	0.04	0.08
	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)	(0.04)	(0.06)	(0.05)	(0.06)
CSS×1956	0.08*	0.07	-0.01	0.09*	0.15**	0.05	0.09*	0.10**	0.18**	0.07	0.18**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.07)	(0.05)	(0.05)	(0.04)	(0.08)	(0.05)	(0.08)
CSS×1958	0.14***	0.15***	0.16***	0.12**	0.10	0.17***	0.13**	0.16***	0.12	0.19***	0.11
	(0.06)	(0.06)	(0.05)	(0.06)	(0.07)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)
CSS×1959	0.17**	0.18**	0.08	0.19**	0.27***	0.18**	0.17**	0.16**	0.20**	0.14*	0.12
	(0.07)	(0.07)	(0.07)	(0.08)	(0.09)	(0.07)	(0.07)	(0.07)	(0.10)	(0.09)	(0.10)
CSS×1960	0.11*	0.14**	0.13*	0.09	0.19***	0.13**	0.12*	0.11*	0.18**	0.14**	0.15*
	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)	(0.07)	(0.06)	(0.08)	(0.07)	(0.08)
CSS×1961	-0.16***	-0.13**	-0.20***	-0.17***	-0.07	-0.12**	-0.16***	-0.17***	-0.02	-0.09	-0.04
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.08)
CSS×1962	-0.00	0.04	-0.07	0.00	0.08	-0.01	0.02	0.01	0.09	0.05	0.09
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.04)	(0.05)	(0.05)	(0.06)	(0.05)	(0.07)
CSS×1963	-0.01	0.05	-0.07	0.02	0.06	-0.03	0.01	0.01	0.04	0.06	0.06
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.07)	(0.06)	(0.07)
CSS×1964	-0.13***	-0.06	-0.18***	-0.12**	-0.07	-0.13***	-0.12**	-0.13***	-0.14*	-0.08	-0.10
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.07)	(0.06)	(0.08)
CSS×1965	-0.04	0.03	-0.09**	-0.04	0.03	-0.04	-0.02	-0.03	-0.04	0.01	0.04
	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)	(0.04)	(0.04)	(0.04)	(0.06)	(0.05)	(0.07)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.75	0.77	0.78	0.75	0.78	0.76	0.76	0.76	0.80	0.77	0.81
Dep. Var. Mean	.2518229	.2518229	.2518229	.2515824	.2579992	.2515055	.2518229	.2518229	.2570676	.2507721	.2570676
N	3,388	3,388	3,388	3,043	2,292	3,235	3,388	3,388	2,125	2,965	2,125
Clusters	440	440	440	403	347	420	440	440	323	390	323

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. The procurement rate is defined as the fraction of grain output procured by the state (a value between 0 and 1). The analysis uses county-level data from 1954–1965 with county fixed effects and year fixed effects included in every regression. Standard errors are clustered at the county level.

Table A19
Effects on Procurement Rate, Detailed

	Procurement Rate										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	-0.01	-0.02*	-0.03***	-0.02	0.00	-0.02	-0.01	-0.01	-0.00	-0.03**	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1955	0.00	-0.00	-0.01	-0.00	0.02	-0.00	0.00	0.00	0.02	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
HSS×1956	0.01	0.01	-0.01	0.01	0.02	0.00	0.01	0.01	0.03	0.00	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1958	0.01	0.01	0.02**	0.01	0.02	0.02*	0.01	0.01	0.02	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
HSS×1959	0.03***	0.04***	0.02	0.04***	0.05***	0.04***	0.04***	0.03**	0.04**	0.03**	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
HSS×1960	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1961	-0.04***	-0.03**	-0.04***	-0.04***	-0.02*	-0.03**	-0.04***	-0.04***	-0.02	-0.02	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1962	-0.01	0.00	-0.02**	-0.01	0.00	-0.01	-0.00	-0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
HSS×1963	-0.01	0.00	-0.02*	-0.01	-0.00	-0.02	-0.01	-0.01	-0.00	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1964	-0.03***	-0.01	-0.03***	-0.03**	-0.02	-0.03***	-0.02**	-0.03***	-0.03**	-0.01	-0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
HSS×1965	-0.02	0.00	-0.03**	-0.01	-0.01	-0.02*	-0.01	-0.02*	-0.01	0.00	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.75	0.76	0.78	0.75	0.78	0.76	0.76	0.75	0.80	0.77	0.81
Dep. Var. Mean	.2518229	.2518229	.2518229	.2515824	.2579992	.2515055	.2518229	.2518229	.2570676	.2507721	.2570676
N	3,388	3,388	3,388	3,043	2,292	3,235	3,388	3,388	2,125	2,965	2,125
Clusters	440	440	440	403	347	420	440	440	323	390	323

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. HSS equals 1 for counties with sparrow suitability above the median. The dependent variable is the grain procurement rate (share of output requisitioned by the state). Each regression includes county fixed effects. Standard errors are clustered at the county level.

Table A20
Effects on Sown Area, Detailed

	Sown Area										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	6.23	6.02	7.84	4.40	4.89	7.77	6.63	5.16	-0.23	14.07	9.46
	(6.98)	(7.51)	(7.90)	(7.26)	(10.20)	(7.22)	(6.86)	(7.06)	(15.24)	(8.66)	(14.68)
CSS×1955	-3.27	-3.12	3.12	-4.19	-4.32	-1.79	-2.60	-2.30	-4.75	2.15	0.72
	(6.57)	(6.39)	(7.56)	(6.56)	(8.77)	(6.93)	(6.49)	(6.62)	(11.74)	(7.56)	(10.24)
CSS×1956	-5.74	-8.08	2.66	-7.58	-15.52**	-6.54	-5.16	-4.50	-24.66**	-8.86	-27.19***
	(5.67)	(5.42)	(7.66)	(6.11)	(7.44)	(6.71)	(5.48)	(5.82)	(10.56)	(9.39)	(9.85)
CSS×1958	3.49	0.12	-4.07	0.49	3.52	-0.47	3.71	3.03	-4.67	-11.32*	-12.48
	(6.70)	(6.71)	(8.36)	(6.32)	(10.50)	(7.36)	(6.67)	(6.73)	(10.07)	(6.87)	(9.18)
CSS×1959	10.99	8.17	-3.47	2.70	11.90	10.35	11.30	11.59	-1.31	-10.68	-12.83
	(8.58)	(8.45)	(10.13)	(7.30)	(12.67)	(9.84)	(8.54)	(8.62)	(12.86)	(8.92)	(12.04)
CSS×1960	18.67**	15.71*	1.50	15.73*	20.86	16.49*	18.76**	18.92**	6.96	5.13	-6.82
	(9.09)	(8.80)	(10.02)	(9.19)	(13.92)	(9.68)	(8.81)	(9.17)	(13.54)	(9.08)	(13.42)
CSS×1961	19.69**	17.47*	1.51	14.40	17.00	20.73*	19.89**	19.93**	11.18	10.78	-6.68
	(9.75)	(9.58)	(11.13)	(9.15)	(14.00)	(10.62)	(9.58)	(9.73)	(14.01)	(9.93)	(14.41)
CSS×1962	17.15**	14.92*	-0.98	11.74	17.28	18.26**	17.57**	18.34**	9.70	5.97	-11.46
	(8.36)	(8.91)	(9.22)	(7.97)	(12.70)	(9.12)	(8.29)	(8.36)	(12.87)	(9.25)	(14.27)
CSS×1963	13.95*	11.93	-5.25	8.49	14.35	14.61	14.42*	14.04*	2.78	1.17	-17.74
	(8.12)	(8.77)	(9.51)	(7.21)	(12.34)	(8.96)	(8.02)	(8.21)	(11.71)	(7.84)	(12.36)
CSS×1964	9.01	6.11	-9.17	3.02	8.67	9.09	9.16	7.84	-0.64	-10.26	-26.60**
	(9.02)	(9.97)	(10.16)	(7.60)	(13.39)	(10.17)	(8.91)	(9.04)	(12.17)	(8.44)	(13.13)
CSS×1965	4.18	-0.08	-10.65	0.16	4.55	6.20	4.50	4.36	1.43	-10.77	-29.82**
	(8.47)	(10.61)	(9.99)	(7.56)	(12.86)	(9.63)	(8.39)	(8.44)	(12.13)	(10.00)	(14.99)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Dep. Var. Mean	85.15309	85.15309	85.15309	82.88842	86.95354	84.07194	85.15309	85.15309	86.19418	81.38529	86.19418
N	3,741	3,741	3,741	3,345	2,563	3,549	3,741	3,741	2,368	3,233	2,368
Clusters	459	459	459	417	368	438	459	459	343	405	343

Estimation results from Equation 1 for the year-specific effects on total crop sown area, using the continuous sparrow suitability score (CSS) interacted with year dummies. The regressions use the main sample of counties from 1954–1965, including county fixed effects and year fixed effects throughout. Standard errors are clustered by county.

Table A21
Effects on Sown Area, Detailed

	Sown Area										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	1.58	1.19	2.41	1.11	3.43	2.36	1.74	1.36	2.29	2.97*	2.63
	(1.76)	(1.66)	(2.10)	(1.67)	(3.05)	(1.75)	(1.75)	(1.77)	(2.52)	(1.65)	(2.35)
HSS×1955	-0.90	-1.04	0.71	-1.09	0.74	-0.26	-0.72	-0.62	1.47	0.34	1.30
	(1.55)	(1.45)	(1.68)	(1.53)	(2.50)	(1.65)	(1.55)	(1.57)	(2.98)	(1.67)	(2.45)
HSS×1956	1.95	1.35	4.57**	1.78	3.14	2.35	2.22	2.32	0.58	2.10	-0.47
	(1.69)	(1.57)	(2.08)	(1.75)	(2.55)	(1.85)	(1.68)	(1.71)	(2.17)	(2.35)	(2.04)
HSS×1958	0.79	0.28	-0.56	0.61	0.11	-0.29	0.84	0.78	-0.45	-1.71	-1.50
	(1.45)	(1.44)	(1.76)	(1.43)	(2.16)	(1.58)	(1.45)	(1.47)	(2.34)	(1.66)	(2.17)
HSS×1959	0.42	0.11	-2.60	-0.78	-0.08	0.60	0.52	0.54	-1.57	-2.88	-2.70
	(2.09)	(2.03)	(2.58)	(1.78)	(2.92)	(2.36)	(2.09)	(2.07)	(3.18)	(2.30)	(2.99)
HSS×1960	0.72	0.48	-3.13	0.60	1.50	0.52	0.71	0.74	0.38	-0.61	-0.86
	(1.91)	(1.83)	(2.17)	(1.88)	(2.49)	(1.86)	(1.89)	(1.92)	(2.53)	(1.74)	(2.34)
HSS×1961	2.40	2.14	-1.14	1.60	2.42	3.15*	2.42	2.40	2.51	1.70	0.84
	(1.86)	(1.81)	(2.13)	(1.75)	(2.56)	(1.88)	(1.84)	(1.83)	(2.57)	(1.74)	(2.50)
HSS×1962	2.12	2.02	-1.35	1.24	2.73	2.56	2.23	2.34	2.56	1.29	0.91
	(1.78)	(1.78)	(2.05)	(1.72)	(2.67)	(1.84)	(1.78)	(1.77)	(2.74)	(1.78)	(2.75)
HSS×1963	0.74	0.74	-3.07	0.07	0.99	1.19	0.81	0.77	0.43	0.00	-0.70
	(1.86)	(1.77)	(2.17)	(1.66)	(2.70)	(1.93)	(1.86)	(1.88)	(2.80)	(1.58)	(2.31)
HSS×1964	-0.05	-0.00	-3.33	-1.00	0.07	0.31	-0.02	-0.34	-0.46	-1.95	-1.79
	(1.84)	(1.84)	(2.04)	(1.61)	(2.65)	(1.91)	(1.83)	(1.83)	(2.66)	(1.64)	(2.53)
HSS×1965	-0.07	-0.73	-3.00	-0.93	0.10	0.56	0.03	-0.04	0.81	-1.64	-2.33
	(1.74)	(1.96)	(2.02)	(1.64)	(2.64)	(1.88)	(1.74)	(1.72)	(2.81)	(1.87)	(2.94)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Dep. Var. Mean	85.15309	85.15309	85.15309	82.88842	86.95354	84.07194	85.15309	85.15309	86.19418	81.38529	86.19418
N	3,741	3,741	3,741	3,345	2,563	3,549	3,741	3,741	2,368	3,233	2,368
Clusters	459	459	459	417	368	438	459	459	343	405	343

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. HSS equals 1 for counties with sparrow suitability above the median. Each regression includes county fixed effects. Standard errors are clustered at the county level.

Table A22
Effects on Mortality, Detailed

	Mortality										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	3.72	2.69	1.54	4.54	-2.18	9.34**	9.31*	5.67	3.58	7.38	6.77
	(3.86)	(3.65)	(4.41)	(3.66)	(3.56)	(4.22)	(5.49)	(4.17)	(6.28)	(4.55)	(7.73)
CSS×1955	-1.84	-1.10	2.17	-0.79	-5.24	1.12	-0.53	-4.24	-6.26	1.67	-3.38
	(3.57)	(3.51)	(4.75)	(3.98)	(4.37)	(3.30)	(3.52)	(3.72)	(4.55)	(3.92)	(5.08)
CSS×1956	1.13	1.13	-0.82	2.63	-13.20***	2.49	0.93	3.48	-11.08***	4.17	-7.01
	(3.80)	(3.91)	(4.93)	(3.83)	(4.37)	(3.14)	(3.79)	(4.26)	(4.23)	(3.84)	(4.48)
CSS×1958	2.56	2.67	-0.16	4.05	-2.89	-9.12*	1.34	6.95	-6.77	-7.48	-7.52
	(4.92)	(5.02)	(4.84)	(5.17)	(4.68)	(4.72)	(4.78)	(5.53)	(7.13)	(5.03)	(7.30)
CSS×1959	4.12	4.12	6.81	5.14	-4.17	-22.76*	0.54	2.22	10.65*	-24.06**	7.20
	(11.26)	(11.26)	(11.17)	(12.03)	(6.13)	(11.77)	(11.11)	(11.14)	(5.42)	(12.19)	(5.89)
CSS×1960	33.42*	33.45**	35.65	37.09**	19.02	-11.89	23.69	34.27**	26.11*	-7.76	22.08
	(17.03)	(16.97)	(22.63)	(18.26)	(12.08)	(15.88)	(16.25)	(16.70)	(14.93)	(15.84)	(14.38)
CSS×1961	-13.06**	-12.84**	-14.15**	-12.58**	-7.08	-19.44***	-13.75**	-16.19***	-1.74	-19.86***	-6.41
	(5.65)	(5.45)	(6.05)	(5.57)	(4.65)	(6.32)	(5.57)	(6.25)	(5.66)	(5.96)	(6.18)
CSS×1962	-1.61	-1.80	-0.58	-2.36	12.40**	-1.06	-1.67	2.22	8.39*	-1.16	3.05
	(2.70)	(2.73)	(3.19)	(2.61)	(5.09)	(2.49)	(2.76)	(3.05)	(4.60)	(2.63)	(5.56)
CSS×1963	9.66***	9.88**	11.84**	10.18**	6.66	8.62**	9.38**	21.81***	5.65	11.69**	0.38
	(3.69)	(3.83)	(5.16)	(3.99)	(4.12)	(3.70)	(3.72)	(5.02)	(5.21)	(4.93)	(6.13)
CSS×1964	7.31*	7.57*	11.81**	7.18*	-0.35	6.48*	7.74**	17.75***	2.41	5.78	-4.92
	(3.83)	(3.88)	(5.56)	(4.08)	(3.65)	(3.88)	(3.92)	(5.68)	(4.84)	(5.15)	(5.94)
CSS×1965	5.35**	4.91*	6.73**	3.98*	7.21**	4.66*	5.15**	4.45	4.11	4.85	-5.15
	(2.41)	(2.88)	(2.69)	(2.34)	(3.22)	(2.51)	(2.37)	(3.02)	(3.42)	(3.41)	(4.76)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.46	0.46	0.60	0.46	0.63	0.56	0.48	0.47	0.65	0.57	0.66
Dep. Var. Mean	14.6542	14.6542	14.6542	14.6542	13.15465	14.24117	14.6542	14.6542	13.15465	14.24117	13.15465
N	3,699	3,699	3,699	3,699	2,524	3,550	3,699	3,699	2,524	3,550	2,524
Clusters	486	486	486	486	388	470	486	486	388	470	388

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965.This regression using the continuous sparrow suitability score (CSS) interacted with year dummies. Each regression includes county fixed effects. Standard errors are clustered at the county level.

Table A23
Effects on Mortality, Detailed

	Mortality										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	0.36	-0.13	0.09	0.55	0.25	3.09**	1.80	0.61	3.36*	2.30**	4.61**
	(1.12)	(1.01)	(1.15)	(1.11)	(1.15)	(1.23)	(1.59)	(1.13)	(1.99)	(1.08)	(2.29)
HSS×1955	0.53	0.79	1.90*	0.74	0.17	1.88**	0.87	0.46	-0.15	2.23**	0.90
	(0.99)	(1.01)	(1.07)	(1.07)	(1.21)	(0.91)	(0.98)	(1.00)	(1.18)	(1.02)	(1.28)
HSS×1956	0.58	0.74	0.67	0.91	-2.32**	1.43	0.72	0.99	-2.15**	1.97*	-1.03
	(1.06)	(1.11)	(1.38)	(1.09)	(0.99)	(0.87)	(1.05)	(1.10)	(1.07)	(1.01)	(1.19)
HSS×1958	1.99	2.09	1.35	2.25	-0.05	-0.95	1.93	2.26*	-1.79	-0.74	-1.85
	(1.30)	(1.34)	(1.36)	(1.39)	(1.38)	(1.22)	(1.29)	(1.31)	(2.12)	(1.35)	(2.16)
HSS×1959	7.67**	7.73**	8.01**	8.34**	-0.25	-2.74	7.09**	7.64**	2.98**	-2.71	2.29
	(3.39)	(3.40)	(3.39)	(3.70)	(1.24)	(2.20)	(3.34)	(3.36)	(1.44)	(2.29)	(1.68)
HSS×1960	13.14***	13.25***	14.31**	14.32***	5.17**	1.75	11.64***	13.19***	6.24*	2.89	5.25
	(4.20)	(4.24)	(5.56)	(4.85)	(2.32)	(3.97)	(4.20)	(4.13)	(3.24)	(4.62)	(3.41)
HSS×1961	-0.92	-0.85	-1.78	-0.78	-1.37	-1.88	-0.95	-1.47	-0.40	-1.66	-1.33
	(1.77)	(1.79)	(1.99)	(1.92)	(1.25)	(1.65)	(1.77)	(1.91)	(1.41)	(1.95)	(1.54)
HSS×1962	-0.57	-0.47	-0.57	-0.62	2.30**	-0.23	-0.54	0.10	1.60	0.02	0.61
	(0.58)	(0.58)	(0.70)	(0.56)	(1.13)	(0.53)	(0.58)	(0.60)	(0.98)	(0.58)	(1.13)
HSS×1963	2.48***	2.53***	3.13***	2.61***	1.61	2.55***	2.53***	4.53***	1.02	3.20***	0.07
	(0.85)	(0.95)	(1.01)	(0.94)	(1.09)	(0.82)	(0.85)	(0.93)	(1.07)	(1.08)	(1.19)
HSS×1964	2.52***	2.54**	3.83***	2.51**	1.00	2.82***	2.71***	4.29***	1.63	2.82**	0.19
	(0.92)	(1.05)	(1.09)	(1.00)	(1.12)	(0.89)	(0.91)	(1.04)	(1.24)	(1.17)	(1.43)
HSS×1965	1.42**	1.50**	1.69**	1.16**	2.20***	1.37**	1.49***	1.16*	1.56**	1.73**	0.01
	(0.57)	(0.75)	(0.66)	(0.57)	(0.81)	(0.54)	(0.57)	(0.68)	(0.74)	(0.79)	(0.84)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.47	0.48	0.62	0.48	0.63	0.56	0.49	0.48	0.65	0.57	0.66
Dep. Var. Mean	14.6542	14.6542	14.6542	14.6542	13.15465	14.24117	14.6542	14.6542	13.15465	14.24117	13.15465
N	3,699	3,699	3,699	3,699	2,524	3,550	3,699	3,699	2,524	3,550	2,524
Clusters	486	486	486	486	388	470	486	486	388	470	388

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965. HSS equals 1 for counties with sparrow suitability above the median. Each regression includes county fixed effects. Standard errors are clustered at the county level.

Table A24
Effects on Fertility, Detailed

	Fertility										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CSS×1954	-10.83*	-15.58***	5.69	-11.84*	-20.13***	1.20	-0.59	-13.29**	-0.99	-6.83	-13.68
	(6.13)	(5.99)	(6.64)	(6.18)	(7.38)	(6.08)	(5.13)	(6.49)	(10.69)	(6.04)	(11.47)
CSS×1955	-1.28	-2.16	8.70	-3.90	-3.23	3.86	1.80	-1.31	1.08	-5.39	1.64
	(5.86)	(5.92)	(5.61)	(5.94)	(7.34)	(5.88)	(5.42)	(6.07)	(7.50)	(6.63)	(7.85)
CSS×1956	7.73	6.44	9.36	7.93*	8.65	5.49	8.44*	4.95	3.33	1.11	-0.56
	(4.90)	(4.82)	(5.73)	(4.77)	(6.44)	(4.80)	(5.00)	(5.19)	(6.61)	(5.01)	(6.68)
CSS×1958	6.44	7.12	9.95	5.48	9.67	9.76*	7.24	3.50	13.06*	9.26	13.23*
	(4.83)	(4.87)	(6.10)	(4.83)	(7.43)	(5.65)	(4.89)	(5.05)	(7.58)	(5.68)	(7.41)
CSS×1959	5.81	7.00	5.78	4.80	15.11**	11.44**	7.73	7.14	1.08	11.98**	2.00
	(4.79)	(5.03)	(5.42)	(4.69)	(6.33)	(5.48)	(4.74)	(4.74)	(5.79)	(5.48)	(5.93)
CSS×1960	-17.02***	-14.80**	-11.58**	-19.78***	-4.36	1.08	-12.98**	-19.67***	-7.38	-0.61	-6.19
	(5.34)	(5.98)	(4.74)	(5.34)	(5.54)	(5.51)	(5.04)	(5.46)	(5.41)	(5.38)	(5.84)
CSS×1961	5.04	8.53	9.38*	3.70	4.27	11.96**	6.49	4.16	8.75	17.64***	9.87*
	(5.51)	(6.09)	(5.37)	(5.48)	(5.98)	(5.75)	(5.48)	(5.62)	(5.48)	(5.85)	(5.97)
CSS×1962	7.42	10.99*	8.61	6.27	-5.09	5.65	6.96	2.58	-10.99	7.64	-9.99
	(5.69)	(6.33)	(7.45)	(5.54)	(6.12)	(6.47)	(5.63)	(5.79)	(6.90)	(7.28)	(7.73)
CSS×1963	-1.11	3.81	4.06	-2.31	6.64	-4.68	-1.06	-9.21*	1.85	-1.82	3.61
	(5.31)	(5.38)	(5.53)	(5.14)	(5.95)	(4.98)	(5.35)	(5.39)	(6.78)	(5.53)	(6.86)
CSS×1964	3.19	9.38	9.57**	1.30	9.82**	2.59	2.52	-1.18	13.26**	10.78*	17.21**
	(5.01)	(5.83)	(4.75)	(5.12)	(4.76)	(5.21)	(5.12)	(5.24)	(5.19)	(6.23)	(6.76)
CSS×1965	1.69	6.58	3.84	1.26	-0.70	-0.86	0.86	-3.11	4.45	3.18	4.93
	(4.75)	(6.25)	(4.19)	(4.94)	(5.26)	(5.06)	(4.80)	(5.29)	(5.93)	(7.04)	(8.51)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.68	0.72	0.76	0.69	0.75	0.71	0.70	0.69	0.78	0.74	0.79
Dep. Var. Mean	31.61839	31.61839	31.61839	31.61839	32.02254	31.69093	31.61839	31.61839	32.02254	31.69093	32.02254
N	3,649	3,649	3,649	3,649	2,503	3,500	3,649	3,649	2,503	3,500	2,503
Clusters	482	482	482	482	388	466	482	482	388	466	388

Notes: Estimation results from Equation 1 for year-specific effects on fertility (birth rates), using the continuous sparrow suitability score (CSS) interacted with year indicators. Each regression includes county fixed effects. Standard errors are clustered at the county level.

Table A25
Effects on Fertility, Detailed

	Fertility										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
HSS×1954	-2.76*	-3.51**	0.15	-2.95*	-4.09**	-0.02	-0.67	-3.23**	-3.81	-2.19	-5.58**
	(1.54)	(1.57)	(1.73)	(1.52)	(1.86)	(1.79)	(1.32)	(1.64)	(2.36)	(1.66)	(2.75)
HSS×1955	0.72	0.20	2.37	0.34	-0.10	2.04	1.30	0.30	0.13	-0.22	0.60
	(1.51)	(1.49)	(1.67)	(1.50)	(2.31)	(1.73)	(1.39)	(1.54)	(2.58)	(1.83)	(2.41)
HSS×1956	1.69	1.37	1.66	1.81*	2.18	1.32	1.81*	0.78	0.13	0.16	-0.61
	(1.08)	(1.07)	(1.21)	(1.08)	(1.69)	(1.09)	(1.08)	(1.12)	(1.66)	(1.12)	(1.57)
HSS×1958	2.13**	2.01*	3.38***	1.96*	4.48***	3.27***	2.29**	1.68	5.09***	2.84**	4.88***
	(1.06)	(1.06)	(1.27)	(1.10)	(1.73)	(1.21)	(1.06)	(1.10)	(1.73)	(1.28)	(1.70)
HSS×1959	1.84*	1.83*	2.31*	1.70	5.47***	3.74***	2.24**	2.07*	2.27	3.39***	2.26
	(1.07)	(1.11)	(1.19)	(1.10)	(1.44)	(1.10)	(1.01)	(1.06)	(1.55)	(1.12)	(1.67)
HSS×1960	-3.79***	-3.65***	-2.75**	-4.40***	1.09	0.15	-3.09***	-4.32***	-0.21	-0.90	-0.52
	(1.19)	(1.32)	(1.14)	(1.31)	(1.47)	(1.10)	(1.12)	(1.25)	(1.58)	(1.30)	(1.73)
HSS×1961	1.85	2.23	3.13**	1.61	2.83*	3.53***	2.14*	1.69	3.44**	4.13***	2.93*
	(1.22)	(1.37)	(1.26)	(1.24)	(1.53)	(1.26)	(1.19)	(1.26)	(1.53)	(1.40)	(1.65)
HSS×1962	3.67**	4.01**	4.68***	3.52**	2.06	3.44*	3.67**	2.67*	0.23	3.17	-0.55
	(1.50)	(1.62)	(1.60)	(1.51)	(1.78)	(1.76)	(1.50)	(1.54)	(2.05)	(1.93)	(2.19)
HSS×1963	1.17	1.82	1.72	1.02	2.46*	-0.23	1.18	-0.58	0.72	-0.51	-0.17
	(1.35)	(1.30)	(1.25)	(1.44)	(1.47)	(1.24)	(1.37)	(1.39)	(1.77)	(1.41)	(1.85)
HSS×1964	2.32*	3.19**	2.93**	2.04	2.47*	1.26	2.20	1.52	2.37	2.02	1.90
	(1.40)	(1.34)	(1.29)	(1.49)	(1.45)	(1.35)	(1.41)	(1.42)	(1.58)	(1.40)	(1.75)
HSS×1965	1.81*	2.30**	1.93**	1.82*	0.92	0.88	1.78*	0.89	1.21	0.70	-0.36
	(0.98)	(1.10)	(0.96)	(1.04)	(1.24)	(0.99)	(0.98)	(1.06)	(1.34)	(1.25)	(1.67)
Baseline Population-by-Year FE	N	N	N	Y	N	N	N	N	Y	Y	Y
Steel Production Growth	N	N	N	N	Y	N	N	N	Y	N	Y
GLF Variables	N	N	N	N	N	Y	N	N	Y	Y	Y
Crop Suitability	N	N	N	N	N	N	Y	N	Y	Y	Y
Yearly Weather	N	N	N	N	N	N	N	Y	Y	Y	Y
Year FE	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Region-by-Year FE	N	N	Y	N	N	N	N	N	N	N	N
Provincial Linear Trends	N	Y	N	N	N	N	N	N	N	Y	Y
R^2	0.69	0.72	0.77	0.69	0.76	0.71	0.70	0.69	0.78	0.74	0.79
Dep. Var. Mean	31.61839	31.61839	31.61839	31.61839	32.02254	31.69093	31.61839	31.61839	32.02254	31.69093	32.02254
N	3,649	3,649	3,649	3,649	2,503	3,500	3,649	3,649	2,503	3,500	2,503
Clusters	482	482	482	482	388	466	482	482	388	466	388

Notes: Estimation results from Equation 1 for the main sample spanning 1954 to 1965.HSS equals 1 for counties with sparrow suitability above the median. Each regression includes county fixed effects. Standard errors are clustered at the county level.

A Data Appendix

This section provides details on our data sources and variable construction.

A.1 County Level

Sparrow Suitability Score

Estimated by the habitat suitability model BIOCLIM: Eyal to fill in.

Crop Data from Gazetteers

The county-level crop output data is collected from county gazetteers. County gazetteers were published in the 1990s and compiled from historical archives into one archive. To collect crop-level data, we collect data from two sections, "Economy" and "Agriculture". The "Economy" section typically provides the aggregate statistics on the total cultivated area, gross output of grain crops, and gross output of cash crop by year. The "Agriculture" section provides annual panel data of more granular crop-level cultivated area and crop output. In total, we find XXX counties provide detailed crop-level

Crop Data from Province/Prefecture Statistics

The agricultural output data comes from 81 decrypted government documents and one published statistical compilation. We collected these documents from provincial libraries in China, university libraries in mainland China and Hong Kong, the Chinese full-text book search engine "Duxiu" and the largest second-hand or antique book trading platform in China, the "Kongfuzi" website. Complete agricultural statistical data compiled by provincial agricultural bureaus or statistical bureaus are available for 22 provinces and 1,699 counties. In areas without provincial-level statistical data, we used statistical compilations from prefecture-level cities, including county-level statistical data. We found statistical data compilations for 47 prefecture-level cities and 406 counties.

Here are the sources of agricultural output data for each county which are arranged by province, and the number before the province name represents the administrative code of that province.

11 Beijing Municipality

Beijing Municipal Bureau of Statistics & Beijing Rural Sample Survey Team. (1987). *Statistical data on grain production in Beijing Municipality, 1949-1986.*

12 Tianjin Municipality

Tianjin Agricultural and Forestry Bureau. (1977). *Statistical data on agricultural production in Tianjin Municipality, 1949-1976.*

13 Hebei Province

Hebei Provincial Agricultural Bureau & Chengde Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Chengde Area, 1949-1978.*

Hebei Provincial Agricultural Bureau & Shijiazhuang Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Shijiazhuang Area, 1949-1978.*

Hebei Provincial Agricultural Bureau & Baoding Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Baoding Area, 1949-1978.*

Hebei Provincial Agricultural Bureau & Cangzhou Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Cangzhou Area, 1949-1978.*

Hebei Provincial Agricultural Bureau & Handan Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Handan Area, 1949-1978.*

Handan Area Administration Agricultural Bureau. (1980). *Statistical data on agricultural history in Hengshui Area, 1949-1978.*

Langfang Area Administration Statistics Bureau. (1980). *Statistical data on national economic statistics in Langfang Area, 1949-1979.*

Qinhuangdao City Statistics Bureau. (1985). *Statistical data on national economic statistics in Qinhuangdao City, 1949-1984.*

Tangshan Area Administration Agricultural Bureau. (1980). *Statistical data compilation on national economic statistics in Tangshan Area, 1949-1979.*

Xingtai Area Revolutionary Committee Statistics Bureau. (1976). *Statistical data on national economic statistics in Xingtai Area, 1949-1975.*

Hebei Province Zhangjiakou Special Zone Office Statistics Bureau. (1965). *Statistical data compilation on national economic and socio-cultural statistics in Zhangjiakou Special Zone, 1949-1964.*

14 Shanxi Province

Shanxi Provincial Agriculture Department. (1982). *Statistical data on agricultural production in Shanxi Province, 1949-1979.*

15 Inner Mongolia Autonomous Region

Inner Mongolia Autonomous Region Statistics Bureau. (1983). *Statistical data on agricultural and animal husbandry production (Volumes 1-4).*

21 Liaoning Province

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Pesticide Use

The sales volume of chemical pesticides in each county mainly comes from the county-level cooperative supply and marketing society records and the commercial section of the county records. Chemical pesticides, as important agricultural production materials, are primarily managed and distributed by cooperative supply and marketing societies in various regions during the sample period. For example, the cooperative supply and marketing society records of Chaling County and the commercial section of the Zhaozhou County records - the third section on cooperative supply and marketing societies, document the annual sales volume of pesticides in the respective regions. In addition, county-level national economic statistical data, such as the Compilation of National Economic Statistical Data of Deqing County from 1949 to 1979, also include various indicators of regional economy, including pesticide sales volume.

Quantity of Sparrows Killed

The quantity of sparrow killing in each county comes from the hygiene records of each county or the hygiene section of the county records. Since the founding of the People's Republic of China, the "Four Pests Campaign" (including the "New Four Pests" after the replacement of sparrows with cockroaches since 1961) has been under the responsibility of the Patriotic Health Campaign Committees at the central and regional levels. The hygiene records in various regions may document various major hygiene campaigns and related data over the years. For example, the hygiene records of Zhuanglang County and the hygiene and sports section of Xishui County records - the twenty-second section, provide information on the quantity of sparrows killed.

Crop Procurement, Population, Fertility and Mortality

Data from "Kasahara, H. & Li, B. (2020). Grain Exports and the Causes of China's Great Famine, 1959-1961: County-Level Evidence. *Journal of Development Economics*, 146, 102513".

Agricultural Population

From gazetteers. Fill in by Yang.

A.2 Province Level

Sparrow Suitability Score
Aggregated from the county level : Eyal to fill in.

Quantity of Sparrows Killed
The data on the quantity of sparrow killings in each province comes from the main provincial newspapers, such as the Beijing Daily, which is the official organ of the Beijing Municipal Party Committee. The "Four Pest Campaign" was a significant event in the agricultural sector during the Great Leap Forward period, and most party newspapers provide detailed tracking records of the process and the number of sparrows killed.

Pesticide and Fertilizer Use
The data on the sales volume of chemical pesticides in each province is derived from provincial-level cooperative society publications, agricultural statistical data, or national economic statistical data, such as the "Cooperative Society Publication of Liaoning Province" and the "Agricultural Economic Statistical Data of Zhejiang Province, 1949-1985".

Population and Mortality
Data from "Meng X., Qian N. and Yared P. (2015). The Institutional Causes of Famine in China, 1959-61. *The Review of Economic Studies*, 82(4), 2015, p. 1568-1611".

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Data from National Bureau of Statistics of China.

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