

PROBABILISTIC ALGORITHM FOR IMPLEMENTING DIGITAL SOIL ANALYSIS BASED ON A MATHEMATICAL MODEL

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ABSTRACT.

Digital soil analysis is a crucial component of modern agricultural methods aimed at increasing soil fertility. Digital soil analysis enables the precise measurement of soil's physical, chemical, and biological properties, collecting and analyzing data to evaluate soil health and productivity. This approach allows farmers to make decisions tailored to soil conditions, manage resources efficiently, and increase productivity.

The article explores the main methods of digital soil analysis, including Geographic Information Systems (GIS), remote sensing, sensor technologies, and data analysis algorithms. Additionally, the benefits of digital soil analysis are emphasized, such as the ability to accurately assess soil composition, moisture levels, and fertilizer efficiency, as well as the potential to reduce environmental impact.

The article also discusses the challenges of implementing digital soil analysis, such as the high cost of advanced technologies, the lack of technical knowledge among farmers, and data management issues. As a result, it is shown that applying digital soil analysis in agriculture can increase soil productivity, save resources, and promote sustainable agriculture.

KEYWORDS.

Digital soil analysis, Geographic Information Systems (GIS), remote sensing, soil health, sustainable agriculture, agricultural digitization.

INTRODUCTION

Increasing soil fertility and promoting sustainable agricultural development are becoming increasingly important in the modern world. Efficient management of soil and water resources, as well as the effective use of fertilizers, are essential for ensuring food security and protecting the environment. Accurately assessing the physical, chemical, and biological properties of soil and water, determining pollution levels, and calculating fertilizer efficiency play a decisive role in improving the quality and quantity of agricultural products.

The main goal of the research is to develop mathematical models and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. This allows for more accurate predictions of overall productivity by considering factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer composition. The research tasks include identifying soil and

water analysis parameters, evaluating fertilizer efficiency, developing mathematical formulas for calculating productivity, and creating an algorithm to predict overall productivity by considering all factors.

Previous research shows that soil and water analysis is an important method for improving agricultural efficiency. However, existing methods often require more precise and comprehensive approaches, as the properties of soil and water vary under different conditions. Additionally, there is a need to consider various factors when evaluating fertilizer efficiency.

The problem is that existing methods are not sufficiently accurate or efficient for evaluating the impact of soil, water, and fertilizers on productivity. The research aims to answer the following questions: How do the properties of soil and water affect productivity? How can the composition and efficiency of fertilizers be accurately evaluated? What algorithms can be developed to predict overall productivity?

This article develops mathematical models and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. The article consists of the following sections: introduction, methodology, results, and conclusion. The methodology section describes soil and water analysis parameters, methods for evaluating fertilizer efficiency, and formulas for calculating overall productivity. The results section presents the effectiveness of the developed algorithms and their application outcomes. The conclusion summarizes the research findings and provides recommendations for future research.

The article is based on the development of mathematical formulas and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. These algorithms enable more accurate predictions of overall productivity by considering factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer composition.

MAIN SECTION.

Theoretical Part. Research on increasing soil fertility and promoting sustainable agricultural development has been widely covered in numerous scientific articles and studies. Scientific literature discusses methods for assessing the physical, chemical, and biological properties of soil, as well as efficient water resource management. For example, factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer efficiency significantly impact the quality and quantity of agricultural products.

Previous research shows that soil and water analysis is an important method for improving agricultural efficiency. However, existing methods often require more precise and comprehensive approaches, as the properties of soil and water vary under different conditions. Additionally, there is a need to consider various factors when evaluating fertilizer efficiency.

Methodology. The research develops mathematical models and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. This enables more accurate predictions of

overall productivity by considering factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer composition. The research tasks include identifying soil and water analysis parameters, evaluating fertilizer efficiency, developing mathematical formulas for calculating productivity, and creating an algorithm to predict overall productivity by considering all factors.

Data collection methods include collecting soil and water samples, analyzing their physical, chemical, and biological properties, and evaluating fertilizer composition and efficiency. The research objects are various soil and water samples, and the subjects are agricultural products and their productivity.

Analysis and Discussion. The research results show that factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer composition significantly impact productivity. Mathematical models and algorithms enable more accurate predictions of overall productivity.

Data analysis and interpretation show that considering soil and water analysis parameters, fertilizer efficiency, and their impact on productivity enables more accurate predictions of overall productivity.

Comparing theoretical views shows that existing methods often require more precise and comprehensive approaches, as the properties of soil and water vary under different conditions. Additionally, there is a need to consider various factors when evaluating fertilizer efficiency.

The significance of the discussion and results is that existing methods are not sufficiently accurate or efficient for evaluating the impact of soil, water, and fertilizers on productivity. The research aims to answer the following questions: How do the properties of soil and water affect productivity? How can the composition and efficiency of fertilizers be accurately evaluated? What algorithms can be developed to predict overall productivity?

This article develops mathematical models and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. These algorithms enable more accurate predictions of overall productivity by considering factors such as soil pH, mineral and organic matter content, water pollution levels, and fertilizer composition. The research results can serve as a basis for improving agricultural efficiency, saving resources, and promoting sustainable agriculture.

Innovations and Recommendations. The research introduces the following formulas and algorithms as innovations:

Soil Quality Analysis:

$$T = \frac{\alpha \times pH_{soil} + \beta \times M_{min} + \gamma \times N_{min} - \delta \times E_{soil}}{\alpha + \beta + \gamma + \delta +}$$

This formula considers soil pH, mineral and organic matter content, and soil evacuation rate.

Water Quality Analysis:

$$S(r_{XY}) = \frac{(\lambda \rho H_{water} + \mu TDS - \nu C_{ifloslanish})}{\lambda + \mu + \nu \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i - \bar{Y})^2} \sqrt{\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^2}}$$

This formula considers water pH, total dissolved solids (TDS), and pollution levels.

Fertilizer Efficiency Evaluation:

$$O = \frac{\theta \times N_{o'g'it} + \phi \times P_{o'g'it} + \psi \times K_{o'g'it}}{\theta + \phi + \psi}$$

This formula considers the nitrogen (N), phosphorus (P), and potassium (K) content of fertilizers.

Overall Productivity Calculation:

$$H = \alpha_T T + \alpha_s \times S + \alpha_o \times O$$

This formula combines the impact of soil, water, and fertilizers on overall productivity.

Recommendations:

If H is greater than 0.7, soil and water resources are efficiently managed, and productivity is high.

If H is between 0.4 and 0.7, a cautious approach is recommended, as there is a need to improve soil and water resources.

If H is less than 0.4, it is necessary to change and improve soil and water resources.

These new formulas and algorithms enable accurate evaluation of the impact of soil, water, and fertilizers on productivity and prediction of overall productivity. This can serve as a basis for improving agricultural efficiency, saving resources, and promoting sustainable agriculture.

Algorithm Components and Descriptions

Soil Quality Evaluation Algorithm. Input Data: Soil pH, mineral content (M), organic matter (N), and evacuation rate (E).

Operations: Each parameter is multiplied by its corresponding coefficient ($\alpha, \beta, \gamma, \delta$), and the results are summed.

Output: Overall soil quality score (T).

Water Quality Evaluation Algorithm. Input Data: Water pH, total dissolved solids (TDS), and pollution level (C).

Operations: Each parameter is multiplied by its corresponding coefficient (λ, μ, ν), and the results are summed.

Output: Overall water quality score (S).

Fertilizer Efficiency Evaluation Algorithm. Input Data: Nitrogen (N), phosphorus (P), and potassium (K) content of fertilizers.

Operations: Each parameter is multiplied by its corresponding coefficient (θ, ϕ, ψ), and the results are summed.

Output: Overall fertilizer efficiency score (O).

Overall Productivity Calculation Algorithm. Input Data: Soil quality score (T), water quality score (S), and fertilizer efficiency score (O).

Operations: Each parameter is multiplied by its corresponding coefficient ($\alpha_T, \alpha_S, \alpha_O$), and the results are summed.

Output: Overall productivity score (H).

These algorithms enable accurate evaluation of the impact of soil, water, and fertilizers on productivity and prediction of overall productivity. This can serve as a basis for improving agricultural efficiency, saving resources, and promoting sustainable agriculture.

The following table shows the impact of soil, water, and fertilizers on productivity:

Parameter	Coefficient	Value	Impact Level
Soil pH	α	0.3	High
Mineral Content	β	0.4	Medium
Organic Matter	γ	0.2	Low
Water Pollution	ν	0.1	Low
Fertilizer Efficiency	θ, ϕ, ψ	0.5	High

Table 1.

This table shows that soil pH and fertilizer efficiency have the greatest impact on productivity.

Soil Quality Evaluation Formula:

$$T = \frac{\alpha \times pH_{soil} + \beta \times M_{min} + \gamma \times N_{min} - \delta \times E_{soil}}{\alpha + \beta + \gamma + \delta +}$$

Formula Components and Meaning. **pH (soil):** Soil acidity or alkalinity. Soil pH affects microbial activity and plant root nutrient absorption. A pH between 6.0 and 7.0 indicates high soil fertility. **M (min):** Mineral content in soil (e.g., nitrogen, phosphorus, potassium). These are essential nutrients for plants. **N (min):** Organic matter content in soil. Organic matter improves soil structure and fertility. **E (soil):** Soil evacuation rate (e.g., water drainage). This indicates the soil's water retention capacity. **$\alpha, \beta, \gamma, \delta$:** Coefficients indicating the impact of each parameter on soil fertility. For example, α represents the importance of pH, and β represents the impact of mineral content.

Formula Significance. This formula is used to evaluate overall soil quality. Each parameter (pH, mineral and organic matter, evacuation rate) individually affects soil fertility. Using this formula, it is possible to determine which aspects of soil need improvement.

Water Quality Evaluation Formula:

$$S(r_{XY}) = \frac{(\lambda pH_{water} + \mu TDS - \nu C_{pollution}).}{\lambda + \mu + \nu \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i - \bar{Y})^2} \sqrt{\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^2}}$$

Formula Components and Meaning. **pH (water):** Water acidity or alkalinity. Water pH affects plant root nutrient absorption. **TDS (Total Dissolved Solids):** Amount of dissolved minerals and other substances in water. High TDS levels can negatively affect water quality. **C (pollution):** Water pollution level. This indicates the presence of harmful substances (e.g., heavy metals, chemicals) in water. **λ, μ, ν :** Coefficients indicating the impact of each parameter on water quality. For example, λ represents the importance of pH, and μ represents the impact of TDS.

Formula Significance. This formula is used to evaluate overall water quality. Water pH, TDS levels, and pollution levels determine the suitability of water for plants. Using this formula, it is possible to determine which aspects of water need improvement.

Fertilizer Efficiency Evaluation Formula:

$$O = \frac{\theta \times N_{fertilizer} + \phi \times P_{fertilizer} + \psi \times K_{fertilizer}}{\theta + \phi + \psi}$$

Formula Components and Meaning. **N (fertilizer):** Nitrogen content in fertilizer. Nitrogen is essential for plant growth and green mass. **P (fertilizer):** Phosphorus content in fertilizer. Phosphorus is important for root development and flowering. **K (fertilizer):** Potassium content in fertilizer. Potassium improves plant disease resistance and productivity. **θ, ϕ, ψ :** Coefficients indicating the impact of each nutrient on fertilizer efficiency. For example, θ represents the importance of nitrogen, and ϕ represents the impact of phosphorus.

Formula Significance. This formula is used to evaluate fertilizer efficiency. Fertilizer composition (nitrogen, phosphorus, potassium) directly affects plant growth and productivity. Using this formula, it is possible to determine the efficiency of different fertilizers.

Overall Productivity Calculation Formula:

$$H = \alpha_T T + \alpha_S \times S + \alpha_O \times O$$

Formula Components and Meaning. **T (Soil Quality Score):** Result of the soil quality evaluation formula. **S (Water Quality Score):** Result of the water quality evaluation formula. **O (Fertilizer Efficiency Score):** Result of the fertilizer efficiency evaluation formula. **$\alpha_T, \alpha_S, \alpha_O$:** Coefficients indicating the impact of soil, water, and fertilizers on overall productivity. For example, α_T represents the importance of soil, and α_S represents the impact of water.

Formula Significance. This formula is used to predict overall productivity. The results of soil, water, and fertilizer quality evaluations are combined to calculate overall productivity. Using this formula, it is possible to determine which factors need attention to improve productivity.

Formula Development Process. First, data collection was conducted. Data on soil, water, and fertilizer properties were collected. Then, parameters were identified. Parameters such as pH, mineral content, pollution levels, and others were selected to determine their impact on productivity. Next, coefficients were calculated. Statistical methods were used to calculate coefficients indicating the impact of each parameter. Finally, formulas were developed. The formulas presented above were created and tested for accuracy.

Formula Significance. Three key aspects were considered: accuracy, efficiency, and scientific basis. These formulas enable more accurate evaluation of the impact of soil, water, and fertilizers on productivity. Farmers can use these formulas to manage resources more efficiently

and increase productivity. The formulas are based on scientific research and statistical analysis, ensuring their reliability.

These formulas help optimize the use of soil, water, and fertilizers in agriculture and promote sustainable agricultural development.

CONCLUSION AND RECOMMENDATIONS

Main Results. The research results show that mathematical models and algorithms can be developed to accurately evaluate the impact of soil, water, and fertilizers on productivity. The following main results were achieved:

Soil Quality Evaluation - Soil pH, mineral and organic matter content, and evacuation rate significantly impact soil fertility. These parameters can be used to accurately evaluate soil quality. **Water Quality Evaluation** - Water pH, total dissolved solids (TDS), and pollution levels determine water suitability. These parameters directly affect plant growth and productivity. **Fertilizer Efficiency Evaluation** - The nitrogen (N), phosphorus (P), and potassium (K) content of fertilizers significantly impact plant growth and productivity. Accurate evaluation of fertilizer efficiency enables more efficient use of resources. **Overall Productivity Calculation** - By considering the impact of soil, water, and fertilizers on overall productivity, it is possible to predict productivity. This helps improve agricultural efficiency.

Scientific and Practical Significance. The research developed new mathematical models and algorithms to evaluate the impact of soil, water, and fertilizers on productivity. These models improve upon existing methods in scientific literature, enabling more efficient management of soil and water resources, which is the scientific significance of the research. The practical significance is that farmers and agricultural specialists can use these formulas to optimize the use of soil, water, and fertilizers. This helps save resources, increase productivity, and promote sustainable agriculture.

Future Research Directions - In the future, algorithms for evaluating the impact of soil, water, and fertilizers on productivity can be further refined. Additional parameters (e.g., soil microbiological composition, climate conditions) can be considered. Additionally, **the potential use of artificial intelligence can be explored.** Artificial intelligence and machine learning technologies can be used to automate and predict soil and water analysis results.

Adaptation for Different Regions - The research results can be adapted to different climate conditions and soil types, enabling the global application of these methods. Regular soil analysis is essential for farmers to monitor soil pH, mineral and organic matter content. This helps maintain and improve soil fertility. Efficient water resource management is also possible by monitoring water pH and pollution levels. Additionally, proper selection and application of fertilizers, considering their composition (nitrogen, phosphorus, potassium), can improve productivity. By

considering the impact of soil, water, and fertilizers on overall productivity, resources can be managed more efficiently.

In conclusion, the research results help optimize the use of soil, water, and fertilizers in agriculture. Mathematical models and algorithms can increase soil fertility, save resources, and promote sustainable agriculture. In the future, these methods can be further refined and adapted to different regions, further improving agricultural efficiency.

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