Jia Songqi
Shijiazhuang Foreign Language School
Shijiazhuang, Hebei
China, Factor5：Climate Volatility

Exploration about Farmland Ammonia Emission Reduction Measures Based on Farming Methods

-- take Hebei, China as an example

As we all know, with the development of economy, the haze in China, especially in north China, has been a serious problem in recent years. Study has showed that nitrogen-containing compounds in the air can aggravate haze, and ammonia released by nitrogenous fertilizer can contribute more than 20% to haze problem.

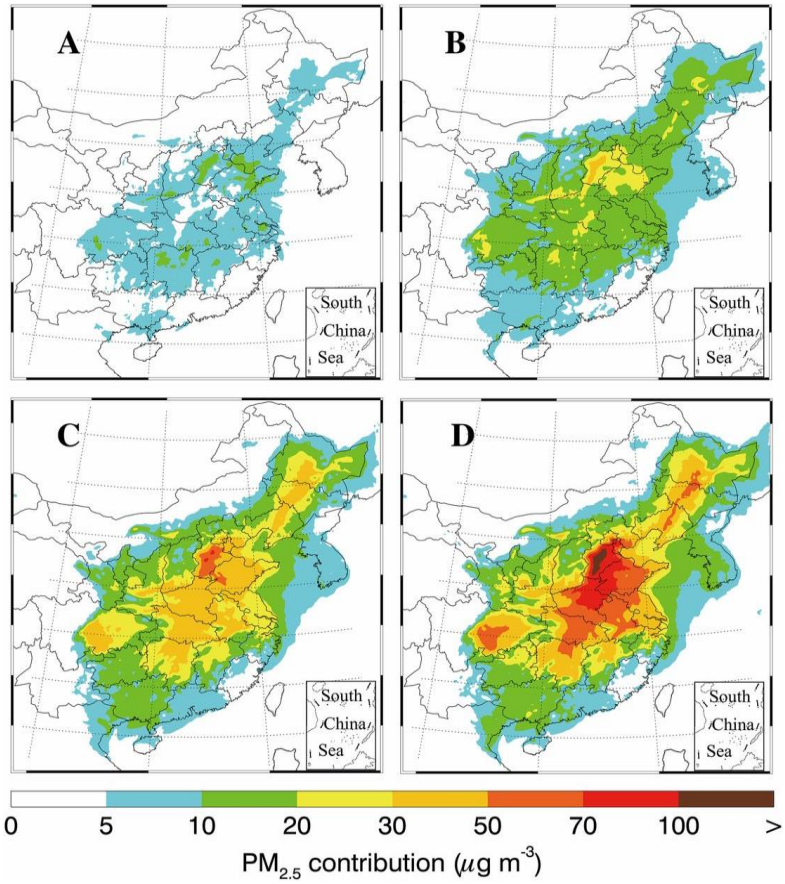

Figure 1Contribution of agricultural NH_3 associated reactions to PM2.5 mass, simulated by the WRF-Chem model in four different scenarios (A–D, representing 25, 50, 75, and 100% of the current NH_3 level, respectively) [1]

Agricultural ammonia emission is the main source of atmospheric ammonia, and nitrogen fertilizer application is one of the most important agricultural ammonia emission sources [2]. In recent years, haze control in north China has focused on coal burning, automobile exhaust and dust, but paid less attention to the harm caused by ammonia volatilization in farmland. Therefore, the study of farmland ammonia emission control measures is of great practical significance to improve the utilization rate of nitrogen fertilizer and alleviate the haze problem in north China.

I. Overview of ammonia volatilization and its influencing factors

Ammonia volatilization refers to the process in which ammonia escapes to the atmosphere from soil surface (dry land), surface water (paddy fields) or plant surface. There are many factors affecting ammonia volatilization in farmland, mainly including meteorology, soil, crops and fertilization factors. Meteorological factors include temperature, precipitation, wind speed and light intensity, among which temperature, wind speed and light intensity are positively correlated with ammonia volatilization, while the influence of precipitation on ammonia volatilization depends on the time of fertilization. Applying fertilizer before precipitation can reduce ammonia volatilization, while applying after precipitation can increase ammonia volatilization. Soil factors are the physical and chemical properties of soil, among which pH, organic matter and water content are positively correlated with ammonia volatilization. Crop factors include crop types and crops' growth patterns, and ammonia volatilization in paddy fields is higher than that in dry land. Fertilization factors include: fertilizer type, fertilizing amount, fertilizing period, fertilizing and irrigating method (table 1).

Table 1 fertilization factors of ammonia volatilization in farmland

fertilizing types	Common industrial fertilizer，among which urea and ammonium bicarbonate are the most important ones
	Slow-controlled-released fertilizer
	Organic fertilizer made by crops，among which returning straw is the most widely used.
	Animal manures，and manure itself is a major source of agricultural ammonia emissions.
fertilizing amount	It is positively correlated with ammonia volatilization
fertilizing period	Affected by plant species, growing season, growing period, meteorological factors
fertilizing and irrigating method	Ammonia volatilization decreased with the increase of fertilization depth, and the reasonable combination of fertilization with tillage method and irrigation could effectively reduce ammonia volatilization.

Among many factors, meteorological soil and crop factors are greatly affected by the geographical location and climate of farmland [3], which are objective factors. The fertilization factor directly reflects the specific operation of farming and is a controllable factor. Therefore, in order to understand the causes of high ammonia emissions in north China and put forward feasible improvement methods, fertilization factors were selected in this survey to investigate the farming methods of farmers in Hebei area of China.

II. Survey design and data collection of farming methods of farmers in Hebei, China

Hebei province is located in the north China plain, between 113°27 '-119°50' east longitude and 36°05 '-42°40' north latitude. It faces the Bohai Sea in the east, the Taihang Mountains in the west and the Yanshan Mountains in the north. Located in the east coast of China, the area is a temperate continental monsoon climate, and has four distinct seasons. The annual average temperature ranges from -0.5℃ to 14.2℃, and the annual extreme maximum temperature mostly occurs in June and July.

This survey includes the basic conditions of rural families, farmers' farming methods, farmers'

scientific quality and environmental protection awareness. It mainly covers farmers' fertilization modes, the weather selection, irrigation methods and environmental protection awareness of the farmers in Hebei area. The questionnaire structure is shown in figure 2, and the sample volume is shown in appendix 1.

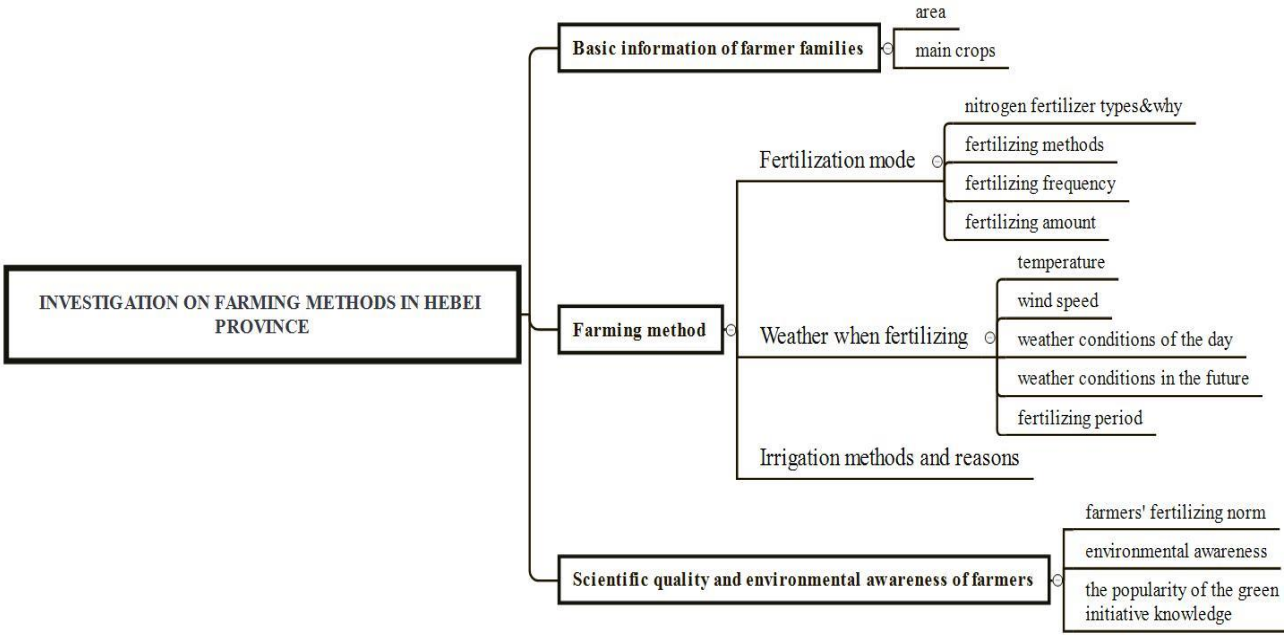

Figure 2 the questionnaire structure

This survey was carried out in the form of an online questionnaire. The farmers in Hebei province were taken as the survey objects and distributed online through Wenjuanxing platform. A total of 277 questionnaires were distributed over 12 days in May 2019. Based on the estimation of the average filling time of the questionnaire, after the unified collection of questionnaires, the questionnaires with filling time of less than 51 seconds were considered invalid and removed, and a total of 233 valid questionnaires were obtained.

III. Analysis of survey results

A. Single factor analysis

1. Fertilization modes

The investigation of fertilization pattern includes three aspects: types, manners and quantity of nitrogen fertilizer.

a. Types of nitrogen fertilizer

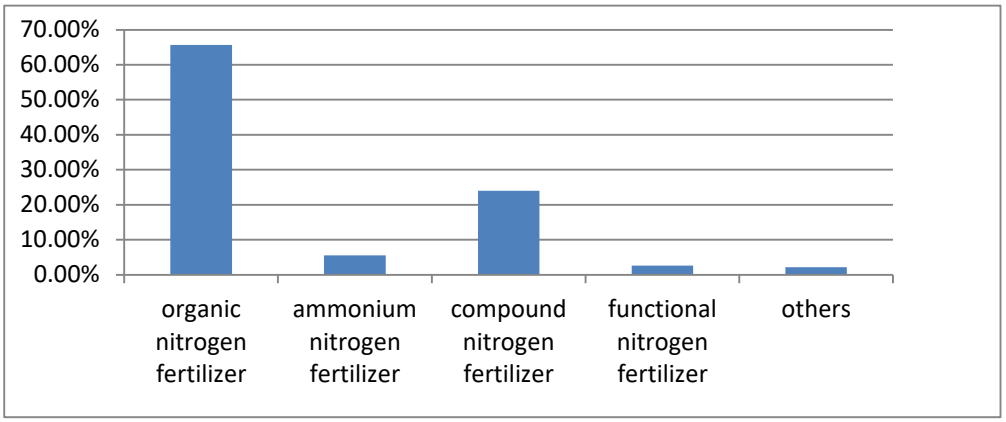

Figure 3 Selected nitrogen fertilizer types

As can be seen from figure 3, organic nitrogen fertilizer such as urea is often used by farmers, and the utilization rate of compound nitrogen fertilizer is also relatively high. At present, urea is one of the most widely used important nitrogen fertilizer varieties in the piedmont plain of north China because of its low cost, high nitrogen content and easy application. Urea, however, is easily hydrolyzed to form ammonia gas and released into the atmosphere[4]. According to the study, urea ammonia volatilization rate is low, but higher than that of other nitrogen fertilizer. And According to different crops, different soil, scientific preparation of compound fertilizer with different nutrient content can basically solve the utilization rate problem in the application of chemical fertilizers to farmers [5]. In summary, that farmers prefer organic nitrogenous fertilizer and compound fertilizer makes for improving fertilizer using efficiency.

b. Fertilization mode

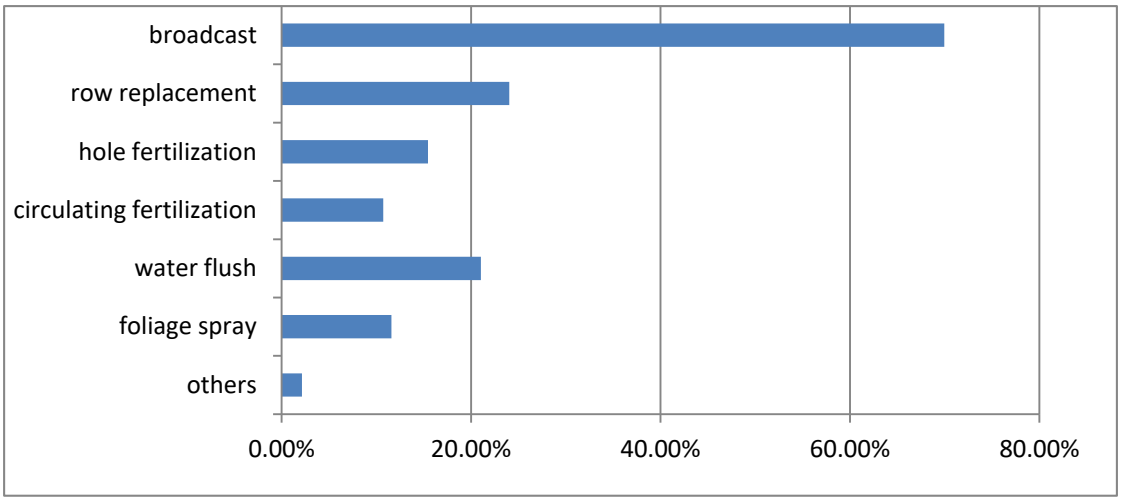

Figure 4 Status of fertilization methods

As can be seen from figure 4, farmers often use the method of spreading fertilizer, namely, directly throwing it onto the field. However, studies show that ammonia volatilization decreases by 80.3% and 92.7% when applying fertilizer at depth of 5 and 10cm compared with that when broadcasting fertilizer [6]. The evaluation system model of ammonia emission reduction measures in the UK shows that NH_3 emission caused by spreading nitrogen fertilizer on the field is the largest, and the deeper the fertilization, the less ammonia volatilization[3]. Obviously, more use of fertilizer by farmers will increase ammonia volatilization.

c. Fertilizing amount

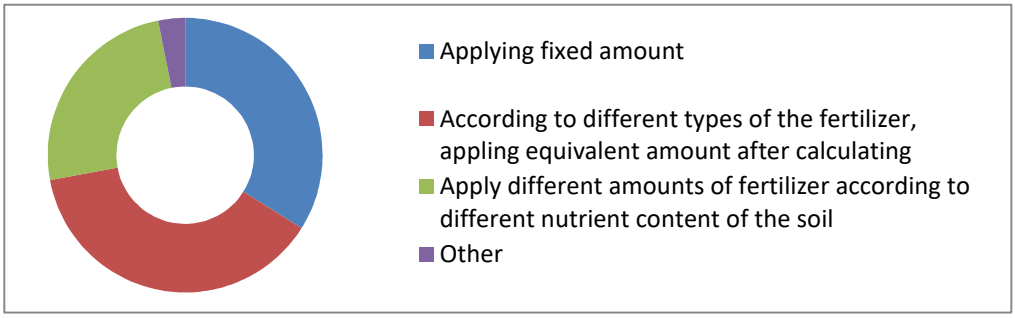

Figure 5 Fertilizing amount

It can be seen from figure 5 that the *fixed amount* and *equivalent amount* are the standards for

farmers to control the amount of fertilizer applied. In fact, the amount and proportion of mineral elements required by different crops are different, and the mineral absorption of crops in different growth stages is different, so fertilization should be based on the characteristics of fertilizer demand of crops, and be considered by integrating crop characteristics, production purpose, growth period, soil fertility, etc. [7], so as to realize sustainable usage of land and environmental protection.

2. Weather conditions during fertilizing

The main study was conducted to investigate the influence of farmers' usual weather conditions (temperature, wind speed, and future weather conditions) on fertilization.

a. Temperature & Wind speed

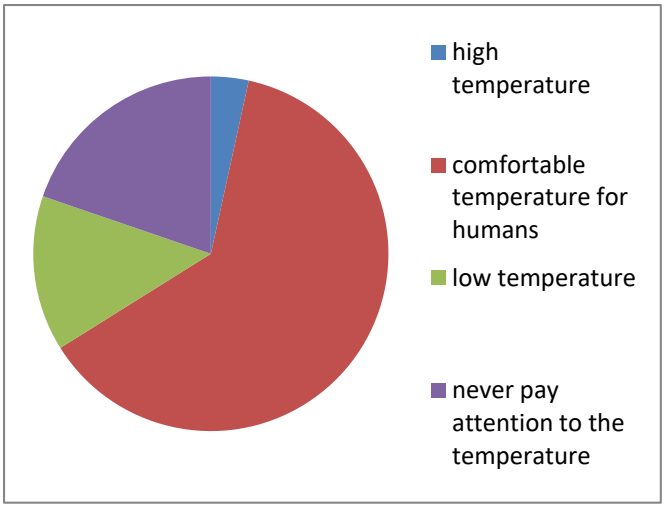

Figure 6 Temperature

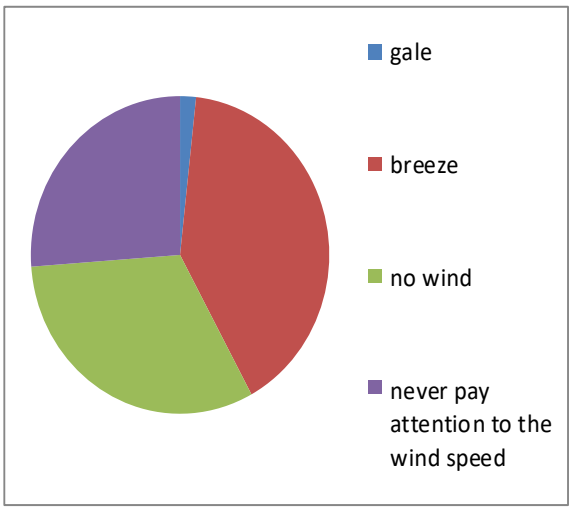

Figure 7 Wind speed

It can be seen from figure 6 and 7 that farmers are accustomed to fertilizing when the temperature is comfortable for farmers and in calm or breezy conditions. Studies have shown that, when other conditions remain unchanged and the temperature ranges from 5℃ to 35℃, the proportion of ammonia gas increases about twice for every 10℃ increase [3]. Among all kinds of nitrogen fertilizers, ammonium bicarbonate and urea are most affected by temperature. Therefore, applying fertilizer at a lower temperature can reduce ammonia volatilization. Farmers in Hebei are accustomed to applying fertilizer at the right temperature, which will increase ammonia volatilization to larger extent. Within a certain range, the wind speed and ammonia volatilization rate are basically positively correlated to ammonia volatilization amount, so it is recommended to fertilize under the condition of no wind or breeze, which is consistent with the fertilization habit of most farmers in Hebei.

b. Future weather conditions

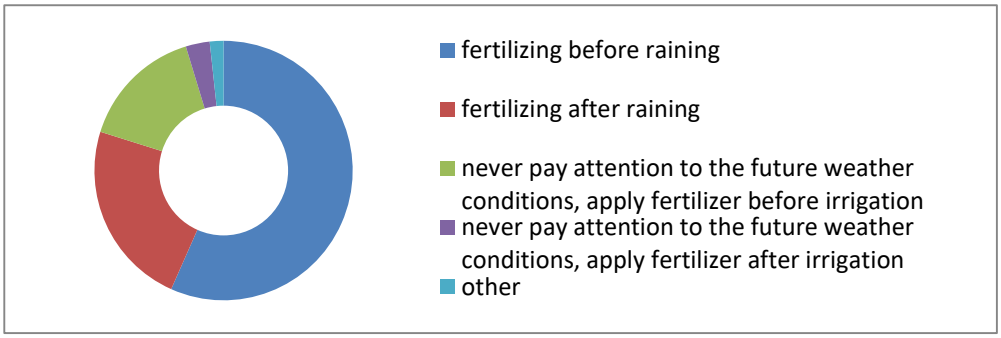

Figure 8 Future weather conditions

It can be seen from figure 8 that farmers tend to apply fertilizer before rain, but it is worth noting that precipitation and irrigation do not reduce ammonia volatilization under any circumstances. The results showed that irrigation significantly promoted the volatilization of ammonia before spreading [8], and according to the previous research on the fertilization method of farmers, spreading is one of the fertilization methods commonly used by farmers in north China. In addition, the order of irrigation (precipitation) and fertilization is also very important. 23.18% of the farmers surveyed apply fertilizers after rain, which also promotes ammonia volatilization.

It can be seen that farmers' mistakes and blind areas in the order of irrigation and fertilization are one of the reasons for the serious ammonia volatilization in north China.

3. Irrigation method

Table 2 Irrigation method

Irrigation methods	Number	Percentage
Flood the cash	146	62.66%
Sprinkling irrigation	47	20.17%
Micro-irrigation	33	14.16%
Other	7	3%

As can be seen from table 2, farmers usually use flood irrigation, which is a relatively backward and wasteful form of irrigation. There are several reasons why the ideal irrigation method cannot be realized.

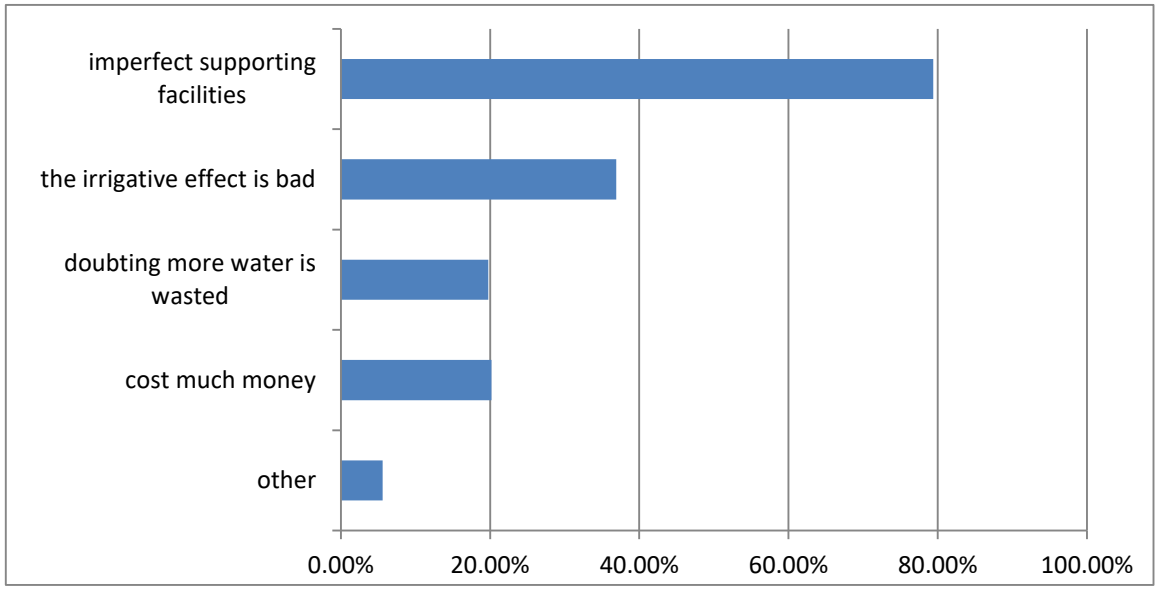

Figure 9 Reasons why ideal irrigation methods cannot be achieved

As can be seen from figure 9, imperfect supporting facilities is an important reason affecting the progress of irrigation methods. It can be assumed that sprinkling irrigation and micro-irrigation have not been well promoted in the vast rural areas due to their higher requirements for equipment. Other reasons include poor irrigation and worries about rising costs.

B. Correlation analysis of scientific lectures and farmers' scientific literacy

Mainly for the frequency of scientific lectures on fertilization method, fertilizer amount, irrigation

method, selection of fertilizer type and environmental protection awareness of the correlation analysis.

1. Correlation analysis between the frequency of scientific lectures and fertilization methods

As can be seen from figure 10, farmers are more likely to spread crops than those in rural areas where science lectures are not given. Advanced fertilization methods such as foliar spraying and flushing were more likely to be used in areas where science lectures are given than in areas where no lectures were given. This suggests that giving scientific lectures could help to reduce not environmental-friendly farming practices.

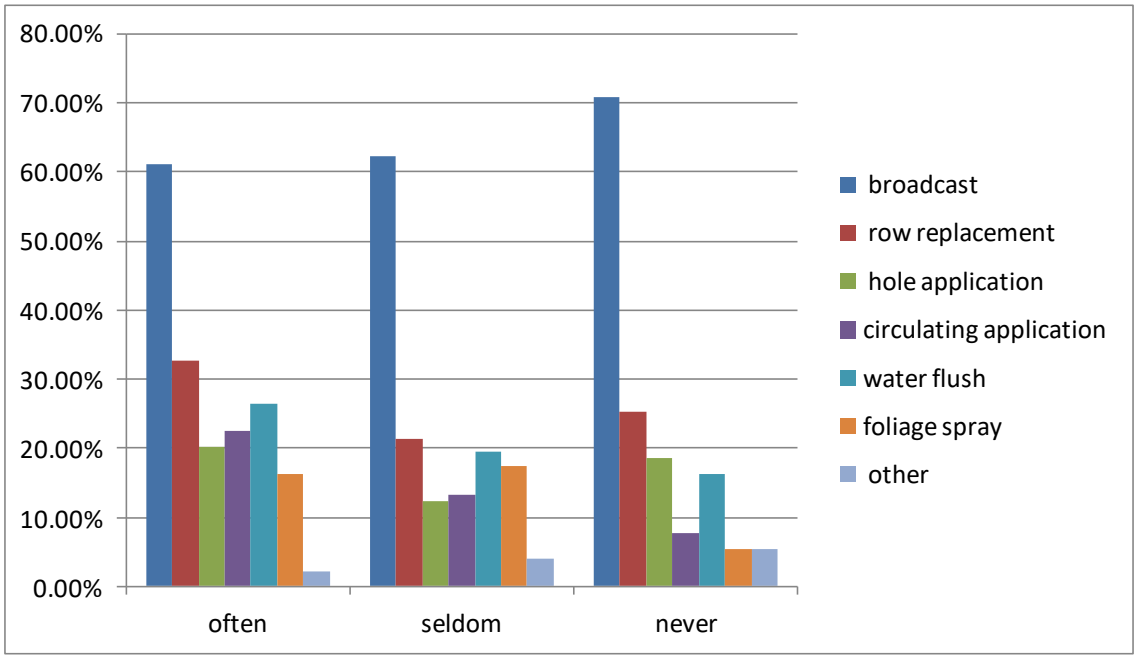

Figure 10 Correlation analysis of scientific lecture frequency and fertilization methods

2. Correlation analysis between the frequency of scientific lectures and the amount of fertilizer applied

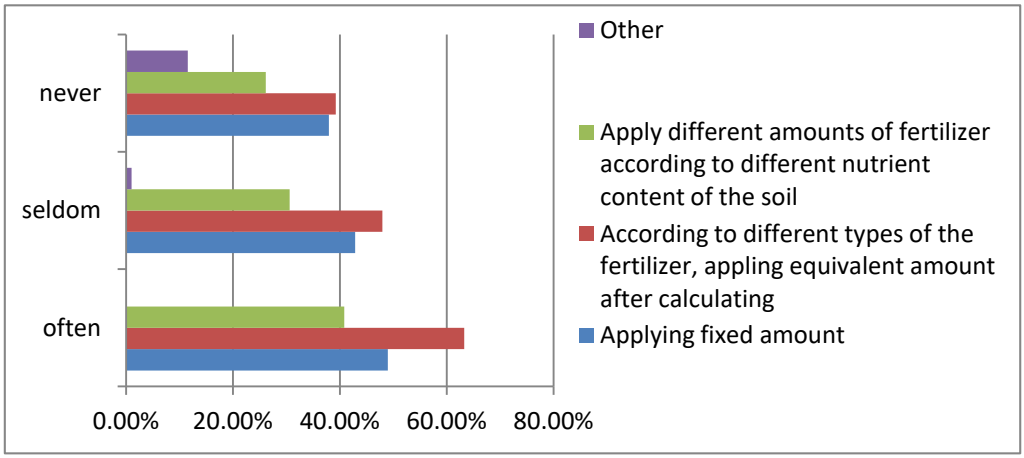

Figure 11 Correlation analysis between the frequency of scientific lectures and the amount of fertilizer applied

As can be seen from figure 11, scientific lectures can play a role in popularizing the idea of rational green fertilization. Therefore, the more scientific lectures there are, the more widespread the scientific practice of applying the same amount of fertilizer and fertilizing according to the soil

conditions, the less waste of resources and environmental pollution.

3. Correlation analysis between the frequency of scientific lectures and irrigation methods

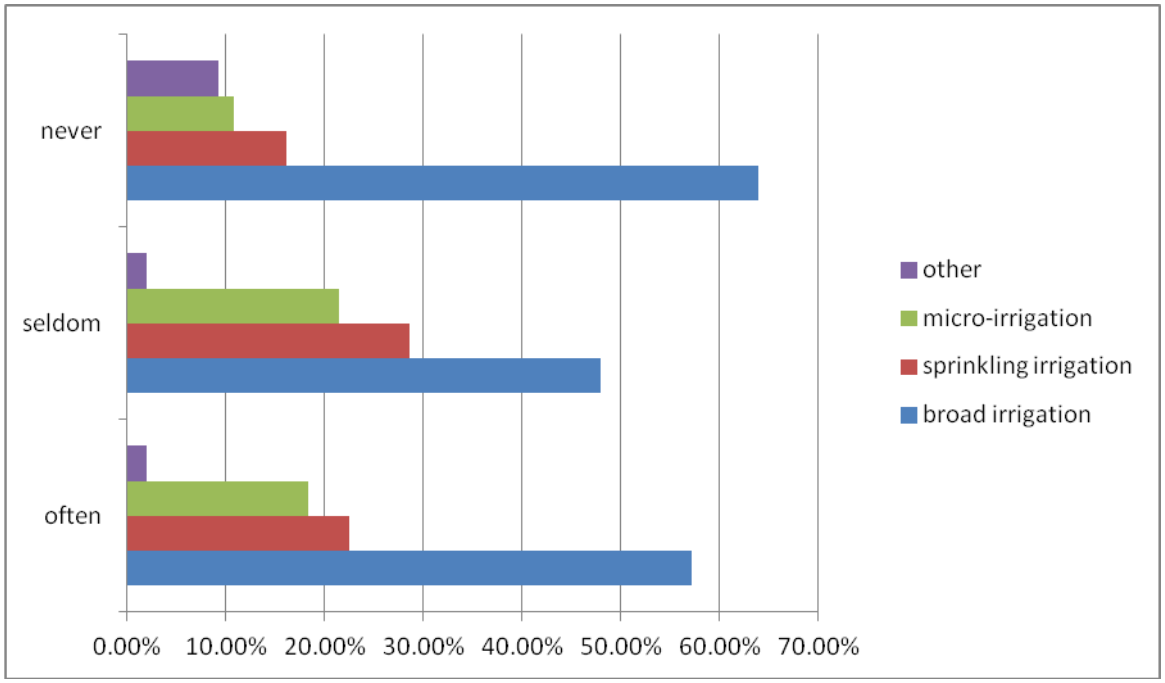

Figure 12 Correlation analysis between the frequency of scientific lectures and irrigation methods

As can be seen from Figure 12, no matter how scientific lectures are conducted, flood irrigation still plays a dominant role in rural areas. Similarly, in areas where scientific lectures are given, spray irrigation and micro-irrigation, two more advanced and green irrigation methods, are more frequently used than those in areas where no scientific lectures are given, while flood irrigation is less frequently used.

4. Correlation analysis between the frequency of scientific lectures and fertilizer selection

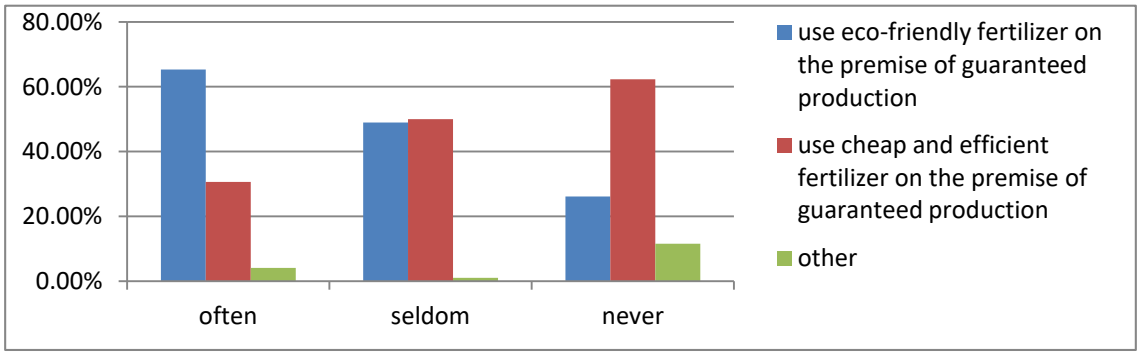

Figure 13 Correlation analysis between the frequency of scientific lectures and fertilizer selection

As can be clearly seen from figure 13, with the increase of the frequency of scientific lectures, the proportion of farmers who choose the fertilizer with priority in environmental protection gradually increases, while the proportion of farmers who choose the fertilizer with priority in efficiency decreases, and farmers have increasingly strong awareness of environmental protection and sustainable development.

5. Correlation analysis between the frequency of scientific lectures and farmers' environmental protection awareness

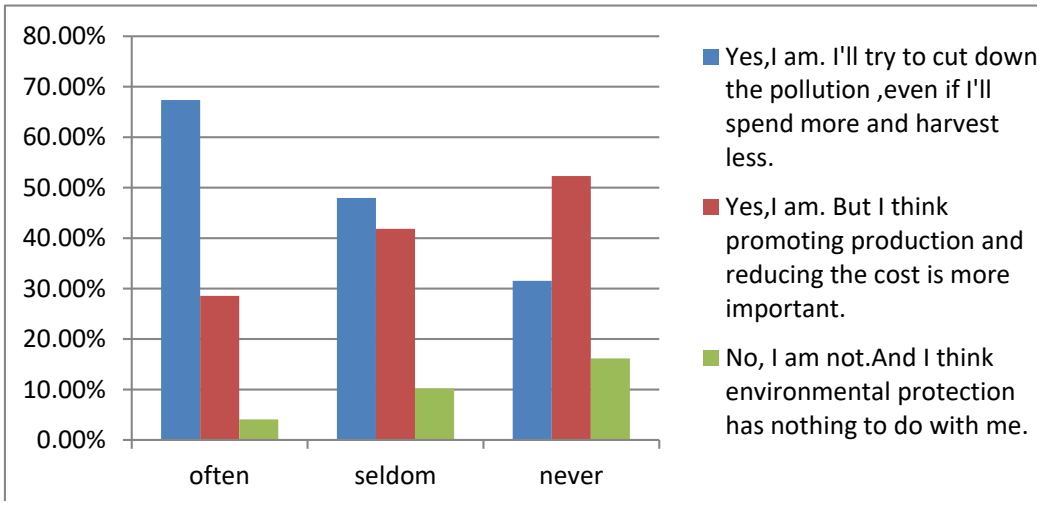

Figure 14 Correlation analysis between the frequency of scientific lectures and farmers' environmental protection awareness

As can be seen from figure 14, with the increase of the frequency of scientific lectures, the number of people who choose to cut down the pollution as much as possible will increase. Meanwhile the number of people who have environmental protection awareness, but give priority to production and who have no environmental protection awareness and think that environmental protection has nothing to do with them will decrease obviously. More and more people choose environmental protection between environmental protection and pollution.

In summary, it can be seen that carrying out scientific lectures and other popular science activities can significantly improve farmers' scientific literacy and environmental awareness, so as to better implement environmental protection policies and apply farming methods with low ammonia emissions.

IV. Measures to reduce ammonia emission

A. Effects from farming methods on field ammonia emission

According to the survey results, from the perspective of farmers' farming methods, the main reasons for the large ammonia emissions in north China come from three aspects.

1.Farmers have many misconceptions about farming methods. For example, some farmers are used to broadcasting nitrogen fertilizer, applying fertilizer at the temperature which is comfortable for farmers, applying fertilizer before it rains, and they don't take soil properties and plant factors into account. These problems will lead to the increase of ammonia volatilization .

2. Affected by the backward and slow development of rural areas, some advanced fertilization and irrigation technologies, such as foliar spray, sprinkling irrigation and micro-irrigation, have high technical and economic requirements. For most farmers, the further upgrading of farming equipments cannot be achieved in a short time, which is a barrier of improving farming efficiency and reducing ammonia volatilization.

3. Some of the farmers have weak awareness of environmental protection. Due to the relatively low backward education level in rural areas, the weak awareness of environmental protection and energy conservation, and the relatively low income of farmers when comparing with urban people, some farmers may pay more attention to income and less attention to environmental damage.

B. Suggestions and measures for reducing ammonia emission in farmland

Based on the above three points, the following Suggestions are proposed for ammonia emission reduction in Hebei, China.

1. The misunderstanding of farmers' farming methods should be changed, and their awareness of environmental protection and scientific literacy should be improved, and the concept of sustainable development should be established. Some farmers have many misunderstanding and weak awareness of environmental protection, which can be easily seen from the survey. On the one hand, we suggest local governments carry out public beneficial activities. For example, the governments can hold regular scientific lectures to show farmers the harm that some of the wrong traditional farming methods brings to the environment, and to introduce more eco-friendly and modern farming methods. On the other hand, we can also follow the pattern of American land-grant college, which means setting up schools for farmers with Chinese characteristics, teaching agricultural and farming knowledge. And the government can also edit and print some free publications to give out in the relatively backward areas.

2. In order to alleviate the impact of the backward development in rural areas, it is suggested to make a series of environmental protection subsidy policies and increase economic subsidies for farmers who adopt green and advanced farming methods. At the same time, relevant departments can also issue economic subsidies to relevant companies so that they can minimize costs while ensuring the quality, efficiency and function of agricultural equipment, so as to improve the market competitiveness of energy-saving and environmentally-friendly agricultural equipment.

3. Local governments can employ some specialists in order to alert farmers to matters needing attention when farming, according to the weather forecast for the coming days through broadcasting or announcement, warning farmers to finish fertilization before it rains, or applying fertilizer during the days when the temperature is relatively low, etc. The governments can help farmers to apply fertilizer scientifically and reduce nitrogen emission, while farmers can gradually develop scientific and eco-friendly farming habits.

4. Companies need to advertise and introduce their energy-saving and eco-friendly products, reduce the doubt and misunderstanding of the advanced products. For example, as we can see from the survey that, 36.91% of the farmers think changing traditional irrigative methods is bad, and 19.74% of farmers are worried that using new irrigative methods will waste water. This will inform the farmers of the advantages of the products, enhance farmers trust and recognition, so as to strengthen the competitiveness of the products and popularize them.

5. Study and introduce the advanced fertilization technology in the world, such as accurate fertilization. This will determine the dosage of fertilizer needed by analyzing the sampling test of the soil or nutrient abundant case detection for growing crops to reduce ammonia volatilization caused by excess fertilizer, and increase agricultural production, improve product quality [9].

In conclusion, ammonia emission reduction in farmland can save resources and reduce ammonia emissions, which is of great significance to the improvement of Chinese environment. Currently, there are still improper practices in farmers' farming methods, which need the joint efforts of the government, relevant companies and farmers.

V. Appreciation

Finally, I'd like to thank Mr. Lv Jianheng, Miss Wang Xianting and Mr. Li Bo for their academic help and encouragement to me. Though they were very busy, they guided me through weekly face-to-face coaching and daily online communication, which has given me a great deal of help when I

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References

[1] Zhisheng An, Ru-Jin Huang, et al: "Severe haze in northern China: A synergy of anthropogenic emissions and atmospheric processes", *PNAS*, April 30, 2019 116 (18) 8657-8666

[2] QuYing, Wang Mian, et al: “基于 BP 神经网络的农田大气氨浓度预测”,《中国生态农业学报》, 2019, 27(04): 519- 528.

[3] Lu Lili, Wu Genyi: “农田氨排放影响因素研究进展”,《中国农业大学学报》, 2019, 24(01): 149-162.

[4] Dong Wenxu, Wu Dianming, et al: “华北山前平原农田氨挥发速率与调控研究”, 《中国生态农业学报》, 2011, 19(05): 1115- 1121.

[5] “发展复合肥氮肥企业优势明显”, 《硫磷设计与粉体工程》, 2006, (06): 52.

[6] Li Shengxiu, Ma Shejiao：“石灰性土壤铵态氮的挥发损失——II.铵态氮肥中氨的挥发与施肥方法的关系”, 《干旱地区农业研究》, 1993, (S1): 130- 134.

[7] Pan Ruichi. 《植物生理学（第七版）》高等教育出版社, 2012, 372

[8] Li Xi, Ju Xiaotang, et al: “不同施肥方式对土壤氨挥发和氧化亚氮排放的影响”,《应用生态学报》, 2008, (01): 99-104.

[9] https://baike.so.com/doc/25783837-26919978. html

Appendix 1

The questionnaire of farming practices in Hebei province.

1. Your location[single choice]

○ Shijiazhuang

○ Hengshui

○ Handan

○ Xingtai

○ Baoding

○ Langfang

○ Cangzhou

○ Zhangjiakou

○ Tangshan

○ Qinhuangdao

○ Chengde

○Other areas in Hebei province

2. Main crops of your family [single choice]

○ Wheat

○ Corn

○ Rice

○ Beans

○ Other

3. The type of nitrogen fertilizer you choose (if you grow a variety of crops, please answer according to the most important crops, the same below) [single choice]

○ Organic nitrogen fertilizer (such as urea)

○ Ammonium nitrogen fertilizer

○ Compound nitrogen fertilizer (such as ammonium sulfate, zinc sulfate, etc.)

○ Functional nitrogen fertilizer (such as controlled release fertilizer)

○ Other _____

4. Why do you usually choose such kind of fertilizer [multiple choice]

□A、Use this fertilizer all the time in the past.

□B、Almost everyone uses it.

□C、The fertilizer is efficient.

□D、It is cheap.

□E、It is said on TV or books or by experts that this kind of fertilizer is good.

□F、It is convenient to use.

□G、Other _____

5. Your usual methods of fertilization [multiple choice]

□ Broadcasting

□ Row replacement

□ Hole application

□ Circulating application

□Water flush

□ Foliage spray

□ Other _____

6. Your fertilizing efficiency[single choice]

○ Once a week

○ Once a month

○ Once a season

○ Other _____

7. Your fertilizing amount[multiple choice]

□ Applying fixed amount

□ According to different types of the fertilizer, applying equivalent amount after calculating

□ Apply different amounts of fertilizer according to different nutrient content of the soil

□ Other _____

8.Future weather conditions when fertilizing[single choice]

○ Fertilizing before raining

○ Fertilizing after raining

○ Never pay attention to the future weather conditions, apply fertilizer before irrigation

○ Never pay attention to the future weather conditions, apply fertilizer after irrigation

○ Other _____

9.When do you apply fertilizer[single choice]

○Morning

○Noon

○Afternoon

○Dusk/evening

○Don't have a fixed time

10. At what temperature do you usually apply fertilizer[single choice]

○ High temperature

○ Comfortable temperature for humans

○ Low temperature

○ Never pay attention to the temperature

11. At what wind speed do you usually apply fertilizer[single choice]

○ Gale

○ Breeze

○ No wind

○ Never pay attention to the wind speed

12. What weather will you choose to apply fertilizer[single choice]

○ Sunny

○ Cloudy

○ Windy

○ Never pay attention to the weather

13. Your usual irrigative method[single choice]

○ Flood the cash

○ Sprinkling irrigation

○ Micro-irrigation

○ Other _____

14. Why do you think your ideal irrigation methods cannot be achieved[multiple choice]

□ Imperfect supporting facilities

□ The irrigative effect is bad

□ Doubting more water is wasted

□ Cost much money

□ Other _____

15. Do you have lectures on rational fertilization and environmental protection in your area [single choice]

○ Often

○ Seldom

○ Never

16. How do you select the fertilizer [single choice]

○ Use eco-friendly fertilizer on the premise of guaranteed production

○ Use cheap and efficient fertilizer on the premise of guaranteed production

○ Other _____

17. Are you environmentally aware when you farm [single choice]

○ Yes, I am. I'll try to cut down the pollution ,even if I'll spend more and harvest less.

○ Yes, I am. But I think promoting production and reducing the cost is more important.

○ No, I am not. And I think environmental protection has nothing to do with me