

Brief Study on Microelement Contents in Topsoils of Farmlands in Xuancheng, South Anhui

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Abstract

The available contents of microelements in the topsoil can influence the yield and quality of flue-cured tobacco. Xuancheng is the dominant tobacco-planting region in Anhui province since 2008. In this paper, the topsoil available Fe, Mn, Cu and Zn contents of 4197 farmlands mainly under rice-rice rotation and wheat-rice rotation in 2008 and of 124 typical farmlands under tobacco-rice rotation in 2015 in Xuancheng city were analyzed in order to disclose the changes and spatial distributions of these microelements and to instruct the reasonable application of the microelement fertilizers. The results showed that the topsoil average available contents in the farmlands under rice-rice rotation or wheat-rice rotation in 2008 were 105.9 mg·kg⁻¹ for Fe, 19.6 mg·kg⁻¹ for Mn, 4.5 mg·kg⁻¹ for Cu, and 3.0 mg·kg⁻¹ for Zn, respectively, increased by 33.14%, 64.29%, 51.11% and 36.67%, respectively, compared with those in the 2nd Soil Survey in 1980s, and the historic, once intensive and overall application of microelement fertilizers was attributed to the great increases. The topsoil average available contents in the farmlands under tobacco-rice rotation in 2015 were 31.1 mg·kg⁻¹ for Fe, 9.8 mg·kg⁻¹ for Mn, 2.1 mg·kg⁻¹ for Cu, and 0.3 mg·kg⁻¹ for Zn, respectively, decreased by 70.63%, 50.00%, 53.33% and 90.00%, respectively, compared with those of the farmlands under rice-rice rotation or wheat-rice rotation in 2008, and the net deficiencies in the input and output of microelements were attributed to the significant decreases in the topsoil microelements. It is necessary to monitor the farmlands under tobacco-rice rotation dynamically and in time in order to decide whether applying microelement fertilizers or not.

Keywords

Microelement, Available Content, Topsoil of Farmland, Xuancheng City

1. Introduction

Microelements are necessary for the normal growth of the crop [1] [2]. They can influence the physiological metabolism, growth and development, interior quality and economic traits of the flue-cured tobacco [3]-[8], thus lots of attentions have been paid on microelement status in the tobacco-planting farmlands [9]-[14].

Xuancheng city is current dominant tobacco-planting region in Anhui province since the its initial tobacco-planting in the year of 2008 with the current regular planting area of flue-cured tobacco of about 1×10^4 hm² (constituted by 90% more of the tobacco-planting area in Anhui province) and yield of flue-cured tobacco leaves of about 1×10^4 t [15]. However, there is little or no information available on the microelements in the tobacco-planting farmlands in Xuancheng city, thus, in this paper, the data of available Fe, Mn, Cu and Zn in the farmland topsoils (0 - 20 cm) in Xuancheng city from different sources in different periods were used to evaluate the microelement status in order to instruct the reasonable application of the microelement fertilizers.

2. Methods and Materials

2.1. General Situation of the Study Region

Xuancheng city is located in the south of Anhui province (117°58'E - 119°40'E, 29°57'N - 31°19'N) with a total area of 1.23×10^4 km², its mean annual sunshine duration, temperature, precipitation, dryness and frost-free period is 1784 h, 15.6°C, 1200 - 1500 mm, 0.68 - 0.90 and 240 d, respectively; its landform is complex and diverse, mountains, hills and valley basins are interlaced in the south with a mean altitude of 1200 - 1800 m, hills and downlands are distributed in the middle with a mean altitude of 15 - 100 m, while alluvial plains are dominant in the north with a mean altitude of 7 - 12 m. Most farmlands in Xuancheng city are currently under the rotation of rice-rice, wheat-rice or tobacco-rice, the tobacco compound fertilizer contains B and Zn but without accurate formula on microelements [16].

2.2. Information of Topsoil Samples of Farmlands

The data of topsoil available Fe, Mn, Cu and Zn of farmlands were obtained from the three sources: 1) the 2nd National Soil Survey conducted in 1980s (without information of the sample sites), 2) data of 4197 farmlands obtained in the Soil Testing and Formulated Fertilization Project surveyed in 2007 (green dots in **Figure 1**), and 2) data of 103 typical tobacco-planting farmlands surveyed in 2015 (red dots in **Figure 1**).

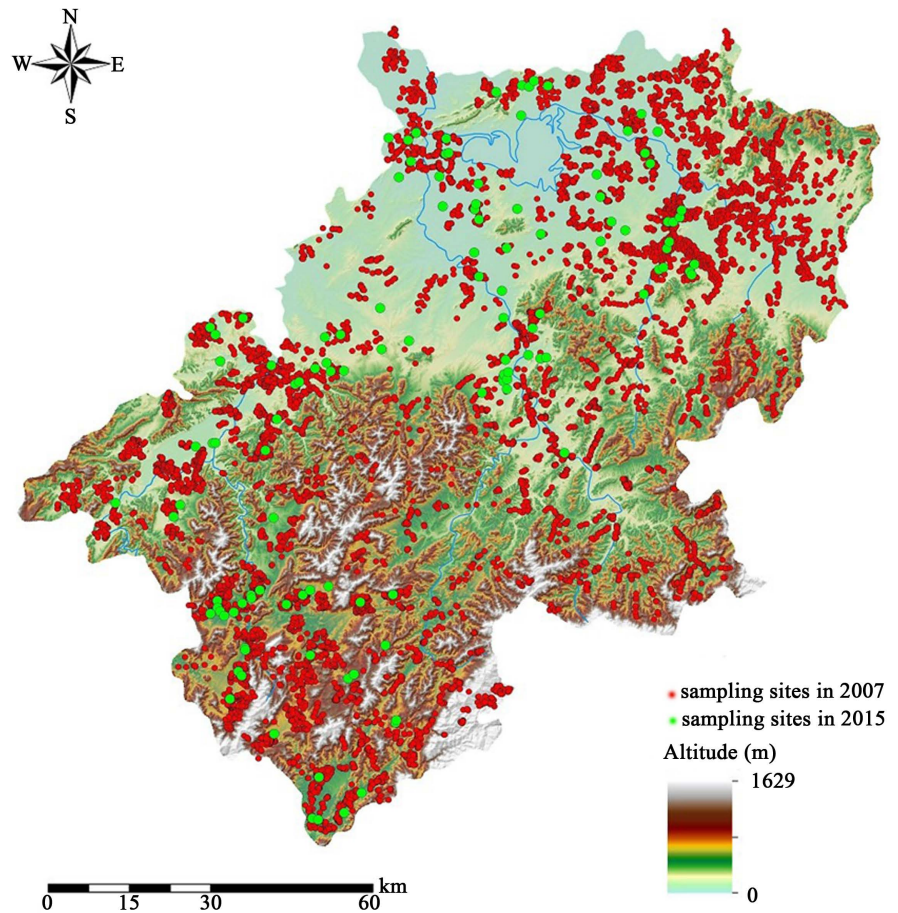


Figure 1. Spatial distribution of topsoil sampling sites of farmlands in Xuancheng.

The typical tobacco-planting farmlands were determined according to the database of tobacco farmers of Wannan Tobacco Ltd. Company in 2015 in which (see **Figure 1** and **Table 1**), these farmlands were selected from different model tobacco farmers who are good in tobacco planting and had the planting area of 2 hm² or more.

The random multipoint method was used for sampling the topsoil (0 - 20 cm) in each typical farmland in 2007 and 2015. Soil samples were air dried, ground and passed 0.25 mm sieve, then available Fe, Mn, Cu and Zn were measured by atomic absorption spectrophotometer after extracted by DTPA [17] [18].

2.3. Classification of Soil Available Fe, Mn, Cu and Zn

Table 2 is the simplified grading standards of available Fe, Mn, Cu and Zn for the typical flue-cured tobacco planting soil according to the original standards by combing “very low grade” into “low grade” and “very high grade” into “high grade” [1].

2.4. Data Processing and Thematic Mapping

Data were analyzed with Microsoft Excel 2013 and IBM Statistics SPSS 20.0, the

Table 1. Regional distribution of topsoil samples of typical tobacco planting farmlands in Xuancheng.

Region	Xuanzhou district	Langxi county	Jingde county	Jing County	Total
2007 sample numbers	919	914	1028	1321	4197
2015 sample numbers	46	27	27	24	124

Table 2. Simplified classification of soil available Fe, Mn, Cu and Zn.

Grade (mg·kg ⁻¹)	Available Fe	Available Mn	Available Cu	Available Zn
Low	<4.5	<5	<0.2	<0.5
Middle	4.5 - 10	5 - 15	0.2 - 1	0.5 - 1
High	>10	>15	>1	>1

spatial distribution of topsoil samples was mapped on the platform of Esri Arc-GIS 10.3.

3. Results and Discussions

3.1. General Statistics of Topsoil Available Fe, Mn, Cu and Zn in 2007

Table 3 shows the statistic information of topsoil available Fe, Mn, Cu and Zn of farmlands in Xuancheng surveyed in 2007.

For topsoil available Fe, it ranged from the low grade to the high grade in total Xuancheng city, also ranged from the low grade to the high grade in Xuanzhou district, but ranged from the middle grade to the high grade in Langxi county and Jing county, ranged in the high grade in Jinde county. For topsoil available Mn and Zn, they ranged from the low grade to the high grade in total Xuancheng city, also ranged from the low grade to the high grade for all its jurisdictions. For topsoil available Cu, it ranged from the low grade to the high grade in total Xuancheng city, it also ranged from the low grade to the high grade in Xuanzhou district and Jing county; but ranged from the middle grade to the high grade in Langxi county and Jingde county.

3.2. Evaluation of Contents of Topsoil Available Fe, Mn, Cu and Zn in 2007

Table 4 shows the sample number distribution in various grades of topsoil available Fe, Mn, Cu and Zn.

Table 4 shows that to the whole Xuancheng city, only 4 (0.10%) and 11 (0.26%) of the topsoil samples were in the low and middle grades of available Fe, respectively, only 293 (6.98%) and 1483 (35.34%) of the topsoil samples were in the low and middle of available Mn, respectively, only 7 (0.17%) and 71 (1.69%) of the topsoil samples were in the low and middle grades of available Cu, respectively, only 28 (0.67%) and 111 (2.64%) of the topsoil samples were in the low

Table 3. Statistic information of topsoil available Fe, Mn, Cu and Zn of farmlands in Xuancheng in 2007 (mg·kg⁻¹).

Microelement contents		Xuanzhou district	Langxi county	Jingde county	Jing county	Total
Fe	Range	1.7 - 541.8	6.4 - 80.3	10.3 - 243.4	5.7 - 102.8	1.7 - 541.8
	Mean/S.D.	210.1/139.1	60.5/9.5	127.5/29.8	48.3/15.2	105.9/92.6
Mn	Range	0.5 - 189.3	3.3 - 44.4	0.6 - 61.5	1.2 - 46.5	0.5 - 189.3
	Mean/S.D.	18.4/18.4	27.4/5.0	14.2/9.8	19.1/11.4	19.6/12.9
Cu	Range	0.4 - 8.3	0.1 - 12.3	0.1 - 27.0	0.1 - 48.6	0.1 - 48.6
	Mean/S.D.	4.0/1.6	3.6/1.0	2.6/1.5	7.0/4.1	4.5/3.1
Zn	Range	0.1 - 10.5	0.3 - 4.0	0.3 - 21.6	0.1 - 43.0	0.1 - 43.0
	Mean/S.D.	2.4/1.3	2.0/0.5	2.5/1.1	4.8/3.8	3.0/2.6

Table 4. Numbers of farmlands under different grades of topsoil available Fe, Mn, Cu and Zn in Xuancheng in 2007.

Region	Available Fe			Available Mn			Available Cu			Available Zn		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
Xuanzhou	1	3	919	91	419	413	0	11	912	16	38	869
Langxi	3	0	914	1	5	911	1	1	915	2	22	893
Jingde	0	0	1028	106	578	344	3	56	969	2	24	1002
Jin	0	8	1321	95	481	753	3	3	1323	8	27	1294
Total	4	11	4182	293	1483	2421	7	71	4119	28	111	4058

and middle grades of available Zn, respectively. The above data suggest most of the farmlands were sufficient in Fe and Cu nutrients, no need for applying Fe and Cu fertilizers, but a few of farmlands in Xuanzhou district (91 farmlands, 9.86% of its total farmlands), Jingde county (106 farmlands, 10.31% of its total farmlands) and Jing county (95 farmlands, 7.15% of its total farmlands) were in Mn and Zn deficiency and should applying Mn and Zn fertilizer.

Figure 2 shows the distribution of the available Mn and Zn in the farmland topsoil in Xuancheng, the deficiency of Mn and Zn mainly were located in the northeast region, and Mn deficiency also sporadically existed other regions.

The reason for insufficient Mn and Zn nutrients in the northeast farmlands is that these farmlands are the historically longest for rice-planting, and the paddy soils are derived from the alluvial sediments of weathered granites and metamorphic rocks, soil texture is coarse with more sand particles¹, Mn and Zn is easily leached down from the topsoils during the season of rice-planting [1] [19], so easily resulted in Mn and Zn deficiency under condition of no or insufficient Mn fertilizer supply. The deficiency of Mn and Zn can worsen the quality of

¹Soil Survey Office & Soil Fertilization Station of Xuanzhou. Xuanzhou Soil, 1987.

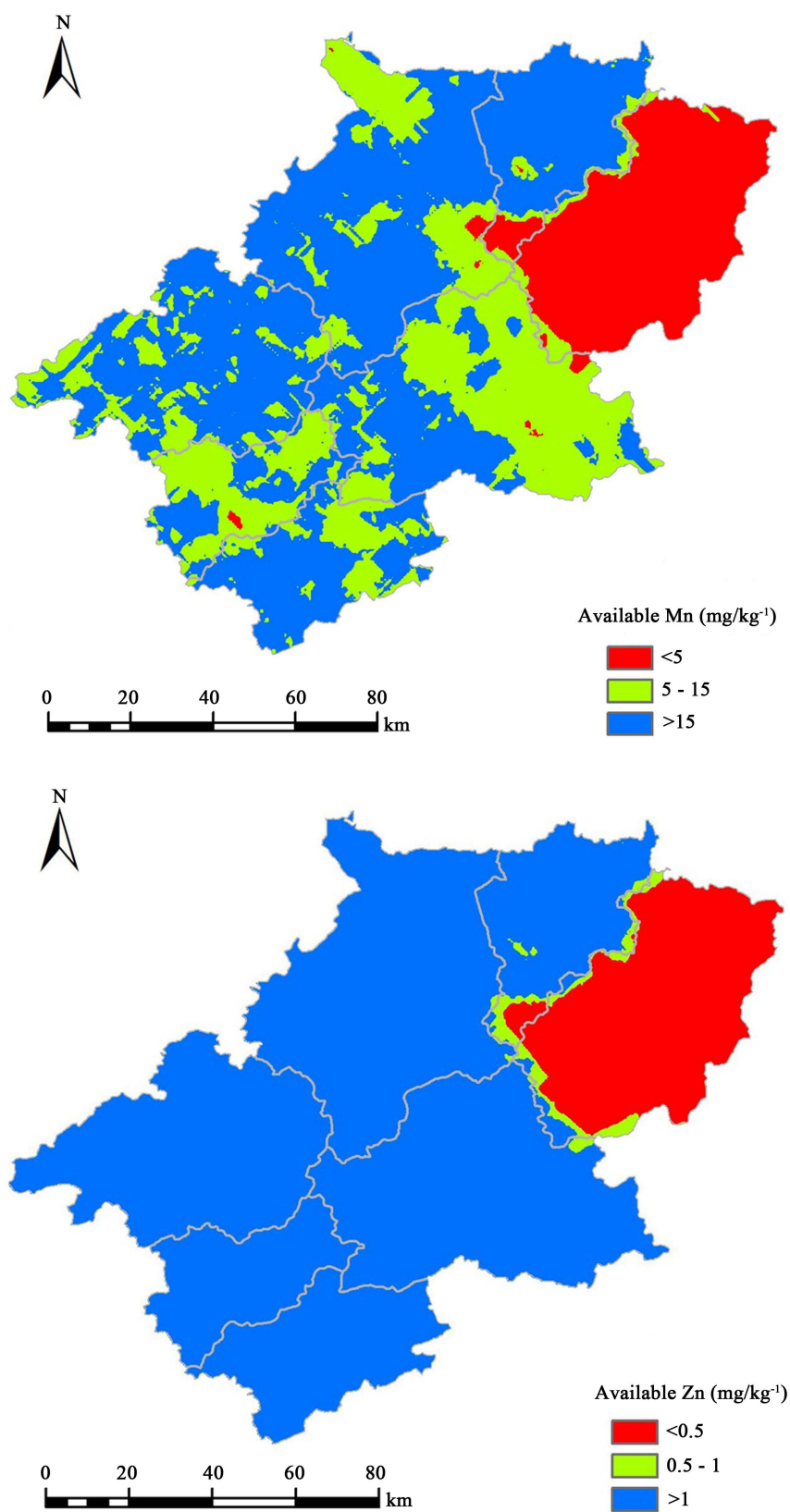


Figure 2. Spatial distribution of available Mn and Zn in topsoil of farmland in Xuan-cheng.

leaves, even cause the wither and death of tobacco [20], so Mn and Zn fertilizers should be applied for these Mn or Zn deficiency farmlands.

3.3. General Statistics of Tobacco-Planting Topsoil Available Fe, Mn, Cu and Zn in 2015

Table 5 shows the statistic information of topsoil available Fe, Mn, Cu and Zn of tobacco-planting farmlands in Xuancheng surveyed in 2007.

For tobacco-planting topsoil available Fe, ranged from the middle grade to the high grade in total Xuancheng city, also ranged from the middle grade to the high grade in Xuanzhou district, but ranged in the high grade in Langxi county, Jingde county and Jing county. For tobacco-planting topsoil available Mn, it ranged from the low grade to the high grade, also ranged from the low grade to the high grade in Xuanzhou district, Jingde county and Jing county, ranged from the middle grade to the high grade in Langxi county. For tobacco-planting topsoil available Cu, it ranged from the middle grade to the high grade in total Xuancheng city, also ranged from the middle grade to the high grade in all its jurisdictions. For tobacco-planting topsoil available Zn, it ranged from the low grade to the high grade in the total Xuancheng city, also ranged from the low grade to the high grade in Xuanzhou district and Jingde county, but ranged from from the middle grade to the high grade in Langxi county and Jing county.

3.4. Evaluation of Contents of Tobacco-Planting Topsoil Available Fe, Mn, Cu and Zn in 2015

Table 6 shows the sample number distribution in various grades of tobacco-planting topsoil available Fe, Mn, Cu and Zn.

Table 6 shows that to total Xuancheng city, no tobacco-planting topsoil samples was in the low grade of available Fe, while only 3 (2.41%) were in the middle grade, 14 (11.29%) and 109 (87.90%) of tobacco-planting topsoil samples were in the low and middle grades of available Mn, respectively. no tobacco-planting

Table 5. Statistic information of topsoil available Fe, Mn, Cu and Zn of tobacco-planting farmlands in Xuancheng in 2015 ($\text{mg}\cdot\text{kg}^{-1}$).

Microelement contents		Xuanzhou district	Langxi county	Jingde county	Jing county	Total
Fe	Range	5.1 - 35.4	24.5 - 36.0	28.2 - 37.6	17.9 - 36.5	5.1 - 37.6
	Mean/S.D.	28.3/6.4	32.0/2.6	34.4/2.2	31.7/4.0	31.1/5.1
Mn	Range	1.5 - 12.8	4.9 - 15.7	3.1 - 13.0	1.7 - 13.2	1.5 - 15.7
	Mean/S.D.	9.3/3.5	10.0/2.7	10.8/2.7	9.3/3.6	9.8/3.2
Cu	Range	0.4 - 3.9	0.8 - 3.0	0.6 - 7.6	0.3 - 4.4	0.3 - 7.6
	Mean/S.D.	1.6/0.9	2.1/0.4	2.6/1.3	2.5/1.0	2.1/1.0
Zn	Range	0.2 - 4.1	0.6 - 2.0	0.4 - 3.2	0.8 - 4.8	0.1 - 2.0
	Mean/S.D.	1.9/0.8	1.3/0.4	2.0/0.9	1.9/0.8	0.3/0.2

Table 6. Numbers of farmlands under different grades of tobacco-planting topsoil available Fe, Mn, Cu and Zn in Xuancheng in 2007.

Region	Available Fe			Available Mn			Available Cu			Available Zn		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
Xuanzhou	0	3	43	8	38	0	0	18	28	2	4	40
Langxi	0	0	27	1	25	1	0	1	26	0	6	21
Jingde	0	0	27	2	25	0	0	2	25	1	5	21
Jin	0	0	24	3	21	0	0	3	21	0	3	21
Total	0	3	121	14	109	1	0	24	100	3	18	103

topsoil samples was in the low grade of available Cu, while 24 (19.35%) were in the middle grade. 3 (2.42%) and 18 (14.52%) of topsoil samples were in the low and middle grades of available Zn, respectively. The above data also suggest most of tobacco-planting farmlands were sufficient in Fe and Cu nutrients, no need for applying Fe and Cu fertilizers, but a few of farmlands in Xuanzhou district (8 farmlands, 17.39% of its total tobacco-planting farmlands), langxi (1 farmland, 3.70% of its total tobacco-planting farmlands), Jingde county (2 farmlands, 7.41% of its total tobacco-planting farmlands) and Jing county (3 farmlands, 12.50% of its total tobacco-planting farmlands) were in Mn and Zn deficiency and should applying Mn and Zn fertilizers.

3.5. Discussion on Changes of Topsoil Available Fe, Mn, Cu and Zn

According to the historical data², topsoil available Fe, Mn, Cu and Zn in the farmlands in Xuancheng were 70.8 mg·kg⁻¹, 7.0 mg·kg⁻¹, 2.2 mg·kg⁻¹ and 1.9 mg·kg⁻¹, respectively, they increased by 33.14%, 64.29%, 51.11% and 36.67% in 2008 respectively. However, topsoil available Fe, Mn, Cu and Zn in the tobacco-planting farmland decreased by 70.63%, 50.00%, 53.33% and 90.00% compared with those of the farmland in 2015. The increases from 1980s to 2008 and the decrease from 2008 to 2015 both are significant. Particularly the latter should be more concerned for tobacco planting.

The reasons for the above changes could be concluded as that during 1980s-1990s the positive effects of microelement in promoting the yields and qualities of plants were gradually disclosed and realized, which once led the large amount of microelement fertilizers were produced and applied widely in China because crop farming was the dominant source of the family income at that time, it was also the reason for the overall great increases in available Fe, Mn, Cu and Zn in the farmlands in Xuancheng from 1980s to 2008. However, with the rapid development of the social economy, the family income of the local farmers is diversified which are mainly from non-agricultural activities, the attention of the local famers on the fertilizers for increasing crop yields and qualities has re-

²Soil Survey Office & Soil Fertilization Station of Xuanzhou. Xuanzhou Soil (unpublished data), 1987.

duced greatly and widely, which results in the decrease in applying microelement fertilizers.

Other study showed that the average data (120 farmlands) of topsoil available Fe, Mn and Cu and Zn in the farmlands of south Anhui were $157.3 \text{ mg}\cdot\text{kg}^{-1}$, $37.0 \text{ mg}\cdot\text{kg}^{-1}$, $2.6 \text{ mg}\cdot\text{kg}^{-1}$ and $1.2 \text{ mg}\cdot\text{kg}^{-1}$, respectively [21], and compared with our data in 2015, which are 49.5% and 88.8% higher in Fe and Mn while 42.2% and 60.0% lower in Cu and Zn. respectively, and these differences may be attributed to the differences in the sampling time and sites.

For the input and output of microelements in the farmland under tobacco-rice rotation, the exogenous available Fe, Mn, Cu and Zn usually are input into the farmland topsoil by fertilization, and no Fe, Mn and Cu has input into the farmland soils by fertilization for they are thought plentiful in the topsoil except Zn which may possibly contained in the compound fertilizer for tobacco-planting farmland, but no accurate information of the applied amount is available, so here we adopted the recommended applying amount Zn $0.25 \text{ kg}\cdot\text{hm}^{-2}$ as the annual input into the topsoil of farmland [22]. Available Fe, Mn, Cu and Zn usually are carried out of the farmland by harvest of tobacco and rice. In Xuancheng tobacco leaves are harvested and tobacco stems usually are removed out from the tobacco fields to avoid disease spread. According to measured data of in total 62 tobacco samples collected from Xuancheng during 2007-2008, the average concentrations of Fe, Mn, Cu and Zn are $0.15 \text{ g}\cdot\text{kg}^{-1}$, $0.18 \text{ g}\cdot\text{kg}^{-1}$, $0.01 \text{ g}\cdot\text{kg}^{-1}$ and $0.08 \text{ g}\cdot\text{kg}^{-1}$, respectively with the total biomass of $4500 \text{ kg}\cdot\text{hm}^{-2}$, thus, about $0.68 \text{ kg}\cdot\text{hm}^{-2}$ of Fe, about $0.81 \text{ kg}\cdot\text{hm}^{-2}$ of Mn, about $0.05 \text{ kg}\cdot\text{hm}^{-2}$ of Cu, about $0.36 \text{ kg}\cdot\text{hm}^{-2}$ of Zn are moved out annually from the farmland by tobacco leaves and stems. The average concentrations of Fe, Mn, Cu and Zn are $0.007 \text{ g}\cdot\text{kg}^{-1}$, $0.004 \text{ g}\cdot\text{kg}^{-1}$, $0.004 \text{ g}\cdot\text{kg}^{-1}$ and $0.013 \text{ g}\cdot\text{kg}^{-1}$ in rice ears [23] with the total biomass of $7500 \text{ kg}\cdot\text{hm}^{-2}$, then about $0.05 \text{ kg}\cdot\text{hm}^{-2}$ of Fe, $0.03 \text{ kg}\cdot\text{hm}^{-2}$ of Mn, $0.03 \text{ kg}\cdot\text{hm}^{-2}$ of Cu, and $0.10 \text{ kg}\cdot\text{hm}^{-2}$ of Zn are moved out annually from the farmland by rice ears, Thus, in total, about $0.73 \text{ kg}\cdot\text{hm}^{-2}$ of Fe, $0.84 \text{ kg}\cdot\text{hm}^{-2}$ of Mn, $0.08 \text{ kg}\cdot\text{hm}^{-2}$ of Cu, and $0.46 \text{ kg}\cdot\text{hm}^{-2}$ of Zn are carried out of the farmland. So the net annual decreases of available Fe, Mn, Cu and Zn in the farmland topsoil are about $0.73 \text{ kg}\cdot\text{hm}^{-2}$ of Fe, $0.84 \text{ kg}\cdot\text{hm}^{-2}$ of Mn, $0.083 \text{ kg}\cdot\text{hm}^{-2}$ of Cu, and $0.21 \text{ kg}\cdot\text{hm}^{-2}$ of Zn, respectively. Thus, for the farmland with the rotation of tobacco-rice, it is necessary to monitor the dynamic changes of microelements in time in order to decide whether applying the microelement fertilizers or not.

4. Conclusion

Our survey showed that there were great increases in topsoil available Fe, Mn, Cu and Zn of the farmlands mainly under rice-rice rotation in Xuancheng city from 1980s to 2008 due to the historic intensive and overall application of microelement fertilizers, but significant decrease in topsoil available Fe, Mn, Cu and Zn of the farmlands under tobacco-rice rotation due to the net deficiency in

the input and output of microelements. It is necessary to monitor the farmland dynamically and in time in order to decide whether applying microelement fertilizers or not.

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