Technology of Antierosive Soil Surface Deriving

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Abstract. Soil condition influences on its water conductivity, defining the completeness usage of atmospheric precipitations. Water conductivity relatively may be divided into summer and winter. Summer water conductivity depends much upon ground density but winter water conductivity solves more demanding challenge – accumulation of all winter precipitations in short time and depends not so much upon the density as its moisture [1]. It is obvious, that ground moisture and the depth of its freezing define of snowmelt runoff and reflect the ability of the frozen ground to pass through itself moisture. However, more passing over the moisture is carried out by the soil with less moisture of topsoil and the depth of its freezing before spring period. Thus, carried out investigations allow to understand thoroughly the nature of spring flow of melt water and the character of washing away the soil from the slope. During crop cultivation in the steppe zone some parts of the soil rotation (up to 30%) is occupied by fallow fields, without vegetation for much time. These soils are more subjected to water and wind erosion. In this case the only possible methods of conservation them from destruction are special regional agrotechnical methods and means of tillage mechanization. Formation of planting holes on the field surface made by digging and embossing (pressing) will be more acceptable method of soil conservation from erosion under complex topography when the same field has versatile exposure and different steepness slope up to 4°. There are few articles devoted to the problem of antierosive treatment. But high agrotechnical effectiveness of holing by embossing (pressing) method on the steep slope up to 4° [2] has been established in these works. Decreasing water holding capacity of the holes influenced by form and the size of the holes as well as their position relatively slope is taken place by increasing the slope steepness. In order to exclude the influence of these factors on the hole capacity it is recommended to form them of bowl form with small capacity and in order to accumulate all snowmelt runoff on the unit area it is recommended to regulate the amount of holes, defined hydrometrical criteria of melt water flowing.

1. Introduction

The method concluding soil volume pulled out from the tracts of land by tillage tool and placed on the field surface between interfacing deepenings is used. It is known the implement with eccentrically fastened spherical disks on the shaft where plain of rotation makes up some angle with direction of forward motion (approach angle), which provides formation of deepening on field surface due to digging and soil build-up to the soil side [3, 4]. The holes of oval form are received and elongated to the direction of forward motion and located in checkrow plan. Volume of holes is regulated by angle approach. Such technology has some essential disadvantages: holes of big volume are formed and they accumulate much water, where mass possesses the storage of potential energy on the slope and pressure
on the hole sides. Loose soil owing to the previously flat-cutting tillage and method of hole formation, moisture achieves the least moisture-retaining power level (LM) becomes very flexible and semi-stable to breaking - up, and that is why if the hole side is destroyed by water in one place, as immediately avalanche effect is appeared which intensified by the destruction of next hole. Thus, the hole itself has the aim to detain some water and may become the course of water erosion (fig. 1). The holes of big size complicate their subsequent incorporation, the conditions of farmer’s work is sharply become worse but uneven density in former hole places and interhole space do not supply quantitative incorporation of seeds according to the depth of sowing. The work of disk hole-making machines supposes the direction of aggregate across the slope, which is impossible in the conditions of complex exposure of topography.

**Figure 1.** The field during spring snowmelting, tilled by disk hole-making machine

Elimination of disadvantages of hole method by pulling out the soil with tillage tool and placed it on the field surface between interfacing deepenings, however, this method may be changed by embossing. The embossing method concludes that stamp of special form is pressed into the soil and formed compacted holes (fig. 2).

**Figure 2.** – The field during spring snowmelting, tilled by pressing stamp

The process of embossed deepenings formation in the soil is carried out by pressing due to rolling with tillage tool for pushing of the soil [5], on the field treated for winter tillage.
2. Theoretical investigations

Let's consider the agrotechnological advantages of the holes in conjunction with implementation technology, sizes and volume.

2.1. The analyses of filtration rate in the holes of different volume

Under the condition, when the meaning of maximum level of melt water above the soil is more than zero \( h_{\text{max}} > 0 \), demonstration of erosion process, caused by the flow of this water is possible on the slope lands.

To prevent runoff, the retention of water on the field surface with subsequent filtration inside it is suggested to carry out with the help of moisture accumulation holes, located evenly on the field and formed below day field surface, where the volume would correspond to the amount of water, coming from snow and defining the volume \( h_{\text{max}} \), the meaning of which depends upon the rate of filtration into the soil.

Let's consider the influence of hole volume on the change of water filtration rate in them.

According to Darsi's law \[6\], filtration of water in the soil with pores of medium diameter \( d \), takes place with rate:

\[
\nu = \frac{Sd^3}{32\eta \Delta \rho}
\]

where \( \nu \) – filtration rate of water in the soil, mm/s
\( S \) – square of surface filtration, mm\(^2\);
\( \Delta \rho = \frac{\partial P}{\partial x} \), P – liquid pressure, g/mm\(^2\);
\( \eta \) – liquid viscosity, g/sm\(^2\)s
\( \rho \) – liquid compact, g/mm\(^3\);
\( g \) – intensity of gravity, m/s\(^2\).

If the depth of soil wetting along trajectory of stream movement equals \( z \), but the water layer over the filter equals \( h \), then the difference of pressure on the low and high filter borders is calculated according to the formula:

\[
\Delta \rho = -\rho gh / z .
\]

For simple calculations consider that in diametrical section the hole has rectangular form with the base of width \( a \) and height \( h \) (fig. 3).

**Figure 3. Parameters of holes**

Then the volume of water \( V \) in hole of length, equals 1, corresponds:

\[
V = l \cdot a \cdot h .
\]

The problem is arisen: what volume of the hole provides higher filtration of water in the holes? As the filtration in the hole is carried out both through the hole bottom and through its sides, then it is normally to suppose that the volume of filtration surface may be taken as:

\[
S = a + ah ,
\]
Where \( \alpha \) – the ratio, taking into account the form of the hole.

Carry out the comparative analyses of filtration rate in holes of different volumes \( V_1 \) – big (mm\(^3\)) and \( V_2 \) – small (mm\(^3\)), which are defined:

\[
V_1 = ah, \quad V_2 = \frac{V_1}{2} = \frac{a \cdot h}{\sqrt{2}}. \tag{5}
\]

Adding the meanings (2), (4), (5), (6) in equation (1), receive the filtration rate of water in the first hole:

\[
\nu_1 = K(a + \alpha \cdot h) \left(1 + \frac{h}{z} \right), \tag{7}
\]

where

\[
K = \frac{\alpha \cdot \rho \cdot g}{32 \cdot \eta}. \tag{8}
\]

The filtration rate of water in the second hole is:

\[
\nu_2 = K \left(\frac{a}{\sqrt{2}} + \alpha \cdot \frac{h}{\sqrt{2}}\right) \left(1 + \frac{h}{\sqrt{2} \cdot z} \right), \tag{9}
\]

Multiplying the expression (8) on the value \( \frac{\sqrt{2}}{2} \), receive:

\[
\nu_2 = \frac{(a + \alpha \cdot h) \left(\sqrt{2} + \frac{h}{z} \right)}{2}. \tag{10}
\]

From ratios (7) and (9) arise, that \( 2\nu_2 > \nu_1 \), may be conclusion that more preferable the holes of small sizes, where increasing of filtration rate will equal to value:

\[
\sqrt{2}(a + \alpha \cdot h). \tag{11}
\]

Let consider the dependence of filtration rate in hole upon its width and height. The formulated task comes down to as follows:

\[
\left\{ \begin{array}{l}
\left(\frac{V}{h} + \alpha \cdot h\right) \left(1 + \frac{h}{z} \right) \to \text{max} \\
16 \geq h \geq \frac{V}{100}
\end{array} \right. \tag{11}
\]

Under rather depth wetting of soil, this task has calculation: \( a = 100; h = V / 100 \), that is hole must be wider. However, during the initial stage, when regenerating flows in the soil depth are not interfuse in common flow, deeper hole will provides faster filtration.

It is necessary to note that holing provides not only holding of melt water on the slope, but allows to carry out filtration in low soil layer on the depth of 16 cm. in early stage. It allows to decrease moisture volume which is not absorbed into the soil in comparison with calculated thawing period of next day. Thus filtration in more compact layers is extended to the long time period.
3. Experimental investigations

3.1. Main agrotechnological indexes of comparative technologies and the results of experimental investigations

Make the comparative analyses of erosion-resisting and moisture accumulating capacity of holes, carried out by digging and pressing method.

Main parameters of holes are presented in the table 1. The volume of digging hole is 15 l, and pressing hole is 2.1 l, the total volume on unit area is achieved by their quantitative ratio respectively equals to 1.5 and 11 pcs/m².

Table 1. Parameters of holes

| №  | Indexes                        | Holes made by method |
|----|--------------------------------|----------------------|
|    |                                | digging   | pressing |
| 1  | Hole volume, l                 | 15.0      | 2.10     |
| 2  | Hole depth, m                  | 0.14      | 0.10     |
| 3  | Hole width, m                  | 0.39      | 0.20     |
| 4  | Hole length, m                 | 1.10      | 0.34     |
| 5  | Amount of holes on 1 square m  | 1.50      | 11.00    |
| 6  | Total volume on 1 square m     | 22.5      | 23.1     |

Accumulation of moisture from winter precipitations by the soil is defined due to the difference of soil moisture in the periods of winter beginning and after snow melting. Saturation with melt water is defined in ratio percentages of accumulated precipitations to the water storage in snow, coming during its melting (table 2). Comparative analyses testifies that the criteria of accumulated melt water by the soil is autumn weather conditions of previous year, defined soil condition before winter. The main criteria, defined the capacity of the soil to pass through itself melt waters in the steppe zone of the Western Siberia is the volume of autumn moistening of the soil, particularly its upper horizons [7, 8].

Table 2. Dynamics of winter precipitations moisture in soil layer of 1 meter, mm

| variant | Autumn moisture accumulation | Water storage in snow | Technology of holes making by the method |
|---------|-------------------------------|-----------------------|-----------------------------------------|
|         |                               |                       | Spring moisture accumulation | Moisture accumulation | Assimilation of melt water, % | Spring moisture accumulation | Moisture accumulation | Assimilation of melt water, % |
|         |                               |                       | digging                      | pressing              |                               | digging                      | pressing              |                               |
| 1       | 210.0                         | 108.0                 | 210.2                       | +0.2                  | 0.2                           | 214.6                       | +4.6                  | 4.3                           |
| 2       | 175.4                         | 103.0                 | 217.0                       | +42.1                 | 40.9                          | 225.9                       | +50.5                 | 49.0                          |
| 3       | 175.8                         | 112.0                 | 189.9                       | +14.1                 | 12.6                          | 207.6                       | +31.9                 | 28.4                          |
| 4       | 134.0                         | 93.0                  | 159.7                       | +25.7                 | 27.6                          | 219.1                       | +85.1                 | 91.5                          |
| medium  | 173.4                         | 104.0                 | 194.3                       | +20.5                 | 19.7                          | 216.8                       | +43.0                 | 41.4                          |

In autumn under maximum wetting of upper layer (variant 1) 0-10 cm up to 40 % to the soil mass, in spring the moisture accumulation was minimum during all investigation period and in smaller holes made up + 4.6; in bigger holes + 0.2 mm. Assimilation of winter precipitations moisture respectively equals to 4.3%, 0.2%. In spring, when the soil was dry (variant 4), moisture was nearly to wilting point (WP) and made up about 13 %, flow was not observed in any hole method. However, maximum assimilation of melt water, 91.5 % (+ 85.1 mm) was marked in small holes. In bigger holes – assimilation was lower and made up 27.6 % (+ 25.7 mm). Under medium autumn storage in layer of 1 meter is 175
mm (variant 2 and 3) moisture accumulation in spring was defined by hole making method. The accumulation + 50.5 and + 31.9 mm was respectively observed according to the variants in smaller holes, that in 1.2 and 2.3 times more than in bigger ones. Water accumulation by the soil during the same interval in different holes at an average according to 4 variants made up: on the plots with big holes + 20.5 mm; on the plots with small holes – + 43.0 mm. If we take the filtration rate as the relation of absorbed water to time period, during which the absorption has taken place, that relation of filtration rates during the same period of time will be equal to the relation of quantity of the absorbed water:

\[ \frac{v_1}{v_2} = \frac{Q_1}{Q_2} \].

(12)

Numeral meaning of the expression for our case will be:

\[ \frac{v_1}{v_2} = \frac{43.0}{20.5} = 2.1 \].

(13)

Filtration rate of smaller holes in 2.1 times higher than in big holes.

The reverse relationship is revealed between the quantity of the absorbed water and the flow of melt water. Figures about flows distribution according to the variants on the comparative holes are given in the table 3.

Table 3. – Water flow in the holes of different volume, m\(^3\)/ha

| variant | Technology of holes making by the method |
|---------|----------------------------------------|
|         | digging                                |
| 1       | 652.0                                  |
| 2       | 534.0                                  |
| 3       | 557.0                                  |
| 4       | Flow was not observed                   |
| medium  | 436.0                                  |
|         | pressing                               |
| 1       | 635.0                                  |
| 2       | 234.0                                  |
| 3       | 268.0                                  |
|         | 284.3                                  |

**Figure 4.** – Dependence of flow water from autumn soil moisture: 
a – in big holes, b – in small holes

Experimental investigations allow to make the conclusion, that soil moisture nearly to HB, information of holes making methods can’t influence effectively on increase of water filtration in the soil and on reduction
of its flow as the increase of water layer from the snow is higher than its filtration capacity, however on the slopes they are able to retain moisture corresponding to the volume of waterholding capacity of holes without its filtration into the soil.

When moisture near to the WP, collapse filtration independent upon the hole size is observed.

Under medium autumn moisture of the soil during interrelation both factors are observed, at that runoff volume is in inverse dependence on the filtration rate, which we can regulate (according to the calculation results) by the hole sizes of the same volume which is corresponded to the theoretical calculation of maximum water flow $15.7 \text{ m}^3/\text{ha}$ [59]. Namely under these conditions the most effective method is the pressing of small holes.

The result of water filtration into the soil will be the additional heat transportation in deep horizons. Then during the condensation of 1 gr. of water the sufficient heat for ice melting 7.5 gr. is generated, for this reason the first water drops in frozen soil do not catch freeze down, but thaw it. Daily length of water filtration is increased owing to its accumulation and thawing process takes place more intensive, for example, the thawing depth in large holes is $19.5 \text{ cm}$, in small holes is $20.7 \text{ cm}$. The difference of $1.2 \text{ cm}$ on thawing of the soil between large and small holes is explained by the processes taking place in holes during twenty-four-hour period.

During the day water is accumulated in hole and some part is passed through the soil, another is stayed [9]. All holes are filled up with water to the night, water from the snow in this period of time is declined up to the minimum, it is possible to accept that infiltration process takes place without additional water flow. During the nights negative temperatures water surface in holes freezes up, forming ice crust (fig. 5), however its thickness is different and makes up $3.7 \text{ mm}$ in large holes, and in particular cases up to $5 \text{ mm}$ and $2.2 \text{ mm}$ in small holes that proves the difference of filtration rates.

![Process in hole in snow loss period](image)

Figure 5. – Process in hole in snow loss period

It is necessary to note, that the rest of water in both holes at the beginning of melting is not observed next day. However the condition of hole bottom is different. In the morning the depth of soil melting in the bottom is different and makes up $2.1 \text{ cm}$ in large holes, and $7.0 \text{ mm}$ in small holes. It is explained that under initial similar conditions of ice crust melting small holes are loosen from ice faster and immediately changed the radiation properties of hole surfaces: the surface of conserved ice in big holes absorbs only 30-40% of sun radiation, at the same time water in small hole absorbs more than 50%, that is heat accumulation in small hole is more and as the result it is ready to take and pass through itself the first portion of melt water earlier.

The processes of twenty-four-hour period of alternate soil freezing – thawing of soil for compacted hole play the positive role in decomposition of walls and volume changing in the direction of reduction [9]. More intensive decomposition of the soil is observed in bottom of the hole, because it has maximum
density of composition up to 1.2 g/cm³, process decomposition grows on with moisture increasing of upper horizon, which reaches 40% to soil mass in the period of snow melting, according to these meanings decomposition of the soil reaches maximum value [10].

The depth of small hole is reduced from 10.1 to 4.0 cm in the period of snow melting. Changing of large hole depth is 0.4 cm in the period of snow melting decreasing up to 13.6 cm. The process of swelling soil, that is increasing soil volume plays an important role in changing hole volume in addition to the process of freezing – thawing. Upper humus layers swell more than lower, this process will take place in holes differently due to the way of their formation. Thus, the power of humus horizon is not changed in small holes and swelling is observed to a large extent than in large holes, the power of humus horizon in large holes is reduced according to the depth of selected soil – 14 cm, that is why soil swelling in the hole is less. Thus, after loss of snow field surface with small holes has large uniformity in comparison with big holes, providing less area of evaporation and therefore the best conservation of soil moisture.

Soil fertility indexes: removal of the soil, humus and macroelements were defined from water samples and proportionated to its runoff [10]. In small holes in comparison with large holes: washing away soil by 1.7, removal of humus as the main index of soil fertility by 4, phosphorus by 1.8, potassium by 1.8, but the analyses of nitrogen content in this period is difficult due to the high flexibility.

4. Conclusion

Making of small holes to a large extent satisfies antierosive system of agriculture on slopes in districts of freezing soil, as in comparison with larger holes less runoff, soil losses, increasing of soil fertility and additional moisture accumulation of winter participation have been reached.

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