

Spread of COVID-19 from Wuhan to rural villages in the Hubei Province

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Article Summary Line: Although COVID-19 spread from Wuhan to the rural villages in the Hubei Province, there were only limited number of cases in these villages, and most villages did not report any cases.

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Abstract –

This study aimed to describe the spread of coronavirus disease 2019 (COVID-19) from Wuhan to rural villages in the Hubei Province. The analysis revealed the following: 1) COVID-19 spread from Wuhan to other cities and rural areas in Hubei, but the disease did not become widespread in rural villages because of strict prevention measures and urbanization; 2) According to the fluctuation in the number of confirmed cases reported in Hubei after January 23, 2020, we inferred that the infected patients on the same day will become ill during the next 20 days; 3) the advanced traffic system facilitates the direct spread of COVID-19 from Wuhan to counties, towns, and villages in the Hubei Province. There is a low possibility of COVID-19 spread from prefecture-level cities to rural areas. The findings imply that the government should limit the travelers from the cities to the rural areas, pay more attention to the prevention and control of SARS-CoV-2 in cities, and appropriately prolong the isolated observation period of travelers.

Keywords: COVID-19, SARS-CoV-2, rural population, infectious disease transmission, Wuhan

Introduction –

A new type of coronavirus was first detected in Wuhan, the capital city of Hubei Province in China, in early December 2019 among a group of patients with severe pneumonia (1), it subsequently spread to other cities. The World Health Organization named the new virus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and the disease caused by this new virus, Coronavirus Disease 2019 (COVID-19) (2). The emigration of inhabitants of Wuhan led to additional confirmed cases and was associated with an increased mortality rate throughout Hubei Province (3). Human-to-human transmission of SARS-CoV-2 among close contacts was confirmed in mid-December 2019 (4). During that period, China was facing its annual Lunar New Year travel peak, causing the epidemic to spread beyond Wuhan (5). Among the initial cases diagnosed among non-residents of Wuhan, 72.3% had contact with residents of Wuhan, including 31.3% who had visited the city (6). The transmission of SARS-CoV-2 by travelers continues to pose a serious public health threat (7). Therefore, controlling the transmission of SARS-CoV-2 to people in currently unaffected areas is vital (8).

Before the Wuhan government locked down the city on January 23, 2020, many people had already left the city for their hometowns to celebrate the 2020 Chinese traditional Lunar New Year holiday. Data collected from Baidu Map Insight, an app developed by the Chinese search engine Baidu, showed that more than 70% of those who left Wuhan between January 10 and January 24 traveled to other cities in Hubei, especially to Xiaogan (13.8%) and Huanggang (13.0%) (9). The possible transmission from this travel caused a serious threat to the public health (7), particularly to the rural population, since, in general, medical treatment is worse in rural areas and the rural population response to the

COVID-19 threat lagged behind that of Wuhan residents. Consequently, on February 8, 2020, Wang Xiaodong, the Governor of Hubei Province, warned that the epidemic in Hubei was spreading to rural areas (10). In this study, we analyzed the transmission features of COVID-19 from Wuhan to rural villages in Hubei. This intent of the analysis was to synthesize information that could be used to prevent the spread of COVID-19 in rural areas, and to provide valuable data for governments implementing prevention measures worldwide.

Methods

Data Sources

Data were collected from the following:

1) Baidu Map Insight (Baidu.com, Inc.) (9). Based on the dataset collected by Baidu Map LBS (Location Based Services) and Baidu Tianyan, Baidu Map Insight was designed to track the characteristics of the flow of people in China and uses an innovative mode of visual presentation. We entered the information for “Time”, “City”, and “Destinations for moving out” on the website and then obtained the travel data. For example, we found the destinations for moving out of Wuhan during 2020-01-10~2020-01-24 by entering “01-10~01-24”, Wuhan (武汉), and destinations for moving out (迁出目的地) (Figure 1). The website has announced that it has stopped updating since May 8, 2020.

2) Official Website of Hubei Province (11). We collected the COVID-19 pneumonia notifications in Hubei from January 22 to February 21, 2020. The number of confirmed cases in cities, including Wuhan, prefecture level cities, and county level cities directly under the Hubei government, was reported daily. Yang Yunyan, the vice governor of Hubei Province, reported that there were 89,685 samples tested in Hubei and 19,665 cases confirmed

through 24:00 on February 5, of which 12,277 samples were tested and 2,987 were confirmed on February 5 itself. There were 97 testing institutions performing nucleic acid tests in Hubei, with an average daily testing capacity of 10,000 samples, and actual average daily tests of 4,000-5,000 samples (12).

3) Official Website of Huanggang (13). We collected rapid epidemic updates of Huanggang from January 25 to February 23, 2020, which reported the number of confirmed cases in the city capital and counties daily. The municipal government of Huanggang received the first batch of 2019-nCoV Detection Kits for Nucleic Acids on January 23 (14). Liu Xuerong, Secretary of Huanggang Party Committee, reported that 13,000 febrile patients were found, 16,533 close contacts were tracked, and 2,332 cases were confirmed in Huanggang through 24:00 on February 10; 279 recovered, and 52 died. The municipal government authorized 10 institutions to do nucleic acid tests, with a daily testing capacity of more than 900 samples and a total of 13,755 samples had been tested by February 11 (15).

4) Official Websites of the other prefecture-level cities in Hubei (13,16-26). We identified the counties with confirmed cases, and the number of confirmed cases per county as well as the towns with confirmed cases in Yichang, a prefecture-level city (22).

5) Official Website of The Epidemic Prevention Headquarters for Novel Coronavirus Pneumonia of Qichun County (27). We collected the available rapid epidemic updates of Qichun County from February 1 to February 18, 2020, which reported the number of confirmed cases per town and where each case resided in Qichun, and the movement trajectories per case. No rapid epidemic update was available for the period from February 19 to March 1, 2020 as no new confirmed cases were reported in Qichun County during this

period. Qichun People's Hospital reported the capability of nucleic acid testing on January 29, and the first case in Liuhe Town, Qichun County was detected by blood testing and CT (14).

Data Analysis

To describe the fluctuation trend in the number of new confirmed cases and transmission features of COVID-19 from Wuhan to the rural areas in Hubei, several methods were used to analyze the data. Frequency and percentage analysis were performed using SPSS 19.0 (IBM Corp., Armonk, NY, USA). Excel 2003 (Microsoft, Redmond, WA, USA) was used to create the figures (Figures 3, 4, and Figure 5), and the drawing tools of Office 2003 (Microsoft, Redmond, WA, USA) were used to create Figures 1 and 6. ArcGIS 10.2 (Esri, Redlands, CA, USA) was used to develop the distribution map of confirmed cases reported in the county-level regions of Hubei.

The address of a family at a Chinese rural village which should be No. 467 (family), Xihuli (village), Guanyao (town), Qichun (county), Huanggang (prefecture-level city), Hubei (province) .

As of 18:00 on January 20, there were 224 infected patients in China, 217 of them were confirmed (198 in Wuhan, 5 in Beijing, 14 in Guangdong), and 7 were suspected (28). Due to the novel nature of the virus, the data likely did not include every infected patient; nonetheless, it indicated that the COVID-19 epidemic had not yet fully spread through China. On January 20, a teleconference held by the Joint Prevention and Control Mechanism of the State Council, President Xi Jinping, and Premier Li Keqiang delivered important instructions and a comprehensive plan for the prevention and control of COVID-19 (28).

Furthermore, Deputy Premier Sun Chunlan and the Central Guidance Team arrived in Wuhan on January 27, and remained in Hubei until the end of the epidemic. The team's focus was joint prevention and control mechanism in Hubei (29). Because patients infected with SARS-CoV-2 do not die immediately, and authorities had sufficient testing capability by February 5 (12), it's available to track the spread features of COVID-19 from Wuhan to the rural areas in Hubei with the data analysis.

Results

COVID-19 spread to rural regions in Hubei from its epicenter, Wuhan

The earliest date of illness onset was identified as December 1, 2019 (30). The outbreak occurred during the busiest travel season in China, as Chinese citizens were returning to their hometowns to celebrate the Lunar New Year holiday. This increased travel led to spread of the disease (31) from Wuhan to the other cities (32). At least one case was identified in all cities in Hubei, according to the data up to January 27, 2020, reported by the People's Government of Hubei Province (11).

Wuhan is considered the epicenter of the COVID-19 epidemic which spread to rural areas in Hubei Province. As Wuhan was sealed off on January 23, 2020, cases identified in the other cities may be related to travelers from Wuhan. According to the movement data obtained from Baidu Map Insight between January 10 and January 24, 2020, and data on confirmed cases in other cities in Hubei between January 22 and February 21, 2020, the distribution of travelers from Wuhan resembled that of the confirmed cases in Hubei Province (Figure 2).

This study presumed that the people who left before the closure of Wuhan on January 23 contained an unknown number of infected cases. Since there was no official or authorized notice concerning travel, they left randomly as normal. The COVID-19 epidemic among the travelers was likely similar to the people who remained in Wuhan. When residents of Wuhan and those who had left Wuhan became ill, they likely showed similar characteristics in symptoms and transmission. Because infected patients who had returned to their hometowns from Wuhan were the primary cases in the local areas, the trend in the number of daily confirmed cases in Wuhan and the prefecture-level cities in Hubei should be similar. On the basis of random mobility of these individuals, we found that the incidence rate of COVID-19 among these individuals was similar to that among those remaining in Wuhan. Between January 27 and February 14, the fluctuation in the number of new confirmed cases in Wuhan was similar to that in other cities (Figure 3), and there was a similar fluctuation in the number of newly confirmed cases in the prefecture-level cities (Figure 4). The analysis of the development trend was used to confirm that the travelers from Wuhan spread COVID-19 to the other cities in Hubei

Many individuals with confirmed SARS-CoV-2 reported that they had returned from Wuhan or contacted a person from Wuhan. In this study, we analyzed cases reported from Qichun County as an example. Of all individuals with confirmed SARS-CoV-2, 204 (84.3%) reported activities possibly related to their source of infection. In particular, 75 (31.0%) individuals with confirmed SARS-CoV-2 had been to Wuhan, 14 (5.8%) reported contact with a person returning from Wuhan, and only six cases occurred in individuals who had returned from Huanggang, Huangshi, or E'zhou.

Urbanization limited the spread of COVID-19 to rural villages

According to the data reported by each city government on March 1, 2020, the COVID-19 epidemic spread to all 101 counties in Hubei. On average, each county had 168.0 confirmed cases (median: 99). E'cheng District reported the highest number of confirmed cases, whereas the ShiYan Economic Development Zone reported the lowest number (1,021 cases and 2 cases, respectively). The epidemic was more extensive in the county-level regions closer to Wuhan, whereas the remote county-level regions in west Hubei were less affected. The extent of the epidemic increased in an east-to-west direction (Figure 5).

COVID-19 had not spread to all towns in Hubei by the cut-off date for data collection (March 1, 2020). For example, in Yichang, 79 out of 107 towns (73.8%) reported at least one confirmed case (22). The disease was reported in all towns in Qichun County, which is one of the most affected counties in the Huanggang Prefecture since February 11, 2020; Liuhe Town was the most affected, with 56 confirmed cases in 23 villages (44.2% of 52 villages). In contrast, there was only one village with only one case in the 17 villages of the town of Guanyao (5.9% of 17 villages). Seven towns reported no more than three cases, and only two towns had confirmed cases in >20% of the villages in Qichun County (Figure 6).

The trend of SARS-CoV-2 transmission, the number of confirmed cases in different regions and villages, and the distribution of confirmed cases in rural areas showed that SARS-CoV-2 has not been widely transmitted to rural areas. The disease has mainly been manifested as follows:

- 1) The confirmed cases in rural areas were mainly concentrated in county capitals and towns with greater urbanization. Remote rural villages were less affected.

2) COVID-19 spread to the Chinese countryside at a slow speed (Figure 7), and the intensity of the epidemic was low. Apart from the county capital city, only four towns in Qichun County, i.e., Liuhe, Qizhou, Zhangbang, and Hengche, had more than 10 cases. However, only Liuhe showed a wide variation in the number of cases between January 17 and January 30. The COVID-19 epidemic was more extensive in Qizhou, Zhangbang, and Hengche towns. A few cases were confirmed in some villages in these towns, and most affected villages had 1 or 2 cases.

3) Only a limited number of infections occurred among local residents in the villages. For example, Qichun County had 242 individuals with confirmed infection, 73 (30.2%) of whom did not know the source of their infection. In addition, 31 (42.5%) cases lived in the county capital and 25 (34.3%) lived in Liuhe, a more urbanized town. The source of the SARS-CoV-2 infection was obvious in approximately 70% of the confirmed cases. Nevertheless, they were isolated and required to follow strict epidemic prevention measures. The transmission of SARS-CoV-2 by these individuals is unlikely. Approximately one third of infected individuals were infected from an unknown source. However, their further transmission was also limited by the strict epidemic prevention measures. Only approximately 24% of the cases were identified in the town-level regions, except Caohe and Liuhe. These cases mostly included individuals who did not infect anyone else or come from a family with others who were infected. Most of them lived in the county capital cities and towns with higher levels of urbanization such as Liuhe, Qizhou, Hengche, and Zhangbang. Owing to less urbanization and the application of prevention measures, only 76 (15.38%) out of 494 villages in Qichun County reported cases.

COVID-19 did not spread linearly to rural villages in Hubei

The above analysis indicates that COVID-19 spread from Wuhan to the prefecture-level cities in Hubei. We thus conducted an analysis to check whether the transmission of COVID-19 to the rural villages occurred in a linear process. Analyzing the travel routes of confirmed cases from Wuhan to Qichun County, we found that COVID-19 did not spread to the rural villages in a linear manner (Figure 7). Most cases directly returned to the town-level regions and the rural villages from Wuhan, while only two patients might have been infected in the prefecture-level city of Huanggang.

Incubation period of SARS-CoV-2 is about 20 days

According to the published reports, the average incubation period of SARS-CoV-2 is 3-7.2 days (4,6,33,34,35). Several authors and the media have reported that the incubation period can last to a maximum of 24 days (6). According to researchers, some individuals with confirmed infection were asymptomatic (36). However, those who were asymptomatic may have been in the incubation period and developed symptoms later. Variability in individual characteristics results in variable susceptibilities to SARS-CoV-2. This would explain why certain individuals with confirmed infection showed no symptoms. They might have better resistance to the infection, or they may have still been in the incubation period.

We assessed the median incubation period among individuals with SARS-CoV-2 infection in Hubei Province. Since Wuhan and the other cities were locked down on January 23, most individuals are likely to have acquired the infection no later than January 23. The home isolation order after this date might have contributed to preventing further transmission of the disease. Therefore, the fluctuation in the number of confirmed cases

from January 27 to February 14 in Hubei (Figure 3) shows that February 14 may be the last date when confirmed cases leaving Wuhan on January 23 initiated the onset of COVID-19. This implies that the incubation period of SARS-CoV-2 is about 20 days, and all patients infected with SARS-CoV-2 on the day of the shutdown would have developed COVID-19 within about 20 days. This means that the patients infected on January 23 would become ill one after another, and the last one is about 20 days later.

Discussion

After Wuhan was sealed off on January 23, 2020, no travelers could enter the other cities in Hubei from Wuhan, so the COVID-19 epidemic in these prefecture-level cities started to develop with the infected people who had returned from Wuhan. As they moved out of Wuhan and spread to those cities randomly, they had a similar impact on the spread of COVID-19. The fluctuation in the number of new confirmed cases was relatively consistent, and the difference in the intensity might have been because of the variation in the number of imported cases from Wuhan.

The spread of COVID-19 from Wuhan to the rural regions in Hubei Province affected all counties and most towns. However, the confirmed cases were detected in only a small proportion of rural villages indicating that the epidemic had a limited impact on rural regions. Most of the remote villages did not have any cases of COVID-19 reported during the study period, and most confirmed cases lived in the county capital (45.04%) and the towns with higher levels of urbanization (39.67%). Urbanization leads more Chinese farmers to leave their hometowns in rural villages for cities, county capitals, and town centers. Since many confirmed cases did not return to the rural villages, this reduced their transmission of SARS-CoV-2. Furthermore, the centralized living mode in the more urbanized areas has

For COVID-19, rural areas are safer than the cities in Hubei. Staying in the city has a higher infection rate than living in a rural village. However, that does not mean that traveling to or staying in rural villages is an effective preventive measure for the epidemic, just because there are little infected patients. Therefore, local authorities should limit travel, to avoid worsening the epidemic in rural regions.

Acc

Conclusion

These results provided more proof confirming that Wuhan is the epicenter of COVID-19 to the other cities and rural areas in Hubei. However, the COVID-19 did not spread deeply into the rural regions, although there were confirmed cases detected in all of the counties and most of the towns in Hubei. Only a small proportion of rural villages had confirmed cases. This may have been due to authorities in urban areas limiting the infected patients from returning back to their rural villages, since most cases lived in the cities, county capitals, and town centers. We recommend restricting movement, especially to the rural areas to avoid worsening the epidemic in those regions. Currently, authorities should pay more attention to the prevention and control of COVID-19 in cities; for the future, the government should limit the citizens' travel to the rural regions and keep the rural areas safer. Finally, local governments should prolong the isolated observation period to 20 days as far as possible to discover all infected patients with long term incubation.

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Biographical Sketch

You Maolin, Ph.D., is an Associate Professor at the China University of Geosciences in Wuhan. His primary research interest is public health management.

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Figure legends

Figure 1. Immigration data of the destinations for moving out of Wuhan collected from Baidu Map Insight

Figure 2. The association between the number of travelers and the number of confirmed cases in Hubei Province

Migration rate: to calculate the extent of migration in each prefecture city in Hubei Province, the number of people migrating to each city is divided by the total number of people leaving Wuhan between January 10 and January 24 and then multiplied by 100 percent.

Rate of confirmed cases: the rate of confirmed rates in each prefecture city is calculated by dividing the number of confirmed cases in each prefecture by the total number of confirmed cases in Hubei between January 22 and February 21 and then multiplying by 100 percent.

Shennongjia is not included because it was not listed in the top 100 destinations for moving out of Wuhan during January 10 to January 24, and there wasn't data about the rate of immigrants to Shennongjia.

Figure 3. The fluctuation in the number of confirmed cases in different cities in Hubei between January 22 and February 21

On February 12, 2020, 13,436 cases were identified, compared to 3,910 cases on February 13, 2020. These two numbers were unavailable to be displayed in the figure; hence, they were replaced to make the figure clearer.

The box was used to show the similar development trend of COVID-19 in Wuhan and the other cities in Hubei.

Figure 4. Trends of confirmed cases in the other cities in Hubei between January 22 and February 21

The boxes were used to show the similar development trend of COVID-19 in these cities.

Figure 5. Distribution of confirmed cases in the county-level regions of Hubei as of March 1, 2020

Figure 6. Spread feature of COVID-19 in the rural villages of Qichun county as of March 1, 2020

Figure 7. Travel routes of COVID-19 in Qichun county

The colored cells indicate new areas where confirmed cases were reported, while the numbers in brackets refer to the numbers of new confirmed cases.

Figure 1



Figure 2

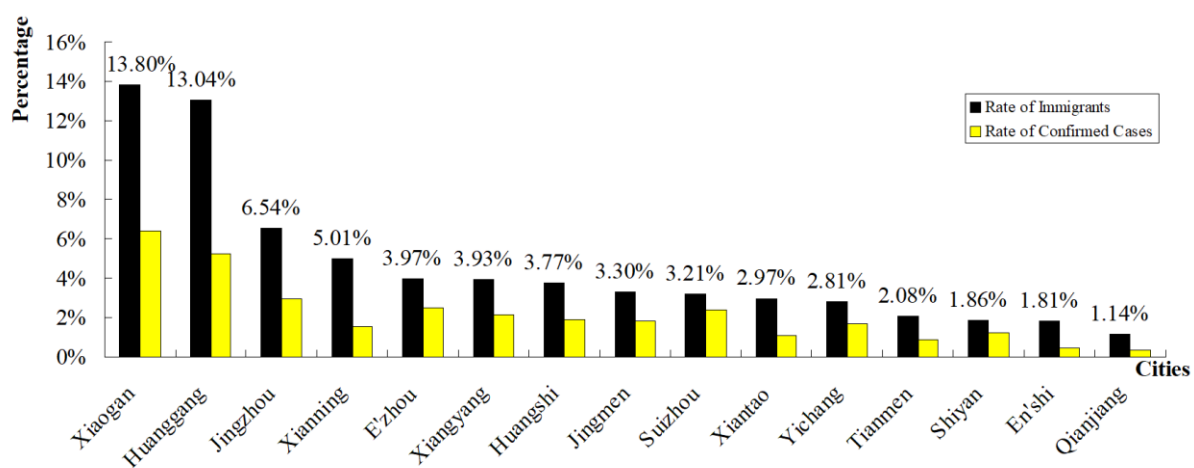


Figure 4

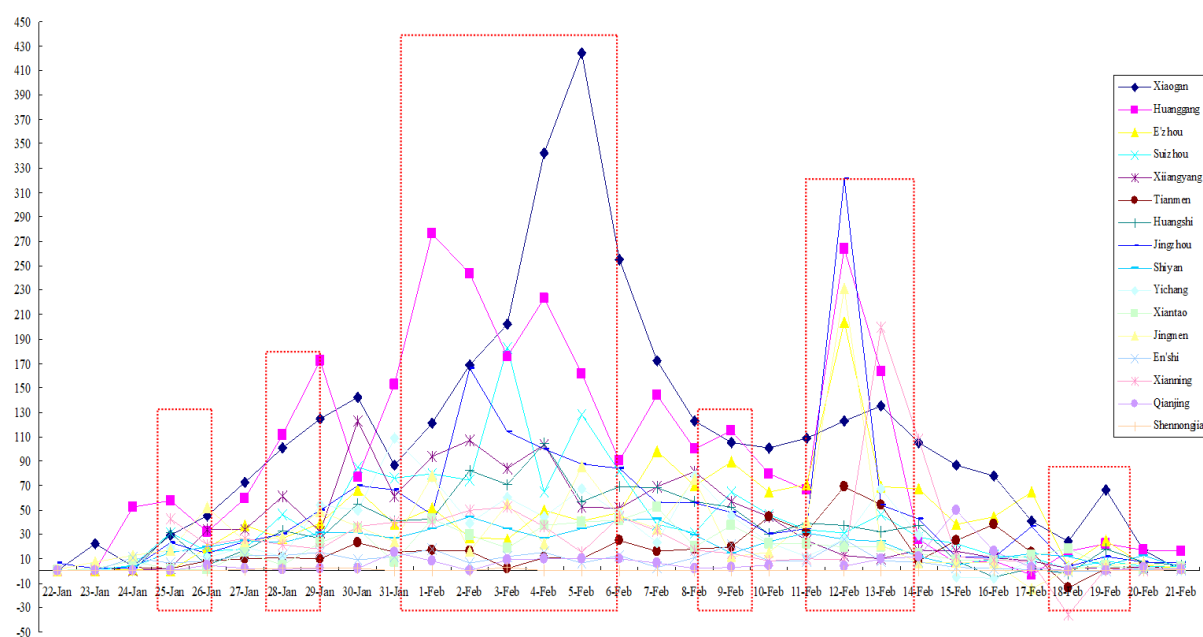


Figure 5

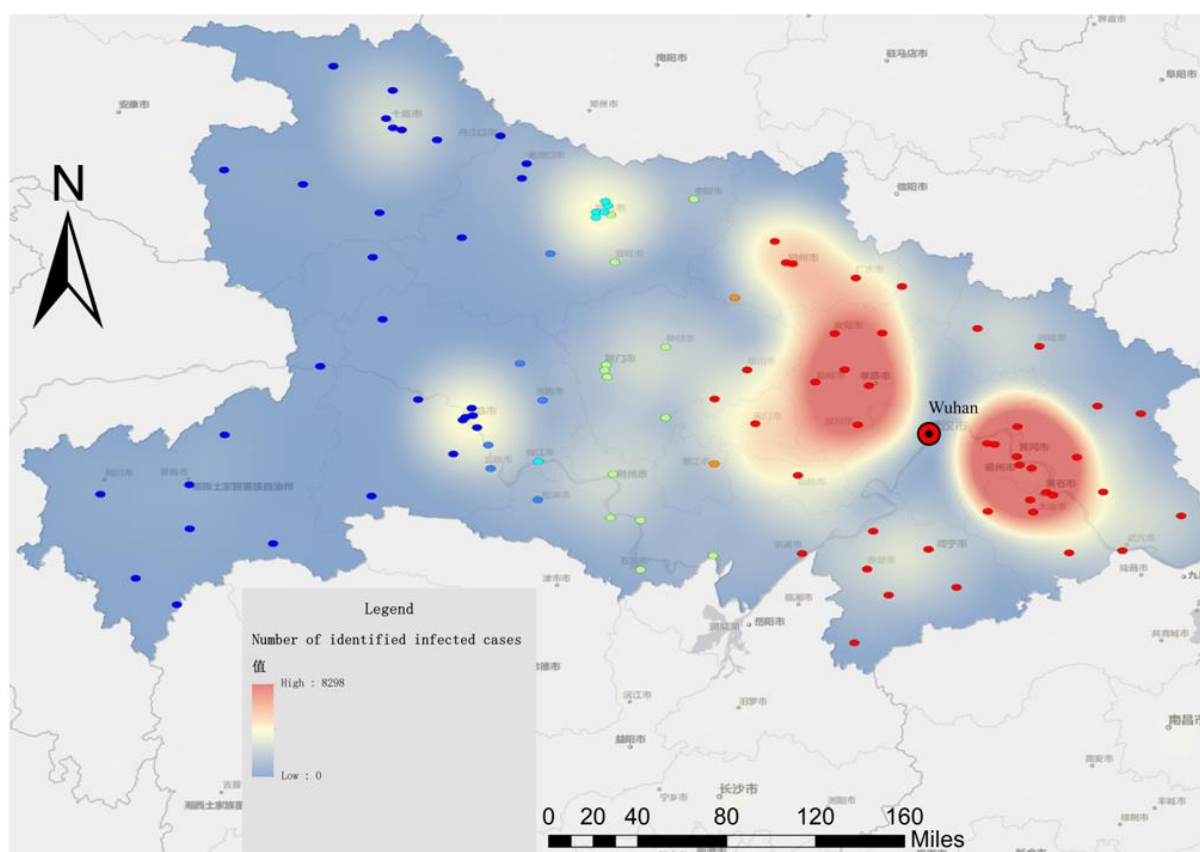


Figure 6

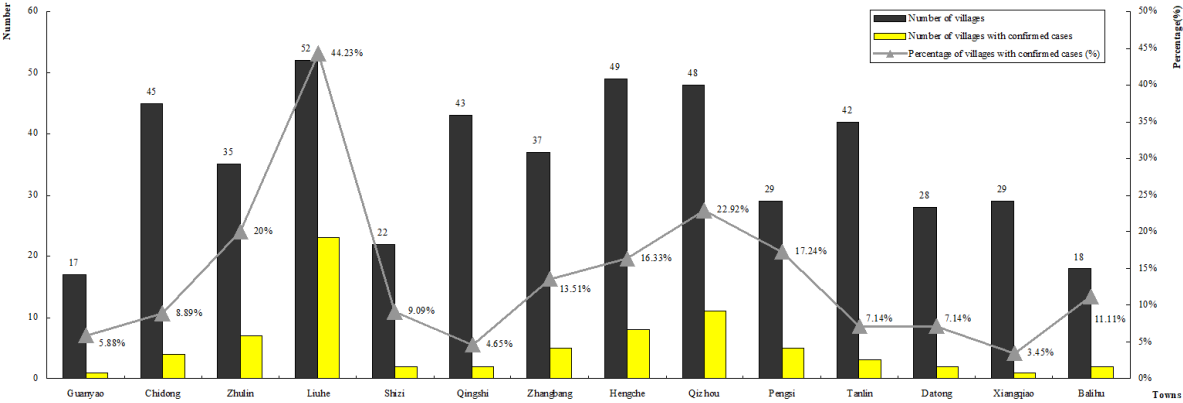


Figure 7

