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Features of Arable Soil Acidity Based on GIS Data in Liaoning Province, China

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ABSTRACT

In this study, soil samples were collected from typical arable lands in Liaoning Province. The location of soil samples was recorded by GIS coordinates. Soil pH was determined and compared with the record in 1980. Results showed that soil pH generally decreased with years, from 7.08 to 6.59 between 1980 and 2008. Areas with soil pH below 6.5 increased. The reduction of soil pH varied with soil types. The eolian sandy soil had the lowest soil pH, followed by brown soil, meadow soil and paddy soil. The eolian sandy soil, acidic and slightly acidic soil accounted for 90%, 91.8% and 90.7% in the corresponding soil types, respectively.

INTRODUCTION

Soil acidification is mostly defined as a decrease in soil pH (Krug 1983). The acidification/alkalization process in nature is driven by the interactions among organisms, soil, climate, and the decomposition of the plant detritus (Chapin III 2011). According to statistics, the area of acidification is about $3.777 \times 10^9 \sim 3.950 \times 10^9$ ha in the world, accounting for about 30% of non-ice cover land area, of which the lower layer of soil acidification occurs in about 2.98×10^9 ha, accounting for 75% in acidic soil area (Von Uexkll & Mutert 1995).

Soil acidification is one of the hot global issues for arable land; about 40% of arable soils are affected by soil acidification. Since the second half of the 20th century, soil acidification has been reported in some countries with a decreasing pH value trend (Hallbacken & Tamm 1986, Falkengren-Gremp 1987a, 1987b, Billet et al. 1990). Acidification can affect soil properties in various degrees, such as enhancing element content like Al, Mn and Fe in soil solution (Neves et al. 2009, Watmough et al. 2007, Boruvka et al. 2005, Hell & Stephan 2003). High concentrations of these element contents could be phytotoxic and decrease the exchangeable base (Dubiková 2002). Dissolution of clay minerals could be triggered by soil acidification. Then aluminium ions from minerals may be released into soil solution leading to acidification (Céspedes-Payret et al. 2012, Barré et al. 2009).

One fifth of pH values of the arable soil have been declined by more than 1.0 unit in less than 20 years without liming of chemical fertilizer (Luewille et al. 2008). Europe has been the phenomenon of large areas of forest death caused by soil acidification. In Helsinki, Finland, soil pH values on the southwest coast forest were reduced by 0.57±0.11 pH units in 60 years (Ahokas 1997). In Britain, the pH of cultivated land and grassland soil declined 19% and 35% during 1982~1988, respectively (Goulding 1998). Unreasonable land managements have accelerated soil acidification in Victoria Province of Australia, resulting in an annual loss of $ 470 million farm productivity due to soil acidification (Rengel 2003). Field trials in Canada, Alberta showed that soil pH values had a continued slowdown (1.0 to 1.5 units) for 18 consecutive years by ammonium nitrate (305 kg N ha^{-1}) (McAndrew & Malhi 1992). Soil acidification with decreasing pH would cause serious grassland degradation, reduce grassy species, and affect biodiversity (Banasova & Sucha 1998, Roem & Berendse 2000).

Liaoning Province, a major agricultural province in China, has been important for its location and special role in producing food. Liaoning Province terrain has sloping from northeast to southwest, mountains and hills locate in east and west sides, saline-alkali soil distributes in central west region, cinnamon locates in the western region and eastern area of mountains. The soil acidity has a regional distribution feature, where soil pH has a big difference from southeast acidic soil to northwest alkaline soil. It is important to clarify farmland soil quality by surveying the characteristics of soil acidity in Liaoning. These research results of acidification of arable soil in Liaoning Province (1980-2008) are important theoretical foundation basis for soil fertility evaluation and soil improvement.

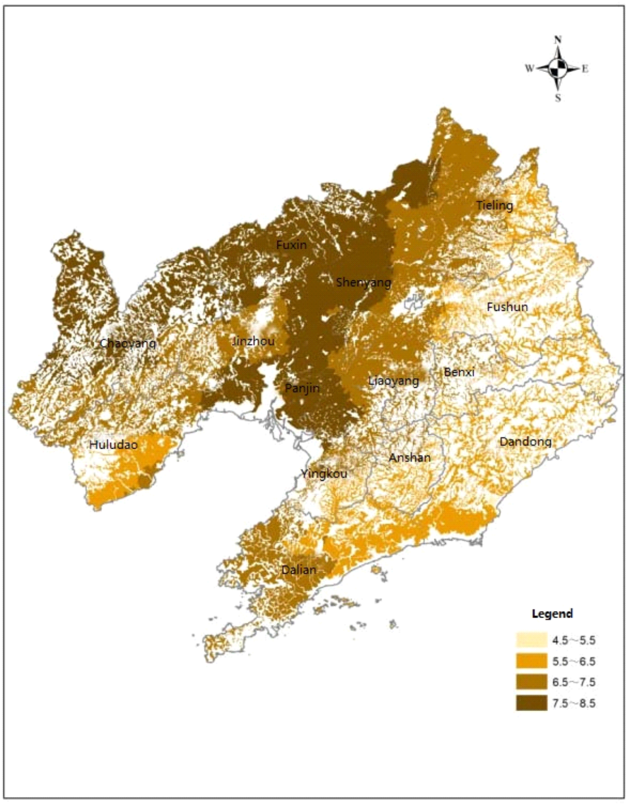

Fig. 1: Distribution map of soil pH in Liaoning province in 1980.

GIS (Geographic Information System) is a widely used tool in agriculture and analysing soil survey data. Acidification features of farmland soil in Liaoning province was analysed using GIS data to better understand soil acidification distribution.

MATERIALS AND METHODS

Liaoning Province is located in the south of northeast China within the east longitude 118°53' to 125°46' and north latitude 38°43' to 43°26'. Terrain roughly inclines toward the middle from north to south and from east to west. This area is located in the east coast of Eurasia, and belongs to temperate continental monsoon climate zone. This region has abundant sunshine with a hot rainy season and a high cumulative temperature value. Liaoning province cultivated land fertility evaluation data covering 14 prefecture-level cities and 67 counties were used in this paper. A total of 9249 sets of data were collected in the year 1982, 2005 and 2008, including latitude, longitude, soil type, soil parent material, accumulated temperature, annual precipitation, organic fertilizer, nitrogen, phosphorus and potassium fertilizer, and crop production. Excel 2007, SPSS17.0, Origin8.0, and ArcGis9.0 were used for analysing data.

RESULTS AND DISCUSSION

Precipitation, temperature and biological types vary in different regions of Liaoning province. The east and south area has higher precipitation while west region is relatively dryer. Soil pH values were analysed in five different orientations, including the eastern, southern, western, northern and central Liaoning province. Fushun, Benxi and Dandong cities (eastern Liaoning), Dalian and Yingkou cities (southern Liaoning), Chaoyang, Huludao, Jinzhou and Fuxin cities (western Liaoning), Shenyang and Tieling cities (northern Liaoning), Anshan, Panjin and Liaoyang cities (central Liaoning) were involved. Soil soluble substance gradually dissolves into soil solution under precipitation or irrigation, leaving the plant rhizosphere soil layer with the flowing water. Leaching occurs with excess base cations, which causes soil acidification (Poss et al. 1995, Van Breemen et al. 1984).

The trend of soil pH in Liaoning Province in 1980 showed the greatest pH value in the western Liaoning region, whereas the lowest in the eastern Liaoning region (Fig. 1 and Fig. 2). Soils with pH between 6.5 and 7.5 (neutral soil) were distributed in the western, southern, and central regions. Soils with pH between 5.5 and 6.5 (slightly acidic soil) were distributed in the northern and eastern Liaoning regions. This can be evidenced by base cations leached by great precipitation in eastern and northern regions. Therefore, climate and organisms greatly contributed to the soil acidity in Liaoning province.

Soil acidity is widely distributed among different regions in Liaoning province (Fig. 3). The soil pH value is mainly below 6.5 indicating acidified soils. The pH of the northern and western soils is neutral. The soil pH in part of the region of Shenyang and Panjin city is greater than 7.5. The weak acidic soil is present in eastern, southern and central regions. Acidic soils with pH lower than 5.5 were distributed in the eastern and southern regions including Dandong, Fushun, Yingkou and in the central region Anshan.

The overall pH analysis was done and shown in Fig. 4, which indicated that most of the soil in Liaoning province was acidized. The sequence of soil pH in different regions of Liaoning was listed as follows, western Liaoning > southern Liaoning > central Liaoning > northern Liaoning > eastern Liaoning.

Further analysis of soil pH of 14 prefecture-level cities in Liaoning province is shown in Fig. 5. Neutral soils were distributed in Benxi, Yingkou, Panjin and Chaoyang, and slightly acidic soil in the rest area. Strong soil acidification was present in eastern Liaoning regions of Dandong and Fushun.

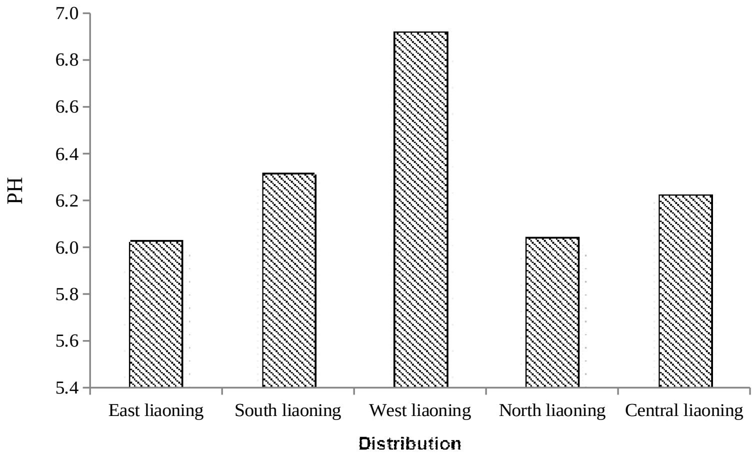

Fig. 2: Soil pH of Liaoning province in 1980.

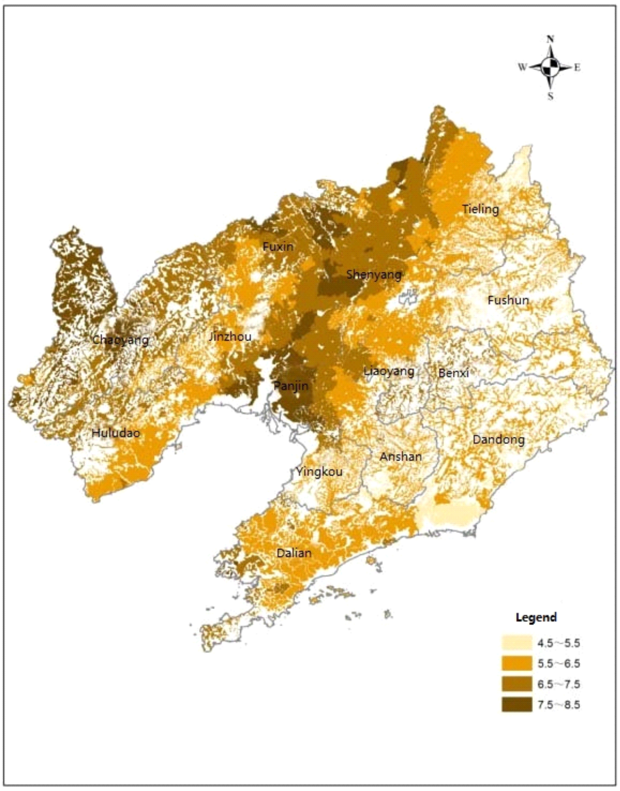

Fig. 3: Distribution map of soil pH in Liaoning province in 2008.

The proportion of acid arable lands (pH 4.6-5.5) in eastern, southern, northern and central areas is higher than in the west (Table 1). Dandong and Fushun have the largest proportion of acidic soils for 94.74% and 88.66%, respectively. Acid soils occupied 77.96 % in Dalian and 83.97% in Tieling in the northern Liaoning. The acidic soils accounted for 70.27% and 69.51% in the central region of Anshan and Liaoyang, respectively. The acidic area in the western region of Jinzhou and Fuxin is more than 55%.

For 28 years (1980 to 2008), the spatial distribution of soil pH of arable land in Liaoning Province showed a similar trend. The soil in southeast area was acidic, whereas northwest area was alkaline (Fig. 1 and Fig. 4). The spatial variability of soil pH was moderate. The overall pH value was decreasing with an average decrease from 7.08 (1980) to 6.59 (2008) (Table 2).

The difference between pH changes of different times is very significant since 1980. Proportion of cultivated land at pH 7.6 to 8.5 (slightly alkaline soil) and 6.6 to 7.5 (neutral soil) decreased by 13336.4 km^2 and 2635.6 km^2, respectively; the alkaline soil farmland decreasing significantly. Proportion of slightly acidic soil (pH 5.6- 6.5) and acidic soil (pH 5.6 - 6.54) increased by 14235.1 km^2 and 1736.9 km^2, respectively (Table 3).

The arable land soil was slight acidic in Liaoning province. Serious acidification area was mainly located in Fushun and Benxi cities (eastern Liaoning), Yingkou city (southern Liaoning), Fuxin and Jinzhou cities (western Liaoning), Tieling city (northern Liaoning) and Anshan city (central Liaoning). This acidification area was 10889.6 km^2 accounting for 21.7% of the total arable land. Weakly acidified soil was widely distributed in Liaoning province as the largest 33742.3 km^2 accounting for 67.2% of the total arable land. In only 11.1% (5594.8 km^2) of the arable land soil pH increased, which was mainly distributed in the Chaoyang city (western Liaoning), Dandong city (eastern Liaoning), and parts of Panjin city (central Liaoning) (Table 4 and Fig. 6).

Probability density changes of arable soil pH in 14 prefecture-level cities with time was analysed and shown in

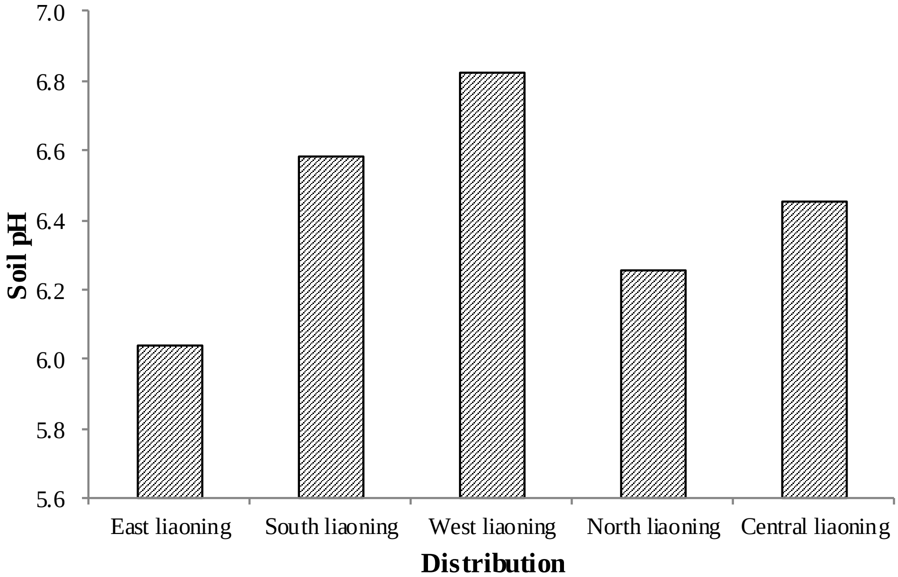

Fig. 4: Soil pH in different regions of Liaoning province in 2008.

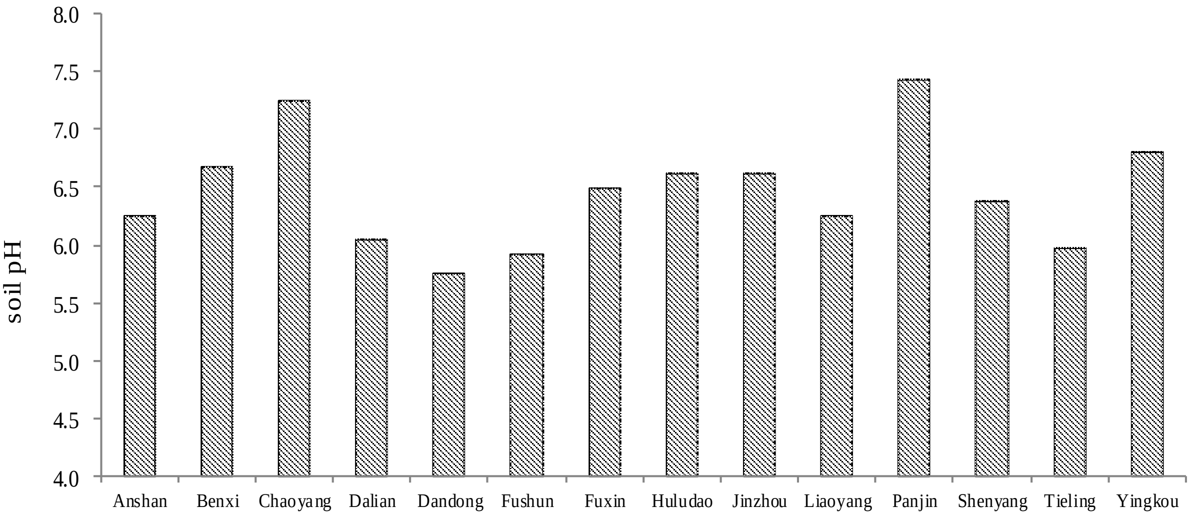

Fig. 5: Soil pH distribution in Liaoning province in 2008.

Fig. 7. The soil pH values more than 6.5 gradually decreased from 2005 to 2009. Soil pH less than 6.5 indicated soil acidification (Fig. 7).

The soil pH values of Shenyang, Tieling, Jinzhou, Fuxin, and Huludao cities were decreasing to less than 6.5 as acidic soil, whereas Dandong and Benxi cities were increasing to more than 6.5. This was mainly related to the amount of fertilization according to a survey in Liaoning Province from 2005 to 2009, in particular, the amount of nitrogen fertilizer is more consistent.

Soil pH values of most arable land soil decreased except for acidic soils during 28 years (Table 5). In addition, the area (98.7%) and decreasing rate of aeolian sandy soil pH value are the most significant.

The pH value of acidic soils presented an increasing trend, with an area of 72.5% by 0-1. Brown soil, meadow soil, and paddy soil accounted for 99.2% of the total area of Liaoning province. This indicated a slight acidification trend with the acidification area of 90%, 91.8% and 90.7%, respectively. These pH mainly concentrated in the range of -1-0.

Table 1: Distribution of soil acidity in Liaoning province.

Region	City	Acidity Degree	pH	Sample No.	Area (hm^2)	Percentage
Eastern Liaoning	Dandong	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	36	4728.17	31.58%
		Weak acidity	5.6-6.5	72	9456.34	63.16%
		Neutrality	6.6-7.5	6	788.03	5.26%
	Benxi	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	0	0	0
		Weak acidity	5.6-6.5	27	3201.28	38.03%
		Neutrality	6.6-7.5	44	5216.90	61.97%
	Fushun	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	26	3022.61	26.80%
		Weak acidity	5.6-6.5	60	6975.24	61.86%
		Neutrality	6.6-7.5	11	1278.79	11.34%
Southern Liaoning	Dalian	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	17	3928.10	28.81%
		Weak acidity	5.6-6.5	29	6700.88	49.15%
		Neutrality	6.6-7.5	10	2310.65	16.95%
		Weak alkalinity	7.6-8.5	3	693.19	5.08%
	Yinkou	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	18	796.74	14.75%
		Weak acidity	5.6-6.5	36	1593.48	29.51%
		Neutrality	6.6-7.5	27	1195.11	22.13%
		Weak alkalinity	7.6-8.5	41	1814.80	33.61%
Western Liaoning	Chaoyang	Strong acidity	≤4.5	0	0	0
		Weak acidity	5.6-6.5	45	3159.48	16.01%
		Neutrality	6.6-7.5	125	8776.34	44.48%
		Weak alkalinity	7.6-8.5	102	7161.49	36.30%
		Alkalinity	8.6-9.5	1	70.21	0.36%
	Huludao	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	16	782.99	7.51%
		Neutrality	6.6-7.5	88	4306.45	41.31%
		Weak alkalinity	7.6-8.5	22	1076.61	10.33%
	Jinzhou	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	5	187.73	2.49%
		Weak acidity	5.6-6.5	108	4054.91	53.73%
		Neutrality	6.6-7.5	66	2478.00	32.84%
		Weak alkalinity	7.6-8.5	20	750.91	9.95%
		Alkalinity	8.6-9.5	2	75.09	1.00%
	Fuxin	Strong acidity	≤4.5	0	0	0.00%
		Acidity	4.6-5.5	11	2251.54	22.00%
		Weak acidity	5.6-6.5	18	3684.33	36.00%
		Neutrality	6.6-7.5	11	2251.54	22.00%
		Weak alkalinity	7.6-8.5	9	1842.17	18.00%
		Alkalinity	8.6-9.5	1	204.69	2.00%
Northern Liaoning	Shenyang	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	149	1028.18	
		Weak acidity	5.6-6.5	260	1805.51	51.69%
		Neutrality	6.6-7.5	51	359.20	10.14%
		Weak alkalinity	7.6-8.5	43	304.12	8.55%
	Tieling	Strong acidity	≤4.5	0	0	0.00%
		Acidity	4.6-5.5	64	3172.59	24.43%
		Weak acidity	5.6-6.5	156	7733.20	59.54%
		Neutrality	6.6-7.5	34	1685.44	12.98%
		Weak alkalinity	7.6-8.5	8	396.57	3.05%
Central Liaoning	Panjin	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	1	104.28	2.56%
		Weak acidity	5.6-6.5	4	417.11	10.26%
		Neutrality	6.6-7.5	12	1251.34	30.77%
		Weak alkalinity	7.6-8.5	22	2294.12	56.41%

Table conti....

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	Anshan	Strong acidity	≤4.5	0	0	0
		Acidity	4.6-5.5	11	1168.50	14.86%
		Weak acidity	5.6-6.5	41	4355.31	55.41%
		Neutrality	6.6-7.5	18	1912.09	24.32%
		Weak alkalinity	7.6-8.5	4	424.91	5.41%
	Liaoyang	Strong acidity	d”4.5	0	0	0
		Acidity	4.6-5.5	5	285.29	6.02%
		Weak acidity	5.6-6.5	61	3480.60	73.49%
		Neutrality	6.6-7.5	17	970.00	20.48%
		Weak alkalinity	7.6-8.5	0	0	0

Table 2: Soil pH from 1980 to 2008 in Liaoning province.

Time	Samples	Mean	Min	Max	Standard deviation	Coefficient of variation (%)
1980	964	7.08	5.40	10.00	0.71	10.03
2008	2525	6.59	5.00	9.32	0.71	10.77

Table 3: The distribution changes of arable land pH in Liaoning province in 28 years.

pH range	Area (hm^2) in 1980	Percentage (%)	Area (hm^2) in 2008	Percentage (%)	Variation (km^2)
4.6~5.5	38.0	0.0	1774.9	3.5	1736.9
5.6~6.5	9184.2	18.3	23419.2	46.7	14235.1
6.6~7.5	20727.0	41.3	18091.4	36.0	-2635.6
7.6~8.5	20277.5	40.4	6941.1	13.8	-13336.4

Table 4: The pH changes in Liaoning province.

pH range	Area (km^2)	Percentage (%)
≤-2	76.6	0.2
-2~-1	10813.0	21.5
-1~0	33742.3	67.2
0~1	5570.1	11.1
≥1	24.7	0

Notwithstanding pH decreasing amplitude of cinnamon soil reached 78.2%, but only 29.3% of its area presented a larger decrease in the range of > -1. The pH changes of different soils in Liaoning province showed a slight acidification, which mainly concentrated in the range of -1-0.

CONCLUSIONS

In the selected 28 years (1980-2008), the spatial distribution of arable soil (Liaoning province) pH showed a similar trend. The pH of soils showed a decreasing trend. The overall soil pH values of arable land in Liaoning province were normally distributed. The average pH values were decreasing to acidification over time in acidulated areas, which account for 50.2% of the total arable land. Soil acidity distribution has been widely varied among different regions. Acidification area in occupied land was 21.7% of the total arable land soil. The trend presented a weak acidification in other soil types. Aeolian sandy soils presented the most significant decreasing amplitude pH values, followed by brown soils, meadow soil and paddy soil.

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Table 5: Different soils and their pH changes.

Type	Variable area of pH range (km^2)					
	≤-2	-2~-1	-1~0	0~1	≥1	Summation
Brown	0.0	4691.2	11999.8	1823.5	24.2	18538.6
Meadow soil	0.0	2902.0	12156.7	1347.8	0.0	16406.5
Cinnamon soil	76.6	2165.6	3736.4	1662.0	0.0	7640.6
Paddy soil	0.0	876.3	5692.2	671.1	0.5	7240.1
Albic soils	0.0	0.0	22.6	59.5	0.0	82.1
Meadow soil	0.0	0.0	27.0	2.6	0.0	29.6
Alkaline soil	0.0	0.0	23.0	0.0	0.0	23.0
Aeolian sandy soil	0.0	177.9	84.6	3.6	0.0	266.1
Summation	76.6	10813.0	33742.3	5570.1	24.7	50226.7
			Soil pH changes			
Type	Variable area of pH range (%)					
	≤-2	-2~-1	-1~0	0~1	≥1	
Brown	0.0	25.3	64.7	9.8	0.2	
Meadow soil	0.0	17.7	74.1	8.2	0.0	
Cinnamon soil	1.0	28.3	48.9	21.8	0.0	
Paddy soil	0.0	12.1	78.6	9.3	0.0	
Albic soils	0.0	0.0	27.5	72.5	0.0	
Meadow soil	0.0	0.0	91.1	8.9	0.0	
Alkaline soil	0.0	0.0	100.0	0.0	0.0	
Aeolian sandy soil	0.0	66.9	31.8	1.3	0.0	

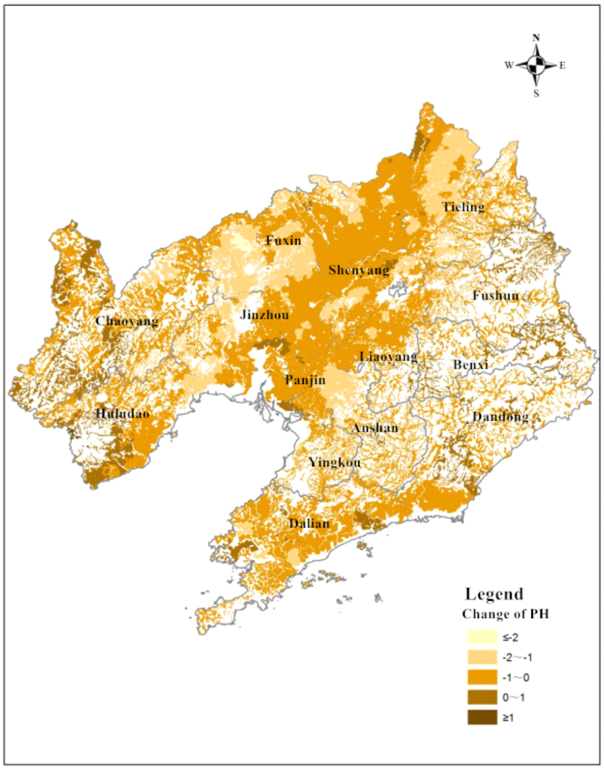

Fig. 6: The pH distribution in arable land of Liaoning province.

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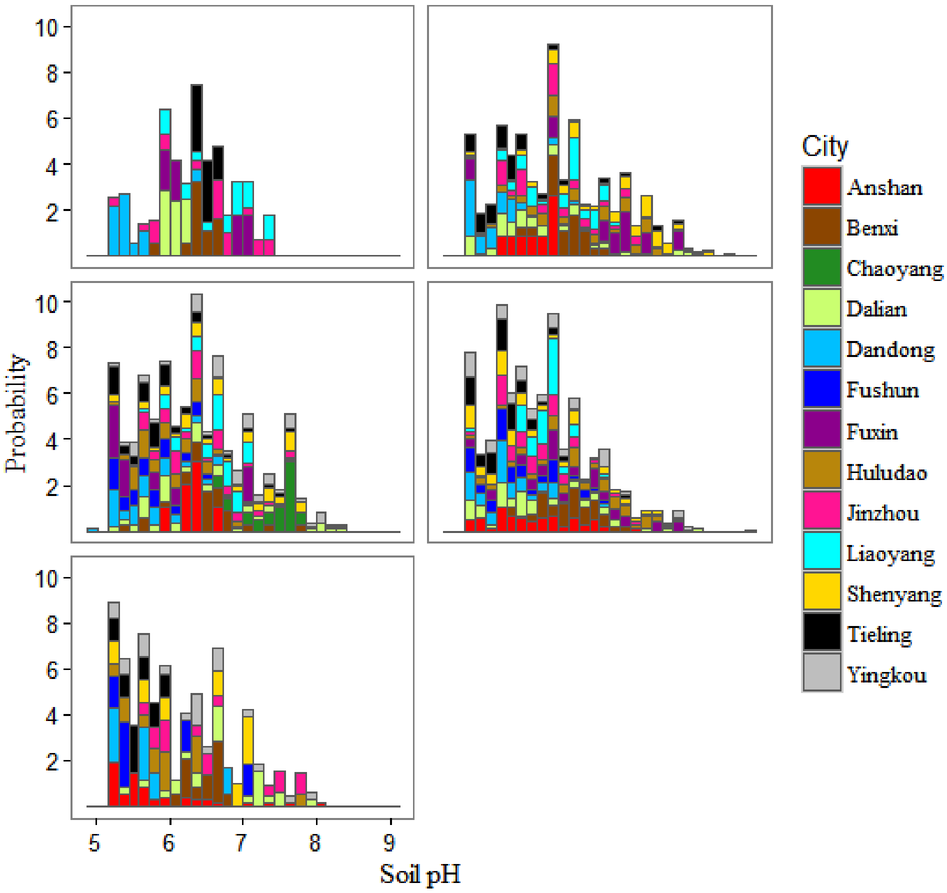

Fig. 7: Probability density of soil pH from 2005 to 2009.

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