# Spatial evolution law of physical properties of subsided farmland soil due to coal mining in the east of China[1]

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**Abstract**

This paper is to study the spatial evolution law of the physical properties of subsided farmland soil due to coal mining in the East of China. Taking Yanzhou mining area for example, soils of various sites and depths of the subsided farmland due to coal mining were studied. Results showed that the physical properties of the soils about the subsided farmland are influenced remarkably by coal mining, the soils of the upper and middle slopes are becoming sandy, and the substance of fine and light particles eroded from the upper and middle slopes are accumulated in the lower and bottom slopes. The biggest of the physical properties influenced by coal mining about subsided farmland soil is the soil water, the second is the physical sandy, and the third is the soil bulk density and the soil pore rate.

[1]Paper presented at Sudbury 2003 conference on Mining and the Environment (28th Annual CLRA Meeting), Sudbury, Ontario, Canada, May 25 – 28, 2003

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[3]THE AUTHOR GRATEFULLY ACKNOWLEDGES THE SUPPORT OF K. C. WONG EDUCATION FOUNDATION, HONG KONG

**Key words:** coal mining; subsided farmland; soil; physical property; spatial evolution law; China

## 1. Introduction

Coal is accounting for more than 70 % of energy resources in China, and its annual output is the biggest in the world (Chen and Ji, 1992). It is well known that coal mining not only occupy large land but also cause the land subsidence. As a result, farmland is destroyed, building is damaged, and the water source is polluted in the surface (Chen and Huang, 1995). According to investigation, the subsided land is 30 ha after per million t coal mining, and on the grounds of total coal output 27 billion t from 1949 to 2001 (State Statistical Bureau of People's Republic of China, 2002) to calculate, the total subsided land is 810 thousands ha in China.

During forming the subsided land, the landforms of the earth's surface are changed in different degrees, their effects on farmland is producing sloping fields, accumulating water, full of bumps and holes, crevices, and so on. In the comprehensive action of the external force of mining subsidence as well as the natural force of rainwater and wind power act, it makes the farmland soil produce the erosion status of destroying, shoving, depositing, and lead to the soil degeneration of farmland. Here, taking Yanzhou mining area for example, soils of various sites and depths of the subsided farmland due to coal mining are determined and analyzed, for the purpose of revealing the spatial evolution law of the physical properties of soils about subsided farmland due to mining coal, and supplying the theory for harnessing the subsided farmland in coal mining areas.

Yanzhou mining area is situated in the eastern part of China, the area is 54 $km^2$, the recoverable reserves is 38 millions t, the major coal mining seam is 3 coal seam, the average thickness of coal seam is 8.65 m. The ground-water table is 3~5 m in this area, therefore, the deep subsided area is generally accumulating water, and the shallow subsided area is changing with year and season, leading to accumulating water in varying degrees. The center area of subsided land make the farmland without product, and the sloping fields around the subsided land is still planting wheat and corn one after the other, but because of the soil erosion in the sloping fields, making the soil quality descend, and leading to reduction of output in varying degrees.

In this area, the average annual atmospheric is 14.1□, the average annual rainfall is 771.7 mm, the frost-free period is 215 d, and the biggest deep of frozen soil is 0.45 m.

## 2. Study methods

In the dry winter season of December 1998, to choose the typical case of 6 years subsided land after coal mining for the object of gathering the soil sample, its area is 53.2 ha. The ground was smooth before coal mining, and the elevation was positive 48.3 m. The center area occupies 20 % of the total area about the subsided land, which average deep of accumulating water is 0.8 m. In the sloping fields around the subsided farmland, to set up the well-distributed gathering soil sample sites along the contour line from the upper slope to the lower slope until the edge of accumulating water at subsided deep 0.5 m for scope, and with the normal farmland without the effects of subsidence for the contrast. The soil samples are gathered by 3 soil depths from surface to ground with 0 ~ 20 cm, 20 ~ 40 cm and 40 ~ 60 cm for every site. The soil samples are classified according to the same soil depth of the same site. The state of the subsided land and the sites of gathering soil samples are shown in figure 1 and table 1.

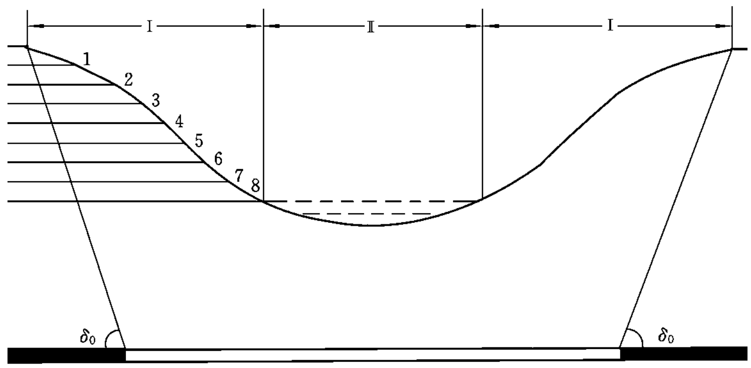


Figure 1. Schematic view about the state of the subsided farmland and the sites of gathering soil samples (□. Sloping fields around the subsided farmland□□. The area of accumulated water in the center of the subsided farmland□1 - 8. Sites of soil samples gathered)

Table 1. The distributed sites of the soil samples gathered

| Parameter | Sequence | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Elevation of contour line (m) | 48.3 | 47.8 | 47.3 | 46.8 | 46.3 | 45.8 | 45.3 | 44.8 | 44.3 |
| Subsided deep (m) | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |

Note: The sequence " 0 " expresses the normal farmland without the effects of subsidence.

The major determining physical properties items of the soils are defined according to the factors of soil physical properties (Wang, 1992) as well as the destroying characteristics of subsided land, and the major determining physical properties items are the soil water, the soil bulk density, the soil pore rate and the physical sandy (diameter > 0.01 mm).

### 3. Results and discussion

The physical properties of the normal farmland soil are shown in table 2. In order to reveal bitterly the spatial evolution law of the physical properties of soils about subsided farmland due to coal mining, taking the practical determining values of the physical properties of the normal farmland soil for contrast, and converting the practical determining values into the relative values about the physical properties of subsided farmland soils, the converting values are shown in table 3. The relative values of various sites and depths of the subsided farmland soils in table 3 are all converted with the practical determining value of the corresponding determining item of the same site and depth soil of the normal farmland for basis.

Table 2. The physical properties of the normal farmland soil

| Soil depth (cm) | Soil water (%) | Soil bulk density ($g/cm^3$) | Soil pore rate (%) | Physical sandy (%) |
|---|---|---|---|---|
| 0~20 | 18.97 | 1.21 | 54.34 | 63.46 |
| 20~40 | 19.78 | 1.30 | 50.94 | 64.20 |
| 40~60 | 20.65 | 1.56 | 41.13 | 64.51 |

Table 3. The conditions of spatial evolution of the physical properties about the subsided farmland soil in contrast with the normal farmland %

| Subsided deep (m) | Soil depth (cm) | Soil water | Soil bulk density | Soil pore rate | Physical sandy | Subsided deep (m) | Soil depth (cm) | Soil water | Soil bulk density | Soil Pore rate | Physical sandy |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0~20 | -3.43 | -10.74 | +9.04 | +9.80 | | 0~20 | +35.53 | +14.05 | -11.80 | +2.79 |
| 0.5 | 20~40 | -6.42 | -10.00 | +9.64 | +1.42 | 2.5 | 20~40 | +32.05 | +9.23 | -8.87 | +0.37 |
| | 40~60 | -7.31 | -13.46 | +19.28 | +0.45 | | 40~60 | +32.20 | +0.64 | -0.90 | -0.26 |
| | 0~20 | +8.70 | -0.83 | +0.70 | +13.95 | | 0~20 | +41.86 | +0.83 | -0.70 | +0.13 |
| 1.0 | 20~40 | +6.07 | -2.31 | +2.24 | +4.21 | 3.0 | 20~40 | +43.18 | 0.00 | 0.00 | +0.16 |
| | 40~60 | +8.72 | -8.97 | +12.86 | +2.47 | | 40~60 | +47.85 | -5.13 | +7.34 | -0.48 |
| | 0~20 | +16.34 | +4.96 | -4.16 | +23.89 | | 0~20 | +58.67 | -2.48 | +2.08 | -8.29 |
| 1.5 | 20~40 | +14.16 | +3.85 | -3.69 | +5.72 | 3.5 | 20~40 | +60.87 | -3.85 | +3.71 | -4.44 |
| | 40~60 | +14.82 | -5.13 | +7.34 | +3.58 | | 40~60 | +66.25 | -5.13 | +7.34 | -2.93 |
| | 0~20 | +29.31 | +9.09 | -7.64 | +10.86 | | 0~20 | +69.95 | -6.61 | +5.56 | -25.73 |
| 2.0 | 20~40 | +27.96 | +6.15 | -5.91 | +1.25 | 4.0 | 20~40 | +80.03 | -6.15 | +5.93 | -18.46 |
| | 40~60 | +24.41 | -2.56 | +3.67 | +0.17 | | 40~60 | +90.80 | -7.05 | +10.09 | -3.61 |

Note: The "+" shows that the practical determining value of the corresponding determining item of the same site and depth soil of the subsided farmland is higher than the normal farmland, the numerical value shows the percent degree of highness, but the "-" shows the contrary.

### 3.1. Soil water

The spatial varied characteristics of soil water of subsided farmland are shown in figure 2. The content of soil water are all decreased as the subsided deep decreasing from the upper slope to the lower slope, the changing tendencies of soil water in 3 depths are of the same view, and the content of soil water of different depths in the same site is declining in the upper depth than the lower depth. Table 3 reveals that the content of soil water of different depths in the upper slope site of subsided deep 0.5 m of subsided farmland are all lower than the corresponding depth soil of the normal farmland, because this site is situated in the edge of the subsided farmland, during forming the subsided land, it is easy to produce crevices and accelerate the evaporate of soil water. The content of soil water of different depths in the upper and middle slope site of subsided deep 1.0 m of subsided farmland are beginning all higher than the corresponding depth soil of the normal farmland, and the content of soil water is higher as approaching the bottom site, this is that because the elevation of subsided farmland is lower than the normal farmland in the neighbor, and the deeper site of subsidence is closer to the ground-water table, the ground-water is easier to permeate to the earth's surface.

### 3.2. Soil bulk density and pore rate

The spatial varied characteristics of soil bulk density and pore rate of subsided farmland are shown separately in figure 3 and figure 4. Figure 3 reveals that the soil bulk density of different depths of subsided farmland are all increased as the increase of subsided deep in the beginning, and to reach the biggest numerical value in the slope site of subsided deep 2.5 m, then as the further increase of subsided deep, the soil bulk density are decrease as the increase of subsided deep. In addition, although figure 3 reveals the characteristic of the lower soil bulk density in the topsoil than the subsoil in the same site of subsided farmland, there are the different degree changes of increase or decrease of the soil bulk density in the different site and depth of the subsided farmland than the normal farmland. These can to be seen from table 3, the soil bulk density of different depths in the slope site of subsided deep 0.5 ~ 1.0 m of subsided farmland are lower all than the normal farmland, and the lower degree is big in the beginning. The soil bulk density of the 1 and 2 depths (0 ~ 40 cm) in the slope site of subsided deep 1.5 ~ 2.0 m of subsided farmland are all higher than the normal farmland, the soil bulk density of the 3 depth (40 ~ 60 cm) is still lower than the normal farmland, but the lower degree is declining. To the slope site of subsided deep 2.5 m, the soil bulk density of different depths of subsided farmland are all higher than the normal farmland, and the increase extent reaches the biggest numerical value. The soil bulk density of the 3 depth in the slope site of subsided deep 3.0 m of subsided farmland is lower than the normal farmland, the soil bulk density of the 1 and 2 depths are close that of the normal farmland. Then, from the subsided deep 3.5 m to 4.0 m, the soil bulk density of different depths of subsided farmland are lower all than that of the normal farmland as the increase of subsided deep, the decrease extent is more and more bigger. Besides, the figure 4 and table 3 reveal that the spatial evolution law of the soil pore rate of subsided farmland is contrary to that of the soil bulk density.

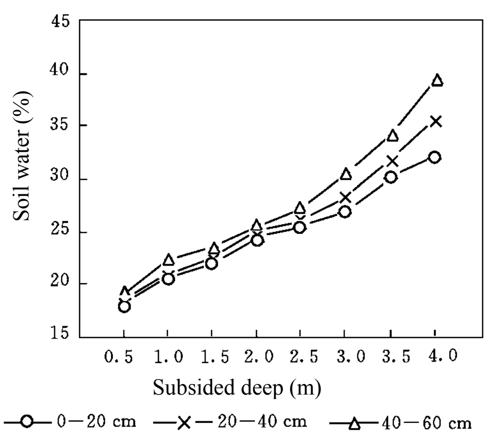


Figure 2. The spatial varied characteristics of soil water of subsided farmland

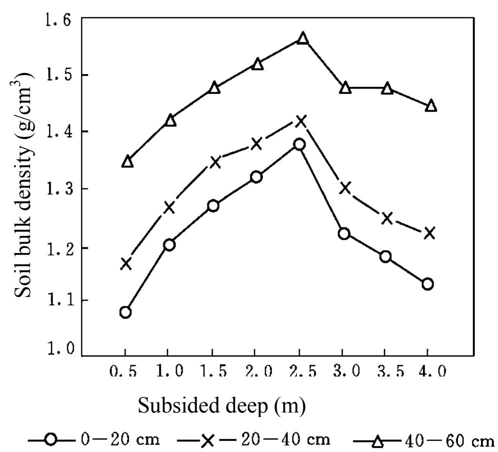


Figure 3. The spatial varied characteristics of soil bulk density of subsided farmland

It is shown from the above analysis that the crevices in the edge of the subsided farmland are the major cause of leading to the decrease of the soil bulk density and the increase of the soil pore rate. The soil bulk density of the 1 and 2 depths in the middle slope (subsided deep 1.5 ~ 2.5 m) of subsided farmland are increased gradually to the biggest numerical value, and the soil pore rate are decreased gradually to the smallest numerical value, these are related to the comprehensive effects of accelerating topsoil erosion due to the slope increase and the soil deposit during the farmland subsidence. The decrease gradually of the soil bulk density in the lower and bottom sites (subsided deep 3.0 ~ 4.0 m) of subsided farmland are related to that the substance of fine and light particles eroded from the upper and middle sites are accumulated in the lower and bottom sites.

### 3.3. Physical sandy

Table 3 reveals that the physical sandy of the depth (0 ~ 20 cm) from the subsided deep 0.5 to3.0 m are increased all in different degree than the corresponding depth of normal farmland, especially in the subsided deep 1.5 m, the increase degree of physical sandy is the bigger, these show that the topsoil of subsided farmland have the trend of becoming sandy. But in the sites of subsided deep 3.5 ~ 4.0 m, their physical sandy have the trend of decrease than the normal farmland, this identifies from the other hand that the substance of fine and light particles eroded from the upper and middle sites are accumulated in the lower and bottom sites. The spatial varied characteristics of physical sandy of subsided farmland are shown in figure 5.

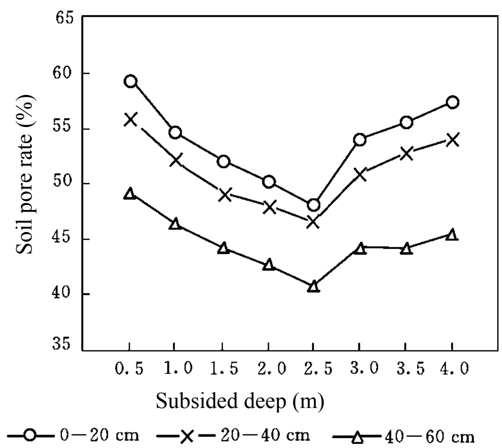


Figure 4. The spatial varied characteristics of soil pore rate of subsided farmland

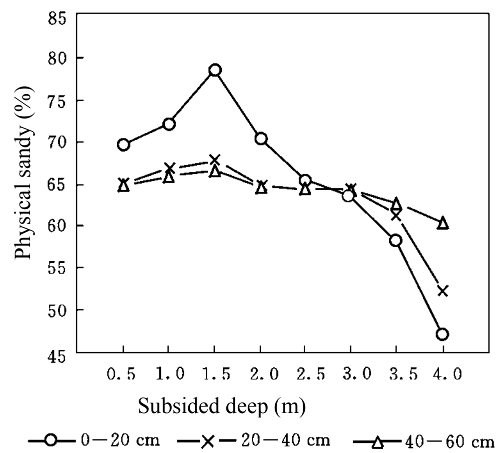


Figure 5. The spatial varied characteristics of physical sandy of subsided farmland

Figure 5 shows that the physical sandy of the 0 ~ 20 cm soil depth in the beginning of subsided deep 0.5 cm is increased as the increase of subsided deep, and reached the biggest numerical value in the subsided deep 1.5 m, then their physical sandy are decreased gradually as the further increase of subsided deep till the bottom slope site (subsided deep 4.0 m). The physical sandy of the soil depths of 20 ~ 40 cm and 40 ~ 60 cm have the corresponding changing trend, but their changing extent are smaller. In the site of subsided deep 3.0 m that is the turning point of physical sandy changing, when the subsided deep is smaller than the subsided deep 3.0 m, the physical sandy of topsoil is higher than that of subsoil, and when the subsided deep is bigger than the subsided deep 3.0 m, the physical sandy of topsoil is lower than that of subsoil. Therefore, the physical sandy of the topsoil about the subsided farmland are influenced by the subsidence due to coal mining. This also further shows that the upper and middle slopes have the trend of sandy, and the lower and bottom slopes are accumulated the fine and light particles eroded from the upper and middle sites.

### 3.4. Coefficient of spatial varied

The coefficient of spatial varied of the physical properties of the subsided farmland soil shown in table 4. The comprehensive average value of spatial varied coefficient of the physical properties in the 0 ~ 20 cm soil depth is bigger than the 20 ~ 40 cm soil depth, but the latter is bigger than the 40 ~ 60 cm soil depth, these show that the varied coefficient of the physical properties about the topsoil is big, and are influenced remarkably by the subsidence due to coal mining. Besides, in the light of the coefficient of spatial varied of different physical properties, the soil water is bigger than the physical sandy, the latter is bigger than the soil bulk density and the soil pore rate, these show that the soil water of farmland is bigger influenced by the subsidence due to coal mining, the second is the physical sandy, and the final is the soil bulk density and the soil pore rate.

Table 4. The spatial variation coefficient of the physical properties of the subsided farmland soil **%**

| Soil depth (cm) | Soil water | Soil bulk density | Soil pore rate | Physical sandy | Average |
|---|---|---|---|---|---|
| 0~20 | 18.79 | 8.05 | 6.89 | 14.73 | 12.22 |
| 20~40 | 21.67 | 6.51 | 6.22 | 7.68 | 10.52 |
| 40~60 | 23.91 | 4.46 | 5.55 | 3.13 | 9.27 |
| Average | 21.46 | 6.34 | 6.22 | 8.51 | |

## 4. Conclusions

(1) The subsidence due to coal mining accelerated the soil erosion of farmland, and influenced remarkably the physical properties of farmland, the biggest influenced is the 0 ~ 20 cm soil depth, the second is the 20 ~ 40 cm soil depth, and the third is the 40 ~ 60 cm soil depth.

(2) The soil water is increased gradually as the deepening of subsided deep. The soil bulk density of subsided farmland is increased as the deepening of subsided deep in the beginning of the upper slope, and to reach the biggest numerical value in the slope site of subsided deep 2.5 m, then are decreased gradually as the further increase of subsided deep. The spatial evolution law of the soil pore rate of subsided farmland is contrary to that of the soil bulk density. The physical sandy of subsided farmland is increased as the deepening of subsided deep in the beginning of the upper slope, and to reach the biggest numerical value in the slope site of subsided deep 1.5 m, then are decreased gradually as the further increase of subsided deep.

(3) The soils of the upper and middle slopes of subsided farmland have the trend of sandy, and the lower and bottom slopes are accumulated by the fine and light particles eroded from the upper and middle sites.

(4) The degree of influenced by subsidence of different physical properties are different, the biggest influenced is the soil water, the second is the physical sandy, and the third is the soil bulk density and the soil pore rate.

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