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Successive volcanic eruptions (1809–1815) and two severe famines of Korea (1809–1810, 1814–1815) seen through historical records

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Abstract

Based on the government's historical records and personal documents of the pre-modern Chosŏn Dynasty, this paper examines the socio-economic impacts in Korea in response to climatic variability from 1809 until 1819 that may have been influenced to some degree by the eruption of the "unknown volcano" (1809) and the Tambora eruption (1815). In the early 1800s, when volcanic eruptions occurred successively, the Korean Peninsula experienced a temporal precipitation variation—drought, abundant rainfall, and normalcy—twice. The precipitation variation in this period had a heavy impact on the yields of rice, major crop on the peninsula. In the phase of drought in 1809 and extreme climatic anomalies in 1814, the country suffered record poor harvests, and in the abundant rainfall phase in 1810 and 1816–1817, it had bumper crops. For this reason, 1816–1817 were the halcyon years for Korea, unlike the case of Europe and the northeastern USA which suffered from extreme climatic anomalies in those years. This case of the Korean Peninsula indicates that the climate change and natural disasters of the 1810s were influenced by not only of the single event of the Tambora eruption but of the successive eruptions of volcanoes in the 7 years from 1809 to 1815, which also affected other areas on the globe for 11 years (1809–1819).

Keywords 1809 unknown volcano · 1815 Tambora eruption · Precipitation variation · Rice farming · 1809–1810 famine · 1814–1815 famine

1 Foreword

There has been much research and numerous discussions on the Tambora eruption in April 1815 and its global impact (Oppenheimer 2003; Wood 2014; Brugnara et al. 2015; Raible et al. 2016), but many aspects of climate change, including the case of Korea, in the 1810s still remain to be fully accounted for. I would like to point out the limitations of existing research on this subject from two aspects. First, they have a too geographically limited

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coverage to explain the change in climate on a global scale. Second, natural disasters and their aftermath were more varied across individual societies worldwide than had been supposed (Harington 1992).

As elaborated in Chapters 3 and 4, Korea recorded its worst rice harvests in 1809 and 1814, and as a result, suffered from severe famines in 1809–1810 and 1814–1815. However, the country saw a good crop year in 1815 and had a bumper crop in 1816 and a modestly good harvest again in 1817. The years of 1816–1817 were a lucky period allowing the country to extricate itself from the agricultural crisis that lasted 7 years starting with the worst harvest of 1809. This is the reason why this article notes the changes in crop yields on the Korean Peninsula as one of the examples proving the variety of the impacts from the climate change of the 1810s on the globe.

Pre-modern Chosŏn Dynasty (1392–1910), an agricultural country heavily dependent upon rice farming, paid special attention to meteorological phenomena, particularly the changes in precipitation. As such, the dynasty has left behind many official documents from the government and personal records about the climate and meteorology. Using such official and personal documents of pre-modern Korea, this article investigates the climate variability, rice harvest results and changes in the prices of crops in the early nineteenth century, to the end of the tracking of climate variability on the Peninsula and its socioeconomic impacts for the 11 years since the eruption of the “unknown volcano” in 1809 until 1819.

2 Successive eruptions of volcanoes (1809–1815) and abnormal low temperature in Korea

During the successive eruptions of five volcanoes for the 7 years from 1809 when the unknown volcano in tropical region erupted until the Tambora eruption of April 1815, the Korean Peninsula recorded a sharp drop in temperature. The lower temperatures of the Peninsula in the early nineteenth century are confirmed by the azalea blooming dates in Taegu, Kyŏngsang-do province (35° 52′N, 128° 60′E) for 32 years (1798–1829) (Fig. 1).

The first azalea blooming dates in Taegu. Given the fact that the blooming dates in Taegu in 1931–1940 and 1971–2000 were April 2 and March 31, respectively (NIMR 2011, 38, 55), the azalea in Taegu in the early nineteenth century bloomed 10 days later than in the 1930s and 13 days later than in the 1970s–1990s. As azaleas normally bloom at 12.9℃, and its blooming advances by 3.9 days for every 1℃ rise in temperature (Lee 2010), the temperature in Taegu in mid-April of the 1800s is presumed to have been 2–3℃ lower than that of the 1930s.

As seen in Table 1, the temperature for the 32 years of in the early 1800s are roughly divided into three: before the volcanic eruptions (1798–1809), the post-volcanic eruption years (1811–1816), and the post-aftermath period (1823–1829). Judging by the fact that azaleas bloomed three days later (April 15 on the average) under the aftermath of volcanic eruptions in the 1810s than the early nineteenth century (Apr. 12), the average temperature of the 1810s is presumed to have been 0.7–0.8℃ lower than the early nineteenth century. It corresponds with the results of the studies that found the temperatures of tropical and temperate regions after the Tambora eruption in 1815 were lower by 0.4–0.8℃ than in the earlier 30 years (Raible et al. 2016). Thus, the successive eruptions of volcanoes are presumed to have been the cause of the abnormal low temperature of the Peninsula (33–43°N, 124–132°E) for 11 years (1809–1819) (Table 1).

Fig. 1 Korean Peninsula and Kyŏngsang-do province. This map was based on the Korean Internet encyclopedia, doopedia, and the author of this article marked District, Prefecture and Provinces on it.

3 Halcyon years of Korea, 1816–1817

The year 1816 was a "year without summer" for Europe and the northeastern USA. Because of abnormal climate and natural disasters, the European and North American regions saw bad harvests of wheat and other crops, steep rises in grain prices, and a rampancy of thieves and beggars. It was the same with the year 1817, when the phenomenon of abnormal low temperature was evident (Post 1977; Wood 2014).

Korea also experienced climate anomalies such as decrease in the amount of solar irradiance, an increase in precipitation, strong northwest winds, cool summers and autumns, and severe cold in 1816–1817.[1] Given these climatic anomalies, it is highly likely that Korea, like Europe and the northeastern USA, would have faced agricultural-socioeconomic crises. However, this was not the case of Korea in 1816–1817. The country suffered no significant loss in the spring–summer barley yield and had a good harvest of the summer-autumn rice crop in 1816 and recorded normal crop yields again in 1817. The result of Korea's rice harvest in 1816–1817 can be obtained by examining the changes in the rice yields and the size of tax-free rice paddies for the 11 years from 1809 to 1819.

The Chosŏn Dynasty used to compile harvest results and determine which paddies should be exempted from taxation, based on the *Chaesil pundŭng changgye* 災實分等狀啟 (Annual Crop Report) submitted at the end of each year by the governors of six provinces, except for the P'yŏngan-do and Hamgyŏng-do provinces bordering China. As the report

[1] It is confirmed by *ND* and *Yŏksang ilgi* (Yi Pyŏng-t'ak's Diary; *YD*) by Yi Pyŏng-t'ak (1760–1832).

Table 1 Azalea blooming dates in Taegu in the early nineteenth century

Year		Blooming dates			1931–1940 Average blooming dates	1971–2000 Average blooming dates
		Date	Average	Total average		
Before volcanic eruptions	1798	4.09	4.10–11	4.12	4.2	3.31
	1801	4.13				
	1803	4.13				
	1808	4.11				
	1809	4.08				
After eruptions	1811	4.16	4.15			
	1815	4.13				
	1816	4.16				
After the end of aftermath of eruptions	1823	4.08	4.11–12			
	1825	4.08				
	1828	4.16				
	1829	4.14				

Source: No Sang-ch'u (1746–1829), *No Sang-ch'u ilgi* (No Sang-ch'u's Diary; *ND*)

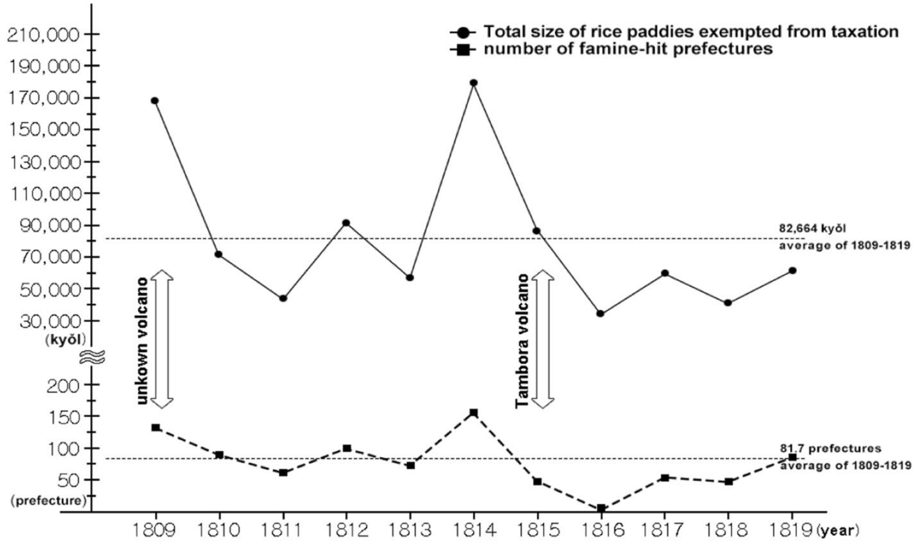

Fig. 2 Rice harvest results and tax-free rice paddies in 1809–1819. *Source:* The *Annual Crop Report* from eight provinces in 1809–1819, *Sŭngjŏngwŏn ilgi* (The Daily Records of the Royal Secretariat; *SI*), reign of King Sunjo

compiled the rice harvest results from eight provinces and tax exemption measures for six provinces, it helps in figuring out the rice yields each year.

According to the Fig 2 in 1816. just 17 (5.1%) out of 336 prefectures across the country reported poor crop yields, and tax-free rice paddies accounted for 11.2% (35,950 *kyŏl*) of the nation's total (321,909 *kyŏl*, 1 *kyŏl* = approx. 2.5 acres). The harvest in 1816 was so good that famine-hit prefectures numbered just 17, accounting for 20.8% of the average number (81.7) of such prefectures for the 11 years from 1809. The size of the tax-free rice paddies of that year was just 43.5% of the 11-year average (82,664 *kyŏl*). The year 1816 was also one of the bumper rice crop years in the 35-year period (1800–1834). The results of the rice harvest and the size of the tax-free rice paddies in Kyŏngsang-do in the early nineteenth century are provided in the Fig 3.

For the 35 years in the early nineteenth century, Kyŏngsang-do only had 6 years of better crop yields than in 1816: 1802–1804, 1811, 1820, and 1825. When the tax-free rice paddies numbered 3,000 *kyŏl* or fewer, the province regarded it as a bumper crop year, and the year 1816 almost reached the level of a bumper crop, with the tax-free paddies totaling 3,700 *kyŏl*. For this reason, the central government of the dynasty called it the "first bumper crop year in 50–60 years" (in the case of Chŏlla-do) and the "best harvest in 10 years" (Kyŏngsang-do).[2]

Crop conditions for the years 1817 and 1818 were not much different from 1816. The number of prefectures that had crop failures and tax-exempted rice paddies in 1817 accounted for just 19.6% (66 prefectures) and 18.8% (60,550 *kyŏl*) of the country's total. All of the eight provinces of the country recorded a similarly good harvest. In 1818, five

[2] *SI*, October 15 and October 29, 1816, in the lunar calendar (December 3 and December 17, 1816). The Chosŏn dynasty used the lunar calendar. This article has converted the lunar dates into the solar calendar dates. It presents lunar dates first along with their solar dates in parenthesis.

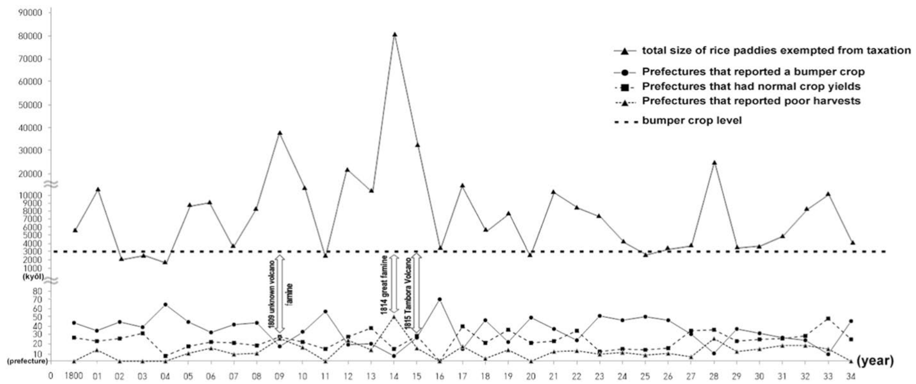

Fig. 3 Rice harvest and tax-free rice paddies of Kyŏngsang-do in 1800–1834. *Source*: The *Annual Crop Report* from Kyŏngsang-do in 1800–1834, *SI*

provinces, including Kyŏngsang-do and Chŏlla-do, had a bumper crop, with Hwanghae-do and P'yŏngan-do only reporting bad crop yields. Prefectures that reported crop failures numbered just 51 (15.2% of the country's total), and tax-exempted rice paddies amounted to 42,000 *kyŏl* (13.2% of the country's total) that year. This indicates that the climate anomalies caused at least in part by the Tambora eruption did not have much impact on rice farming in the country.

However, as is known well, the crop yield of Europe in the same period was quite different from Korea. In 1816, lower temperatures, decrease in solar irradiance and excessive rainfall have stunted growth of crops for two to four weeks in Switzerland, which resulted in decrease of the potato harvest by 20–50 percent and steep rise of the crop prices by 400–500 percent in eastern Switzerland. In 1817, the country also suffered from serious drop in crop yields due to the prolonged cold wave until spring (Flückiger et al. 2017).

The difference in the crop yields between Korea and Europe, in spite of the climatic similarity of the abnormal low temperature, resulted from the different cropping systems for wheat, barley, and potato in Europe and rice in Korea. The yield of rice in Korea per unit area is more than double that of dry field crops such as barley and millet (Ono 1941), and it was a staple food for Koreans for 8–9 months from the rice harvest in early October until late June or early July when barley was harvested. For that reason, the rice yield served as the standard to determine crop conditions for the year, and based on the result of the rice harvest, the government evaluated crop yields for the year and determined the total size of farmland subject to taxation at the end of the year. All the standards to determine crop conditions of 336 prefectures across the country and to provide tax exemptions in the six provinces were based on rice harvest records (*Annual Crop Report*). As tax on rice paddies, the most important tax revenue for the central government was collected in rice; the revenue increased or decreased depending on the rice yield. As such, rice was a grain that had an absolute value for pre-modern Koreans.

Adequate temperature, solar irradiance, and precipitation are required for the growth of rice, commonly cultivated in a climate with a high temperature and humidity, but sufficient precipitation is the most decisive factor in Korea. Since there was a time gap of about 10–20 days between the right time to transplant rice (late June) and the start of the monsoon season (early-mid July), the success of rice farming in Korea depended on whether transplanting could be done on time. In Korea, where irrigation facilities were not well

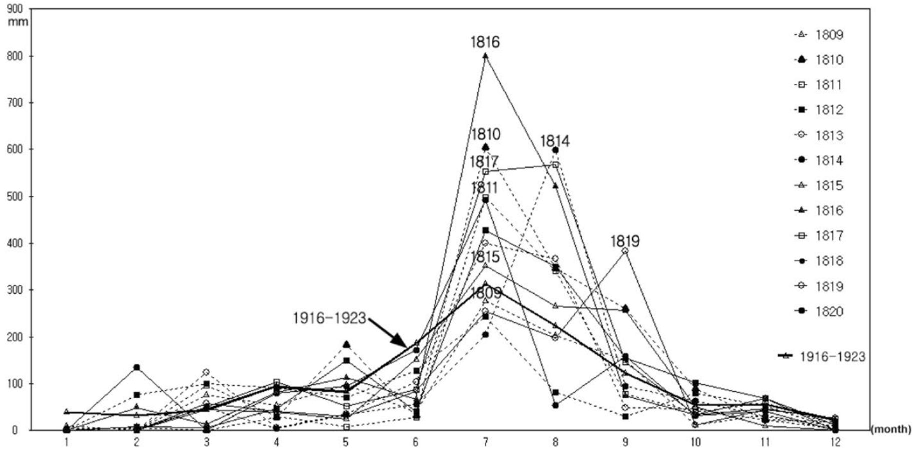

Fig. 4 Monthly precipitation in Seoul in 1809–1820. *Source*: Wada 1917

developed, the water supply to paddies was mostly dependent on rainfall. The optimal condition for rice transplanting was rainfall of 90mm for a week that filled a rice paddy with water 3–10cm deep. In Korea, where the long dry season lasts for nearly 9 months from October until June the following year, the probability of more than 90mm of rainfall for a week at the end of June was less than half (43.6%). It wasn't until the beginning of July that the probability increased to 74.5% to provide stable conditions for rice transplanting (Chi et al. 1958).

As rice often had to be transplanted when the amount of precipitation was insufficient, Korean farmers preferred drought-resistant species. They also opted for cold-resistant and early maturing species, because they had to start rice transplanting in spite of the lack of agricultural water amid the irregular monsoon season. So the rice species adapted to the Korean climate, the coolest and driest among the representative East Asian rice zones, including the Yangtze Delta of China and the Kansai region in Japan, had the three traits of being drought- and cold-resistant and precocious (Kim 2015).

The years of 1816–1817 provided good conditions for farming rice, as the precipitation increased for 3 years after the Tambora eruption. The year 1816 recorded precipitation of 1,880mm, up 48.3% from the average amount (1,263mm) in 1910–1945. The next years, 1817 and 1818, also saw increases to 1,724mm up 36.5%, and 1,426mm up 12.9%, respectively, from the annual average. The larger amount of precipitation was more evenly distributed over the period. Wada estimated the precipitation in 1771–1907 by month and year, based on the pluviometer records of the Chosŏn dynasty. The monthly precipitation in Seoul in 1809-1820 is in Fig 4.

In 1816, 178mm of rain fell from May to June when farmers were preparing rice seedbeds and starting to transplant rice; 1,322 mm fell from July to August when rice grew fast; and 108mm from September to October when the grains were ripening and being harvested. In 1817, there was 138mm of precipitation from May to June, 1,120mm from July to August, and 180mm from September to October. In 1818, 190mm of rain fell from May to June; 778mm from July to August; and 256mm from September to October. As seen here, in spite of abnormal low temperatures, rain fell evenly during the rice growing period

Table 2 Rice farming timeline in 1816–1818 in Iljik, Andong

Year	First rice planting (June 26)*	First harvest (October 15)*	Note
1816	June 29 (3 days late)	September 29 (17 days early)	
1817	June 22 (4 days early)	October 30 (15 days late)	Rainy season for three months led to cooler summer and autumn, and less amount of sunlight
1818	July 2 (6 days late)	October 20 (5 days late)	

Source: *YD*, 1816–1817

* The average dates according to the farming timeline of the early 1800s

(May–October) in 1816–1818 without disrupting the farming schedule. It is confirmed by the rice farming and harvest timeline in Iljik, Andong.

According to the Table 2 above, rice transplanting in 1816 started 3 days later than the annual average (June 26), due to the drought in June (precipitation of 66mm in Seoul), but the rice harvest started on September 29, 17 days earlier than the annual average thanks to sufficient precipitation later in the year. In 1817, rice transplanting was done four days earlier with enough precipitation in June (86mm). However, because the rainy spell lasted for 3 months (552mm in July, 568mm in August, and 146mm in September) with lower temperatures in summer and autumn than usual and an insufficient amount of solar irradiance, the harvest was delayed for 15 days that year. In 1818, the extreme drought in June (40mm) delayed rice transplanting for about 6 days, but the rainy spell started in the early July, and summer temperatures returned to their normal level, helping the completion of the rice harvest around October 20, about 5 days later than usual. The year 1817 when the harvest was delayed due to a long rainy season, lower summer and autumn temperatures, and insufficient solar irradiance was an exceptional year, compared to 1816 and 1818 when the rice harvest was completed earlier than or around the usual date, October 15.

The year 1816, when rice transplanting and harvesting were completed at the right time, saw a bumper crop, with Kyŏngsang-do calling it the "best harvest in 10 years." The crop condition of 1818 was also good, as transplanting and harvesting were delayed for just 5–6 days. On the other hand, in 1817 when the harvest was delayed by a fortnight, the country narrowly managed to reap a normal level harvest. The ratio of rice paddies in Kyŏngsang-do granted a central government tax exemption of 3.5% (3,700 *kyŏl*) in 1816, 15.5% (15,500 *kyŏl*) in 1817, and 5.3% (5,300 *kyŏl*) in 1818 (Fig. 3). This means that the central government judged the harvest of 1816 as a bumper crop yield, 1817 as a normal level, and 1818 as a good year, respectively.

Judging by the rice farming timeline above, timely transplantation and harvesting were the factors that determined the yield of rice in pre-modern Korea. Sufficient monthly and annual precipitation was the most important precondition for a good harvest, as this allowed farmers to keep to their agricultural schedule. This draws attention to the fact that the Peninsula had more precipitation in 1809–1819 than before and after the years. A statistical record on the precipitation in Seoul in 1800–1830 shows that the rainfall in 1810s increased to 1349.7mm, up by 2.8 percent (36.7mm) from 1313mm, the average of the previous 9 years (1800–1808). The amount of rainfall in the early nineteenth century was also larger by 6.7 percent (81.9mm) than the average (1263mm) of 1910–1945. In 1884, 1 year after the eruption of Krakatoa in Indonesia and in 1992 1 year after the Pinatubo eruption in the Philippines, the precipitation in Korea also increased by 1.7 percent and

15.5 percent, respectively (Cho et al. 1996) indicating a possible link between the amount of precipitation in Korean peninsula and tropical volcanic eruption in Southeast Asia.

Thanks to the abundant rainfall in those years, Korean farmers could transplant and harvest rice timely that led to good harvest in 1816–1818. However, the country was not exempt all the time from the climatic anomalies since the eruption of the unknown volcano in 1809. As the thickened volcanic dust layer in the stratosphere made global climate volatile which resulted in severe drought or extremely uneven distribution of rain, Korea suffered from bad harvest and extreme famine during those years.

4 Two severe famines in the last stages of the little ice age

1809 and 1814 were extremely lean years for Korea. The country saw record bad crops in those years whose impacts lasted until the summer of the following years, resulting in what was called the Kigyŏng Famine (1809–1810) and Kabŭl Famine (1814–1815). In 1809, when the unknown volcano erupted, Korea recorded a sharp drop of precipitation (to 1012mm) by 22.9 percent, an indication of the possibility that the volcanic eruptions might have caused the temporary droughts (Adams et al. 2003).

Until March–May in 1809, rain fell relatively evenly in Korea, posing no difficulty in spring farming (76mm in March, 54mm in April in Seoul). However, it was very dry from mid-May to late June (98mm in May, 38mm in June), when farmers started preparing rice seedbeds and transplanting rice. In the midst of the severe drought, rice transplanting was delayed to July. In addition, heavy rainfall in September (202mm) dealt severe damage to rice crops by stymying their maturity, because the paddies needed to remain dry after being drained to provide the right conditions for the ripening of the grains.

Korea's three southwestern provinces, Chŏlla-do, Ch'ungch'ŏng-do, and Kyŏnggi-do, sustained critical damages from the extreme drought that continued until early July, and frequent rainfall, strong winds and early cold from September that also resulted in poor rice yield in other areas.[3] The crop conditions for Chŏlla-do and Ch'ungch'ŏng-do were so bad that they called it the "worst crop year of 50 years."[4] Prefectures that reported crop failure numbered 132 (39.3% of the nation's total), and rice paddies exempt from taxation accounted for 52.7% (169,699 *kyŏl*), recording the worst harvest since the beginning of the nineteenth century (Figs. 2 and 3). However, the country could have normal yields of barley next year as precipitation sharply increased by 29.3 percent to 1633mm. As a result, the country could ease the 1809–1810 Famine after the summer of 1810.

Another lean year, 1814, when the Mayon volcano in the Philippines erupted (VEI 4), recorded a modest drop in precipitation (1,210mm, a drop by 4.2 percent), but had the problem of extremely uneven distribution of rainfall and early cold wave. It had modest amount of rainfall in March (48mm), little precipitation in April (4mm), and less rainfall again in May–June (34mm and 56mm) (Fig. 4). Because of this, the sowing of spring barley was delayed by two weeks (March 26–Apr. 2 in P'ungsan), and cotton could not be sown on time.[5] The severe drought continued until June, putting the preparation of rice

[3] *SI,* October 10, 1809 (Nov. 13, 1809).

[4] *SI,* October 6, 1809 (Nov. 13, 1809); October 15, 1809 (Nov. 22, 1809).

[5] The average farming timeline in Sŏnsan, and P'ungsan and Iljik in Andong prefecture in the early nineteenth century (1808–1829) is as follows: sowing of spring barley on March 15; sowing of cotton on April 23; preparation of rice seedbed on May 16; autumn barley harvest on June 20; rice transplanting on June 26; and rice harvest on October 15.

seedbeds on hold and delaying rice transplanting by more than a month (July 24–August 6 in P'ungsan and June 29–August 5 in Sŏnsan).[6]

The central government judged that normal rice farming was impossible and ordered the governors of eight provinces nationwide to plant glutinous foxtail millet and buckwheat, instead. This was to secure hunger crops in preparation for a bad rice harvest. Farmers who started sowing hunger crops from the mid-July dug the field deep to sow the seeds (July 19 –28 in P'ungsan), based on the knowledge that the seeds buried deeper in the soil survived droughts well (Chi et al. 1958). However, a heavy downpour in late July (204mm) seriously damaged the sprouts of the crops that had narrowly survived the severe drought.

In addition, some adventurous farmers, thinking that the monsoon season has just begun, tried to transplant rice seedlings into the wet paddies after thinning out the sprouts of the hunger crops. Rice transplanting in late July–early August was an unprecedented attempt because such late transplanting would drop the rice yield sharply to around only 10% of an average year.[7] In the case of P'ungsan in Andong, the ratio of the paddy into which rice was transplanted at such a late date numbered just one in dozens.[8] However, after the short duration of rainfall, a drought lasted for about a month, seriously damaging the crops again.

The drought ended with a heavy downpour in the late August. The heavy rainfall (598mm) for 11 days from August 20 until August 30, caused flooding of the Naktong River, the largest river in Kyŏngsang-do, and damaged most of the rice crops located in the lowlands. On top of this, frost appeared on September 22, 20 days earlier than usual.[9] Hunger crops sown in late July and rice transplanted in early August all suffered severe cold damages due to the excessively early frost. Thus, 1814 was the year the country experienced every kind of conceivable calamity all at once.

According to the national tally for 1814, prefectures that had a bad harvest numbered 162 (48.2% of the nation's total), and tax-free paddies amounted to 182,400 *kyŏl* (56.7% of the nation's total). Kyŏngsang-do sustained the most serious damage with famine-hit prefectures numbering 51 (71.8% of the province's total) and 65.2% (65,000 *kyŏl*) of the paddies in the province were given tax exemptions. The southwestern provinces, Chŏlla-do, Ch'ungchŏng-do, and Kyŏnggi-do, also recorded a bad harvest. The 1814–1815 Famine, which started in 1814 and lasted until July 1815, was the "famine of the century" that struck the country almost a century after the 1695–1699 Famine of the late seventeenth century, which reached its peak during the LIA (Kim 1997).

In 1814, Mayon Volcano (VIE 4) in the Philippines erupted, but its climatic influence upon the world was not serious. However, it is worth paying attention to the fact that the series of four small and large volcanic eruptions (unknown volcano (1809), Soufrière eruption in the Caribbean Sea (1812), Suwanose-jima eruption in the Ryukyu Islands (1813), Mayon eruption (1814)) made the volcanic dust layer in the stratosphere thicker, bringing abnormally low temperatures (Stothers 1984; PAGES 2K Consortium 2013). The extremely unbalanced distribution of precipitation and cold wave in Korea in 1814 might

[6] The crop condition of Sŏnsan was based on *ND* and that of P'ungsan in Andong on *Yŏksŏ* 5 (Kwŏn Cho's Diary 5; *KD*) by Kwŏn Cho (1762–1839).

[7] According to a probe by an agricultural institute in Ch'ungch'ŏng-do in 1928–1929, the transplantation on August 1 is expected to reap only 9–12% of the normal yield, when the normal transplantation on June 15 is supposed to produce 100% (Chi et al. 1958).

[8] *KD*, June 28 (August 13), 1814.

[9] The average date of the first frost in the early 1800s was October 12.

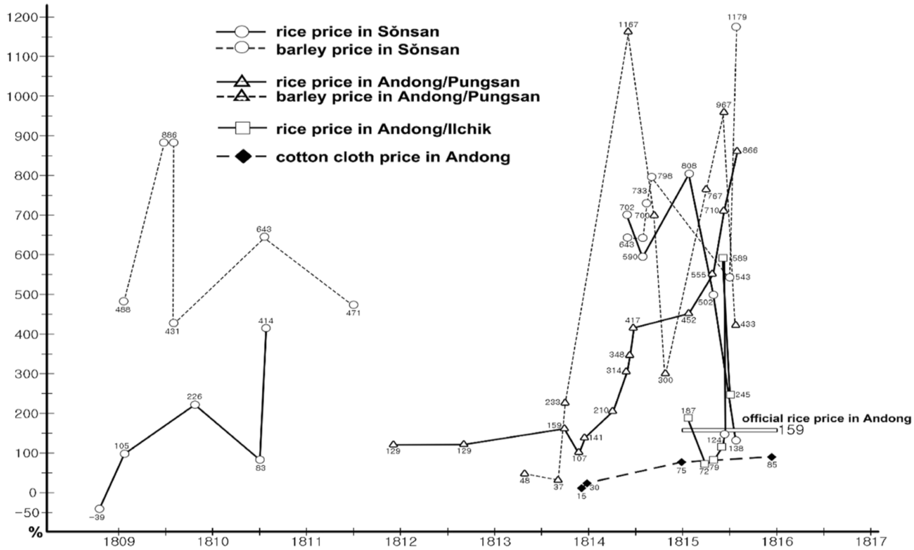

Fig. 5 Changes of grain prices of Sŏnsan and Andong in Kyŏngsang-do in 1809–1815. *Source*: *ND* for Sŏnsan market prices; *KD* for P'ungsan market prices; and *YD* for Iljik market prices

have been one of climatic anomalies caused by four successive volcanic eruptions since 1809. An esteemed bureaucrat-scholar Chŏng Yak-yong evaluated that the impact of the 1814–1815 Famine was greater than the 1809–1810 Famine (Chŏng 1817). The misery of the two famines can be examined by the fluctuations of grain prices in local markets.

According to the Fig. 5 above, rice and barley prices at the time of the 1809–1810 Famine were 414% and 886% higher than usual at the local market of Sŏnsan. On the other hand, in the summer of 1815, rice prices at the Sŏnsan market and An'gye market in Pian, near Sŏnsan, were 808% higher than usual, while they were 865.5% higher at P'ungsan market in Andong. During the same period, dry field crops such as barley, millet, and sorghum were also traded at higher prices: barley at 543.8–1,178.5% higher price in Sŏnsan and 966.7–1,236.7% higher in P'ungsan. Evaluating the severity of the famine in terms of the grain prices in Sŏnsan and Andong, the 1814–1815 Famine is seen to have been 1.5–2 times worse than the 1809–1810 Famine, since the respective rice and barley prices during the former were twice and 1.5 times the latter. The impact of the two famines on Korean society can also be examined in terms of demographic changes. The trend of changes in households and population during the reign of King Sunjo (1800–1834) is in Table 3.

According to the Table 3. table above, the number of households was the largest in 1807 (1,764,801), and the population in 1813 (7,903,167). The official statistics show a discrepancy between the changes in the number of households and population at every 3-year term, with the change in household numbers preceding that of the population. The 1809–1810 famine and 1814–1815 famine were in between the 1808–1810 period when households decreased and 1814–1816 when the population declined. This indicates that the two famines were a direct cause of the decline in households and population in that period.

The pattern of changes in the number of households and population, which were linked to each other in a 3-year time lag, can be used as referential data to track how the two famines impacted Korean society. The population decline after the 1809–1810 famine is

Table 3 Changes in the number of households and population in 1800–1834

Year	Households		Population		Note
1801	1,757,973	-	7,513,792	-	
1804	1,760,469	+0.14%	7,514,567	+0.01%	
1807	1,764,801	+0.25%	7,561,403	+0.62%	
1810	1,761,887	−0.17%	7,583,046	+0.29%	■ Eruption of unknown volcano in 1809 ■ 1809–1810 Famine
1813	1,637,108	−7.1%	7,903,167	+4.2%	■ Soufrière eruption (1812) ■Suwanose-jima eruption (1813)
1816	1,555,998	−5.0%	6,595,368	-16.5%	■ Mayon eruption (1814) ■ 1814–1815 Famine ■ Tambora eruption (1815)
1819	1,533,550	−1.44%	6,512,349	−1.3%	
1822	1,534,238	+0.04%	6,470,570	−0.64%	
1825	1,549,653	+1.0%	6,558,784	+1.4%	
1828	1,563,216	+0.88%	6,644,482	+1.3%	
1831	1,565,060	+0.12%	6,610,878	−0.5%	

Source: *Chosŏn Wangjo Sillok* (Veritable Records of the Chosŏn Dynasty), King Sunjo's reign

reflected in the household census of 1808–1810 (−0.17%) and 1811–1813 (−7.1%) and that after the 1814–1815 famine in the population census of 1814–1816 (−16.5%) and 1817–1819 (−1.3%). Regarding the population of pre-modern Korea, Michell suggested a hypothesis that the actual number of the population should be obtained by multiplying the number of households in the government statistics by 7.95. This figure is based on the assumption that each household had 7.95 family members (Michell 1977–80) (Fig. 5).

Since a decrease in the number of family members was inevitable after a large number of people died from the two severe famines, I estimated that family members per household stayed in the 7.0–7.5 range a while after the famine (Russell 2006). Based on this assumption, presents the demographic changes of Korea in the early nineteenth century.

As seen in the Fig 6. above, the population decreased by 7.3% (1,024,198 people) during the 1809–1810 famine and 17.8% (2,315,014 people) during the 1814–1815 famine.

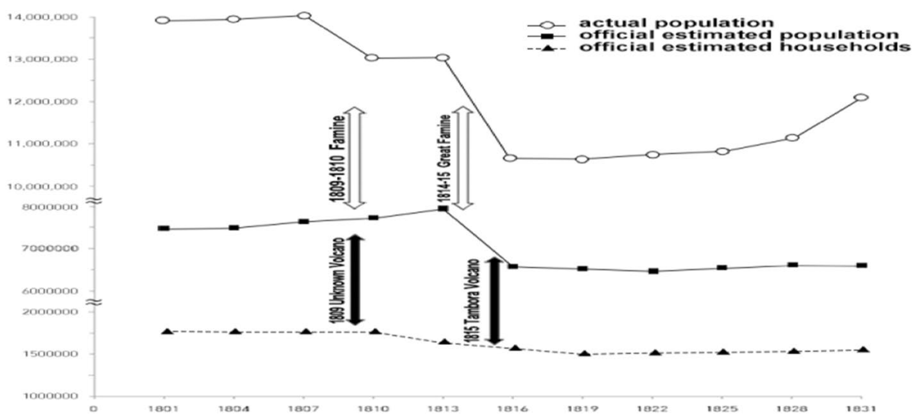

Fig. 6 Population changes in Korea in the early nineteenth century

The aftermath of the famine lasted until 1818, killing an additional 0.6% (68,472 people) of the population.

Judging by the population decline, the impact of the 1814–1815 Famine was two and half times stronger than that of the 1809–1810 famine. As seen in the changes in grain prices (Fig. 5), the economic damage during the 1814–1815 famine was also one and half or two times greater than that of the 1809–1810 famine.

The disasters had different level of impact on the economy and human lives, because the 1809–1810 Famine came after 10 consecutive years of good crops (Fig. 3), whereas the 1814–1815 famine was a disaster the country encountered amid abnormal low temperatures and natural disasters after the serial eruptions of four volcanos, starting with that of the unknown volcano in 1809. Amid the continued abnormal low temperature, natural disasters and poor crop yield after 1809, the government and civil society could no longer cope with disasters. As the country was stricken by the worse famine again just 6 years later, the Korean government and civil sector collapsed without any preparedness for the famine. The economic impact of the 1814–1815 famine was about 1.5–2 times that of the famine of 1809–1810, but its social impact grew to 2.5 times.

In contrast, the climate variability and natural disasters for the 4 years after the Tambora eruption in 1815 did not have much impact on the Peninsula. Deaths due to the impact of the Tambora eruption were less than 1% of the total population (about 68,000 people), with its socioeconomic impact estimated to have been modest.

5 Conclusion

In Korea, 1816–1818 were good years for rice farming. As a result, there was no socioeconomic crisis in Korea such as that which plagued Europe or the northeastern USA during those years. Korean society averted the crisis of 1816–1817 but did suffer from the climatic anomalies triggered by the five volcanic eruptions from 1809. For the 11 years following the eruption of the unknown volcano until 1819, the end of the aftermath of the Tambora eruption, Korea repeatedly experienced climate anomalies and natural disasters such as abnormally low temperatures, long droughts, and rainy spells, like other regions located in the mid-latitudes of the northern hemisphere. Because of the anomalies, the country suffered from record droughts in 1809 and 1814 and experienced the "worst famine of the century" twice within just 6 years.

During the two great famines of the century, the country was also plagued by measles and other epidemics amid deteriorated immunity, and the colder autumn and winter took a huge number of lives. During the famine of 1809–1810, more than 1 million people died, and the great famine of 1814–1815 took a toll of more than 2.3 million lives. The two famines wiped out about 24% (3.4 million people) of the population from its 1807–1808 peak (about 14 million). The country saw the national crisis ease, as it entered the phase of abundant rainfall in 1816–1818. These years had good harvests of most crops, except for cotton. As good crop years continued, Korean society, which was on the brink of collapse, was able to make a recovery (Degroot et al. 2021).

This Korean case might be an exception to the global impacts of the Tambora eruption in the last stages of the LIA (1809–1819). Climatic variability in Korea was likely influenced by four volcanic eruptions, in addition to Tambora, over the period 1809–1815, but I find distinctly different impacts on agriculture of similar climate anomalies in Korea compared to Europe, especially following the eruption of Tambora. The Korean Peninsula had extremely bad crops in 1809 and 1814, while Europe and the northeastern USA suffered from poor harvests from 1816–1817. In Korea, an unprecedented peasant revolt, Hong Kyong-nae Rebellion, broke out in Pyŏngan-do Province in 1812[10]; in northeastern Europe, Napoleon's army failed in its operation to conquer Russia due to the cold winter of 1812–1813; and Europe also saw peasant riots and protests by city dwellers from 1816–1817.

These cases indicate that conventional views on climate change, mainly focused on the aftermaths of Tambora eruption and the 1816–1817 crisis, have some difficulty in properly evaluating the socioeconomic crises in various parts of the world in the early nineteenth century (Raible et al. 2016). This accentuates the need to extend the timespan of the climate change to the 11-year period (1809–1819) and expand the research scope to the global scale. A wider range of study on climate change during 1809–1819 is expected to help a more accurate understanding of the climate anomalies in the last stages of the LIA and human responses to them.

Abbreviations *CS*: *Chosŏn wangjo sillok*; *KD*: Kwŏn Cho's Diary; *ND*: No Sang-ch'u's Diary; *SI*: *Sŭngjŏngwŏn ilgi*; *YD*: Yi, Pyŏng-t'ak's Diary

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[10] Before the successive volcanic eruptions, there were 10,300–10,400 households in Chŏngju prefecture, the last bastion of Hong Kyong-nae's troop, but 3 years and 5 months later after the rebellion in 1815, just 4,500 households remained (−56.5%) (*SI*, September 3, 1815 (October 5, 1815)).

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