Empirical Relationships of Humus Formation in Soils in the Arid Zone of Kazakhstan

N. Khozhanov1, Kh. Tursunbaev1, M. Masathayev1, D. Nurabayev1, P. Assis2

1M. Kh. DulatyTaraz State University, Kazakhstan
2Federal University of Ouro Preto, Brazil

Abstract: It was performed analytical work to determine the relationship between the level of humification of the soil for the rational use of agronomic practices and predicting the biological yields of crops. Since there was a place of irrational use of bioenergy potential of the irrigated areas, the further formation and decomposition of the process of humus formation depends on the level of agricultural engineering and farming system. Rational use and introduction of innovative technologies like drip irrigation, automation, water management creates favorable conditions for expanded reproduction of soil fertility and environmental improvement in irrigated agriculture.

Keywords: Humus formation, radiation index, fertility, terrain height, temperature and humidity

1. Introduction

The European Union, together with Kazakhstan, is implementing a project on transition to a green economy model. Based on this project, in the address of the head of state to the people of the Republic of Kazakhstan from January 31 in 2017 "The third modernization of Kazakhstan: global competitiveness" noted that the agricultural sector should be a new driver of economy. This means about the needs to effectively use land for 5 years to increase the area of irrigated land by 40% to reach 2 million hectares with an increase in investment to agrarian research. While the implementation of priority directions by diversifying agricultural products in the agricultural sector allows increasing the level of processing products with the creation of an efficient system of storage, transportation and sales of goods, to ensure an increase in exports of food products by 40% by 2021 [1]

The level of humus formation in natural conditions depends on agriculture from surface air temperature, temperature and soil humidity, as well as from the evapotranspiration of the plant and evaporation with soil surface that have a direct effect on crop productivity. This allows rational use of climate data and zonal distribution of crops in order to obtain maximum possible biological yield of irrigated farming.

Analysis of years of marketing research has shown that irrational use of energy resources led to strengthening processes of anthropogenic desertification, which causes the need to move to a new level of evaluation of the basic principles and farming system methods.

The practice of farming shows that the indicators of the ameliorative components mode are far from equivalent in zone of the same geographical area. The optimal combination of land in the structure of the natural-ecological complex is a difficult task and its solution should be based on a quantitative description of the interrelated natural, anthropogenic impacts and be optimized with taking into account socio-economic and environmental indicators.

2. Literature Survey

It is known that water and nutrients that determine the regulation of the main factors of plant life are in a state of uninterrupted circulation, and their direction is the same, but the speeds differ significantly. So for example, ash and chemical elements are involved in both as biological and as man-made cycle, does the significant impact on the molecular processes occurring in the soil. Considering that soils are a complex mechanism, where microbiological processes play a significant role along with chemical reactions, agricultural production management should be aimed at regulating internal moisture circulation, balancing the accumulation and mineralization of organic matter and leading to an increase in fertility while satisfying the needs of plants in water and batteries [2,3].

The productivity of the agro-landscape, including the productivity of agricultural land and reclaimed land is assessed as follows. Equation 1.

\[ P = S \times CL \text{ (for natural cenosis)} \]
\[ P = S \times ART \times GGT \]

(1)

where \( P \) = potential productivity of vegetation biomass in given soil and climatic conditions. \( t/ha \) of air-dry matter; \( S = \) index of the soil; \( CL = \) climate favorable factor; \( ART = \) indicator of compliance with the climatic conditions of this culture; \( GGT = \) coefficient depending on the culture of production.

With increasing production potential, it is very important to know the dynamics of accumulation or drawdown of humus reserves in the soil. The change in humus reserves can be approximately described by a differential equation 2 [4].

\[ \frac{dG}{dt} = A - BG. t/\text{(ha \times year)} \]

(2)

Integrating it gives:

\[ G = A/B + (G_0 - A/B) \exp(-B \times t) \]
where \( G_0 \) is the current reserves of humus, \( t / \text{ha} \); \( A = \) formation of new humus due to humification of plant residues \( (G_{plant}) \) or organic fertilizers \( (G_{org}) \); including siderite, as well as loss of humus at descending moisture currents \( (G_{phys}) \), \( t / \text{ha} \); \( B = \) coefficient taking into account the loss of humus, year \(^{-1}\); \( t = \) time, year.

The formation of new humus is estimated by dependency, as shown in the equation 3:

\[
A = G_{plant} + G_{org} + G_{phys}
\]  

(3)

To calculate the amount of humus in the humification of organic residues, you can use the formula 4 [5]:

\[
G = P \ast K_r \ast K_h ,
\]  

(4)

where \( P \) is the yield of agricultural crops, \( t / \text{ha} \); \( K_r \ast \) is the root yield ratio (dry matter); \( K_h \) - coefficient humification dry matter. The values of the coefficients \( K_r \) and \( K_h \) are listed in table 1.

Estimation of the amount of humus coming in the composition of organic fertilizers is carried out using an iso humus coefficient determining the amount of stable humus formed from 1 kg (in terms of dry matter) of organic matter introduced into the soil or organic fertilizer, equation 5 [6]:

\[
G_{eq} = K_r
\]  

(5)

where \( K_r \) is the isohumus coefficient; \( D = \) dose of organic fertilizer, \( t / \text{ha} \) of dry matter.

From the analysis of these materials, it becomes clear that under the influence of vegetation, the number and composition of microorganisms, and consequently, the intensity of the processes in which they participate, change. Such changes, the result of the interaction of plants and microorganisms, determine the degree of development and nutrition of crops. In this regard, it is believed that there is a need to study the microflora of the rhizosphere in order to develop techniques that favorably affect its development and composition, improving the nourishment of aethienia and obtain high yields, taking into account the energy resources of a particular area.

Based on many years of field research for the period 1984–2016 in the region of the southern Aral Sea region, N. Khozhanov [7-11] identified the structure of the formation of the natural environment, the level of soil humus formation \((M_p)\), which shows that the maximum number of factors affecting the soil-forming process, focused on the level of the landscape provinces and geographical areas, is described by the following expression., equation (6).

\[
M_p = (0.42 R_h + 0.15 \beta + 0.09 S_h + 0.09 T_h + 0.08 W_h + 0.04 V_h + 0.040 C + 0.03 M_{org} + 0.03 b) \ast 0.1 \mu
\]  

(6)

where \( R_h \) is the radiation balance taking into account terrain marks, \( \beta \) is the proportion of groundwater salinity, \( S_h \) is the indicator of soil salinity, \( T_h \) is the air temperature in °C.

### Table 1: The value of the coefficients \( K_r \) and \( K_h \) [5]

<table>
<thead>
<tr>
<th>Culture</th>
<th>Organic matter yield of root residues (dry matter) ((K_r))</th>
<th>Coefficient of humification of dry matter ((K_h))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-year perennial grasses for ha/y</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>1-year perennial grasses for ha/y</td>
<td>0.15</td>
<td>0.2</td>
</tr>
<tr>
<td>Perennial grasses 2 and 3 years for ha/y</td>
<td>1.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Perennial grasses 2 and 3 years for green fodder</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Annual herbs in ha/y</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Annual herbs for green food</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Cereals and legumes</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Potatoes (roots)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Corn for silage</td>
<td>0.07</td>
<td>0.2</td>
</tr>
</tbody>
</table>

\( W_h \) is the air humidity in \( \% \); \( V_w \) is wind speed, \( m/s \); \( O_i \) is the amount of precipitation, \( mm/year \); \( M_j \) is the fraction of salinity of irrigation water, \( h_0 \) - level of ground water, \( g/l \); \( \mu \) - coefficient taking into account the use of agricultural methods and farming system [7-9].

In the process of humus formation, solar radiation \((R)\), latitude \((\delta)\) and altitude \((H)\), as well as air temperature in period above 10 ° C [2, 3].

Empirical relationship of the radiation balance \((R)\) with the sum of temperatures \((t)\) above 10 ° C:

- For areas of excessive moisture gives in the following formula (equation below as (6)).

\[
R = 8.52 + 0.01042 \left( \sum(t/n) \right) > 10^0 \text{C (6)}
\]

- For the Urals:

\[
R = 7.0 + 0.011 \left( \sum(t/n) \right) > 10^0 \text{C (6)}
\]

- For Belarus:

\[
R = 10.80 + 0.0093 \left( \sum(t/n) \right) > 10^0 \text{C (6)}
\]

For the arid zone of Russia and Central Asia:

\[
R = 13.39 + 0.0079 \left( \sum(t/n) \right) > 10^0 \text{C}
\]
3. Methodology

In the sequence, the method of mathematical analysys, used the existing empirical formulas, and the basis of these it was identified empirical relationships between the ratio balance and the absolute elevation of terrain.

4. Results and Discussions

For the natural system of Kazakhstan, the indicators of radiation balance(R), depending on the absolute height of the terrain (H), have not been previously considered. Therefore, we tried to identify this gap of science and clarify the actual energy indicators, taking into account the geography of the area:

- for the Southern region of Kazakhstan

\[ R = L\text{Oc}^* (1000-H) / 250 \]  

where \( L \) = heat of vaporization (cal/cm\(^2\)) \( Oc \) = Rain/Water precipitation, mm/year. \( H \) = height of the terrain, m

In this proposed equations it is represented the actual geographical state of a particular region. It clearly expressed indices of latent heat of vaporization (L), height of the terrain (H) and amount of precipitation (mm), which reliably reflects the actual values of the radiation balance (R) [4, 5, 12-14].

The study of the heat balance of the irrigated zone at allowed us to establish a link between the radiation balance (R) and evaporation (E\(_0\)), which is correlated by the dependence. Equation 8.

\[ R = (E_0 + 800) / (10^*H) \]  

Thus, based on the data of the radiation balance, it becomes necessary to further improve the methodology for regulating soil-ameliorative criteria based on the energy.

\[ R_H = R/H \]  

and describe as an indicator of the radiation index per unit of absolute height of the maximum. From here it can be seen that with the same soil and climate in the region, the indicators (R\(_H\)) are not the same. This gives grounds to believe that the agro technical and ameliorative measures used in the long-term section, aimed at obtaining large yields of agricultural crops, have not fully justified themselves. Since here was a place of irrational use of bioenergy potential, which determined insolvency and difference in terms of the indicator R\(_H\) [8-12].

- For the mountainous zone 2.0 < R\(_H\) < 28.96;

- For the foothill zone, the indicators range from 0.3 < R\(_H\) <2.0;

- For the flat zone of Kazakhstan - 0 < R\(_H\) <0.3

On the basis of the calculated climate data, it follows that a minimum values for the soil humus formation level is M\(_H\) = 0.852 %, and at maximum values it corresponds to 2.977%. The soil humus formation level changes depending on the absolute terrain presented in the equation 6.

Thus, over the course of many years in the development of the programme cultivation of crops on the basis of predictive calculations using empirical formulas, scientists and experts distorted the calculated data to predict the food program, which ultimately affected the bruto yield and sustainability of the agricultural sector. Table 2 shows the results obtained by this paper.

<table>
<thead>
<tr>
<th>#</th>
<th>Meteo stations</th>
<th>Calculated bioenergy</th>
<th>Biological crop of corn for silo, t/ha</th>
<th>Opportunities for biological damage, share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Coefficient (9)</td>
<td>when R based on (6)</td>
<td>with calculated R (7)</td>
</tr>
<tr>
<td>1</td>
<td>Suzak</td>
<td>0.061</td>
<td>63.2</td>
<td>104.4</td>
</tr>
<tr>
<td>2</td>
<td>Turkestan</td>
<td>0.090</td>
<td>69.1</td>
<td>155.1</td>
</tr>
<tr>
<td>3</td>
<td>Tulkubas</td>
<td>0.096</td>
<td>63.8</td>
<td>164.5</td>
</tr>
<tr>
<td>4</td>
<td>Arys</td>
<td>0.091</td>
<td>69.9</td>
<td>172.2</td>
</tr>
<tr>
<td>5</td>
<td>Shymkent</td>
<td>0.127</td>
<td>65.9</td>
<td>217.5</td>
</tr>
<tr>
<td>6</td>
<td>Shardara</td>
<td>0.095</td>
<td>69.7</td>
<td>162.6</td>
</tr>
</tbody>
</table>

Since there was a place of irrational use of bioenergy potential of the irrigated areas, the further formation and decomposition of the process of humus formation depends on the level of agricultural engineering and farming system.

5. Conclusions

1. Implementation of the analytical work allows to determine the relationship between natural indicators and the level of soil humus formation (M\(_H\)) for the rational use of agricultural practices and prediction of biological yields of agricultural crops.

2. The proposed methods for calculating humus formation take into account the natural resources reflecting the influence of climate parameters for each region.

3. Studies have established that in the limits of the arid zone of Central Asia and Kazakhstan, in particular in the areas of the Southern Aral Sea region, natural climatic indicators provide an annual and natural/conditions to form from 0.852 to 2.977% of humus.
4. In the plain zone, where the radiation index of the 
absolute height of the terrain (Rd) is 0.3 in order to 
maintain the process of humus formation at the level of 
1-2% and more, it is necessary to intensify the level of 
government budgets through the widespread introduction of 
phyto- meliorative crops.

5. Rational use and introduction of innovative technology, 
such as drip irrigation, water use automation, creates 
favorable conditions for the soil fertility and ecological 
improvement of irrigated agriculture.

6. **Future Scope**

It is expected to improve land use approaches of 
the regional use of land taking into account the radiation in 
balance in a specific geographical area, like Kazakhstan 
and in Brazil.

**Acknowledgments**

The authors would like to acknowledge Mr. Angsar for his 
helpful aid, Taraz State University and Federal University 
of Ouro Preto to provide conditions for publishing this paper.

**Author Profiles**

**N. N. Khozhanov**, Hydraulic Engineer 1978. at 
MGMI. The candidate of agricultural Sciences, 1979, a Senior researcher in 1991. He worked 
as an employee at the Karakalpak Agricultural 
Research Institute named after Musayev for almost 20 
years. Then from 2007 to the present time he works at 
Taraz State University named after M. Kh. Dulaty as an 
Associate Professor of the Department of "Land 
Reclamation and Agronomy". Participated in the 
development of an educational program on reclamation of 
degraded lands and pasture development of Ministry of 
Education and Science of Republic of Kazakhstan. E-mail: khozhanov55[at]mail.ru, https://orcid.org/0000-0003-0671-8307

**Kh. I. Tursunbayev**, Civil Engineer in 1974 at 
TashP.I. Tashken. From 1977 until 1984 
worked in the design and survey Institute 
"Sredazgidro project" worked as a leading 
engineer for almost 7 years. Then for 20 years he worked in 
Tashkettsoy Regional Department as chief economist and 
Deputy mayor for Economics and from 2015 to the present 
senior lecturer of the Department of Land Reclamation and 
M. Kh. Dulatyagronomy Taraz state University., 
Kazakhstan, e-mail: khambar2016[at]yandex.ru

**M. Kh. Masatbayev**, PhD Student, Hydraulic 
Engineer 2007. M. Kh Dulaty Taraz State 
University. In 2009, he got Master's degree in 
"Water resources and water use" at Taraz State 
University. M. H. Dulaty, Kazakhstan. In 2018he entered 
for Doctoral studies in the specialty " Reclamation and 
irrigated agriculture" at M.Kh.Dulaty Taraz State 
University, E-mail: masatbaev82[at]bk.ru, 
https://orcid.org/0000-0002-8171-9716

**D. M. Nurabayev**, D. M. Nurabayev, Hydraulic Engineer 1983 MGMI 1975, 
Moscow. In 1992 he defended his thesis on 
specialty: Candidate of technical Sciences. He 
has been working as an Associate Professor in the 
Department of Land Reclamation and agronomy of Taraz 
state University for almost 19 years. He participated in the 
international project on the topic: "Research of the 
mechanism of sugar beet cultivation with drip irrigation 
and plastic Mulching” within the framework of the 
agreement on international cooperation in the field of 
education and science between Shih-Tzu University of 
China and M. Kh. Dulaty Taraz state University in 2011- 
2013. Docent at M. Kh. Dulaty Taraz State University 
named, Kazakhstan. 
E-mail: Nurabaev_d[at]mail.ru

**P. S. Assis**, Metallurgical Engineer at UFMG, 
Dr-Ing at RWTH, Germany, 1991. He worked 
as Collaborator at Acesita (now APERAM) 
and Mannesmann (now Vallourec) during almost 19 years. 
Then turned to University as Professor at UFOP (Federal 
University of Ouro Preto, Brazil). Visiting Prof at UFF, 
Niterói, Brazil. From 2000, Honorary Prof at Hebei 
University, China. Full Prof at Federal University of Ouro 
Preto, Brazil & Invited Prof. at Taraz State University 
named M. Kh. Dulaty, Kazakhstan.e-mail: 
assis[at]ufop.edu.br, https://orcid.org/0000-0003-0874- 
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