Application of the neuro-fuzzy approach to solving problems of soil phases evaluation

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Abstract. The role of variety in the efficient use of fertilizers is enormous. However, most researchers limited their studies to stating the facts about the different productivity of varieties under certain conditions of mineral nutrition. Varieties bear the "imprint" of the conditions in which they are bred. Hence, it is necessary to studythe features of their nutrition, the crop formation, and the quality of products at different forms, doses, ratios, terms and methods of applying mineral fertilizers on various soils of thecultivation zone of a given crop. The main aim of the article is to evaluate soil phases based on the use of a neuro-fuzzy approach. Three soil types were considered: irrigated typical serozem, serozem-meadow soil, and newly irrigated light serozem. A computational experiment was conducted to assess the type of soil, taking into account characteristics such as soil density and humus in percentage terms.

1 Introduction

Agro chemists have mainly studied the response of different varieties of cotton to fertilizers, recording changes in growth and yield. However, the changes in morphological, physiological processes, crop structure, technological properties of fiber, seed oil content in different varieties at different rates and ratios of fertilizers were insufficiently studied. In addition, conducting such studies on one type of soil does not provide the necessary material about the response of one or another cotton variety to fertilizers on other types of soils [1-3].

The soils of the cotton-growing zone, firstly, vary greatly in the depth of the groundwater table. It is clear that a variety bred in conditions of automorphic soils will grow and develop on hydromorphic soils, but the influence of new soil conditions will be distinctive. It is known that in soils with a close occurrence of groundwater, there is a completely different water, air, temperature regime, a different composition of microorganisms, a different ratio of

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ammonia and saltpetrous forms of nitrogen, phosphorus compounds, and potassium. In spring, hydromorphic soil is highly saturated with water, anaerobic conditions are created for microorganisms, it contains more ammonia nitrogen, the solubility of phosphorus compounds is worse, and the soil has a relatively low temperature, etc. The influence of the water regime of soil is so strong that the soil, which shows nitrogen in the first minimum under certain moisture content, in other conditions shows phosphorus in the first minimum [4-6].

Secondly, the soil texture largely determines the specificity of soil conditions. A variety bred on light soils (which have excellent water-air, temperature regimes and nutrient phases) cannot be recommended for heavy soils since varieties, being in a completely different environment, reduce their productivity. In all soil zones with light soils, the efficiency of fertilizers, especially nitrogenous and potassiumfertilizers increases [7–8].

Thirdly, highly cultivated soils optimally combine factors and plants, using them most productively, providing the highest possible yield. Therefore, a variety bred on medium and poorly cultivated soils will yield a reduced crop.

Let us consider three types of soils: irrigated typical serozem, sierozem-meadow soil, and newly irrigated light sierozem.

Soil-forming rocks of irrigated typical gray soils are thick mesial deposits with favorable hydrophysical properties. Groundwater lies deeper than 10 m. Therefore, they do not affect the formation of soils. The lands have long been cultivated, and various crops have been bred on them.

The described irrigated typical serozem is characterized by a very low content of humus, nitrogen, and mobile forms of phosphorus and potassium both in the arable and subsurface layers. Apparently, the main reason for this is that the plotwas used for many years for vegetable crops without applying enough amount of fertilizers.

With the development of irrigation, which caused the groundwater to rise to 1.5 - 2.0 m, irrigated sierozem-meadow soils develop under conditions of constant capillary moisture. As a result, a meadow process begins: the upper horizons become more humus-rich, while the deep ones become over-wetted and acquire a bluish-greencolor, a sign of gleying.

These soils are heavy loam in texture. The profile of the sectionis rather uniform in terms of the content of physical clay. The water-physical and agrochemical properties of this soil also differ from the typical irrigated serozem.

According to the soil texture, the entire one and a half meters of the soil profile of the newly irrigated light serozem belongs to light loam. Most of the particles are coarse dust ones, which have a great influence on the water-physical properties of soil. The least and total moisture capacity are small. Air occupies a sufficient volume of soil both at the least and totalmoisture capacity

The soil is characterized by a low content of humus and total nitrogen in the topsoil. Apparently, the main reason for this is the intensive decomposition of organic matter in the first years of irrigation. A gradual decrease in their contentis observed in the lower layers. It also contains little amount of total and mobile phosphorus. The largest amount of it was noted in the arable layer. Potassium mobile in the arable and subsurface layers is present in a significant amount, in the lower layers it is noticeably less.

To assess the land, it is appropriate to use a fuzzy and neuro-fuzzy logical models.

The "fuzziness" of human knowledge and way of thinking is now considered a necessary component of any system that is adequate in its capabilities to the abilities and intelligence of a person. Further construction of a rigorous mathematical theory and its application in various fields of knowledge are associated with such well-known scientists as R. Bellman, A. Kofman, T. Saaty, and L.A. Zadeh [12-13].

2 Methods and models

The process of building a fuzzy expert system for soil assessment is conducted according to the following algorithm:

1. Normalization of input data. In the general case, each input variable x_i, $i = \overline{1,n}$ has its own membership functions for fuzzy terms (L - low, bA - below average, A - average, aA - above average, h - high) used in the equations.

2. Fuzzification.

The choice of such functions is due to the fact that they are good approximations of the membership functions obtained by experts by the method of pairwise comparisons.

3. Making a decision. For the input data $X^* = \left(x_1^*, x_2^*, \ldots, x_n^*\right)$, the values of the membership functions $\mu^j(x_i^*)$, $i = \overline{1,n}$, are determined.

4. Calculation of $\mu^{d_j}\left(x_1^*, x_2^*, \ldots, x_n^*\right)$ for $X^* = \left(x_1^*, x_2^*, \ldots, x_n^*\right)$ forall $d_1, d_2, \ldots, d_m$.

4. d_j^* isdetermined, here: $\mu^{d_j^*}\left(x_1^*, x_2^*, \ldots, x_n^*\right) = \max\limits_{j=\overline{1,n}}\left[\mu^{d_j}\left(x_1^*, x_2^*, \ldots, x_n^*\right)\right]$.

After determining the algorithm of the system and partitioning (if necessary) the task into subtasks, the development of a scheme of training examples for each of the subtasks follows. The example scheme includes a list of inputs and outputs for a given subtask.

3 Results

A computational experiment was conducted to assess the type of soil, taking into account the following characteristics: the average temperature in April, the average amount of precipitation in April, humus (%), density (g\cm^3), (Table 1).

Table 1. Fragment of input parameters of the computational experiment.

№	**Average temperature in April (^0C)**	**Average Precipitation in April (mm)**	**Humus(%)**	**Density (g\cm^3)**	**Soil type**
1	15	68.8	1.14	1.27	1
2	15	68.8	0.83	1.37	1
3	15	68.8	0.51	1.34	1
4	15	68.8	0.42	1.32	1
5	14.1	50.5	1.24	1.26	2
6	14.1	50.5	0.98	1.41	2
7	14.1	50.5	0.62	1.38	2
8	14.1	50.5	0.43	1.42	2
9	15.8	42.2	0.64	1.4	3
10	15.8	42.2	0.46	1.41	3
11	15.8	42.2	0.56	1.44	3
12	15.8	42.2	0.21	1.47	3

The results of a computational experiment on the algorithm for making diagnostic decisions using neuro-fuzzy technologies are given in tabular (Table 2) and graphical forms (Figs. 1 and 2).

Table 2. Fragment of the output data of the computational experiment.

No.	Average temperature in April (^0C)	Average precipitation in April (mm)	Humus (%)	Density (g/cm^3)	Soil type	Soil type obtained from fuzzy model	Type soil type obtained from neuro-fuzzy model	Soil type obtained from linear regression model	Soil type obtained from non-linear regression model	Fuzzy model error	Neuro-fuzzy model error	Linear regression model error	Non-linear regression model error.
1	15.00	68.80	1.14	1.27	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.05	0.06
2	15.00	68.80	0.83	1.37	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.03	0.03
3	15.00	68.80	0.51	1.34	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.05	0.01
4	15.00	68.80	0.42	1.32	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.08	0.01
5	14.10	50.50	1.24	1.26	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.04	0.03
6	14.10	50.50	0.98	1.41	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.04	0.02
7	14.10	50.50	0.62	1.38	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0. 01
8	14.10	50.50	0.43	1.42	2.00	2.00	2.00	2.00	2.00	0.00	0.00	0.01	0.00
9	15.50	46.20	0.64	1.40	3.00	3.00	3.00	2.99	3.00	0.00	0.00	0.28	0.01
10	15.70	47.20	0.46	1.41	3.00	3.00	3.00	3.01	3.00	0.00	0.00	0.25	0.00
11	15.80	48.20	0.56	1.44	3.00	3.06	3.06	2.98	2.96	2.12	1.98	0.76	1.44
12	15.90	49.20	0.21	1.47	3.00	3.13	3.12	2.95	2.91	4.24	3.93	1.81	2.86
13	15.20	67.80	0.51	1.34	1.00	0.99	0.99	1.17	1.16	1.45	1.33	17.11	15.84
14	15.10	65.80	0.42	1.32	1.00	0.96	0.96	1.28	1.26	4.36	4.13	27.93	25.51
15	14.30	49.00	1.24	1.26	2.00	1.94	1.95	2.21	2.22	2.97	2.65	10.56	10.98
16	14.50	49.50	0.98	1.41	2.00	1.96	1.97	2.27	2.27	1.98	1.63	13.32	13.34

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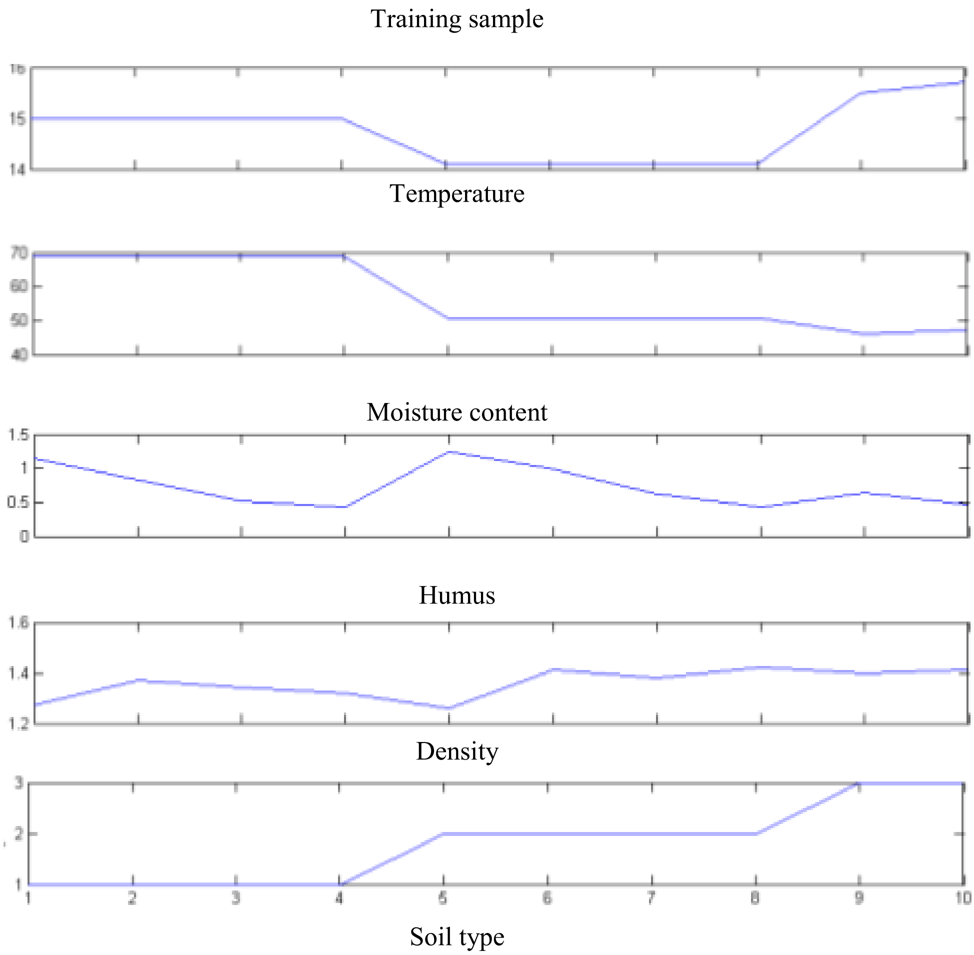

Fig. 1. Training sample for soil assessment.

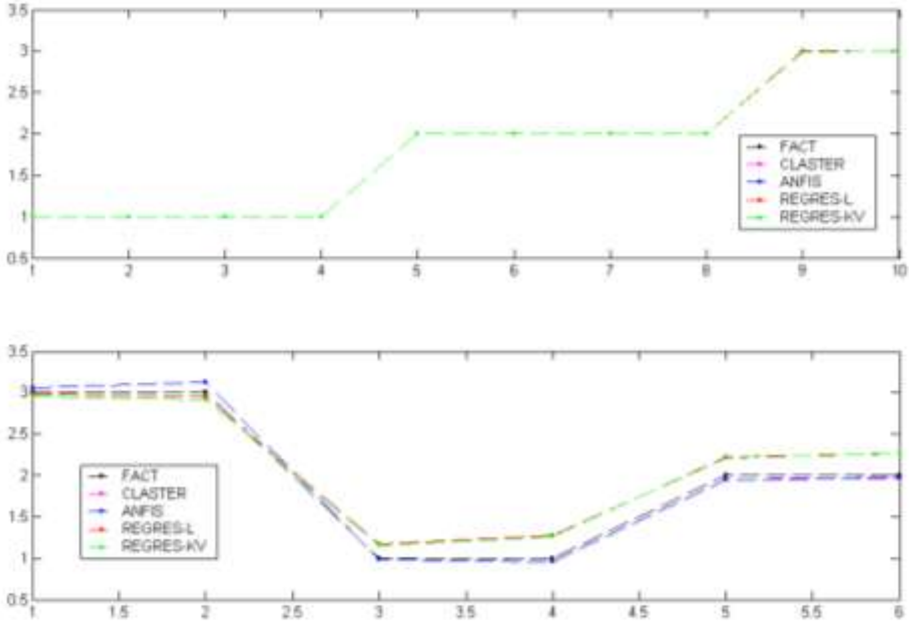

Fig. 2. Graph of results of soil assessment.

4 Conclusion

Thus, the advantages of neuro-fuzzy expert systems over conventional ones are shown; as already mentioned, they appear only when solving difficult problems. As the computational experiment shows, the error for the fuzzy and neuro-fuzzy models is 1.33-4.13%, for the linear regression model - 1.81-27.93%, and for the non-linear regression model - 2.86-25.51%.

The possibilities of neuro-fuzzy methods (correction of the classification model, minimization of training parameters, etc.) make it possible to simplify the process of creating expert systems and determine the directions for scientific research. Further development of diagnostic decision-making is associated with the use of a set of "Soft Computing" technology tools.

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