RESEARCH ARTICLE

Soil and water conservation monitoring and landscape ecological restoration strategy based on big data and internet of things

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Soil and water conservation is an important measure to ensure ecological security and sustainable development. Soil erosion in China is widespread, unevenly distributed, complex in causes, and becoming more and more serious. We must pay attention to the problem of soil erosion, analyze the causes of soil erosion, and promote soil and water conservation and environmental restoration. The intelligent monitoring model built based on big data and internet of things (IOT) technology has improved the accuracy, timeliness, and comprehensiveness of soil erosion monitoring. However, the current soil and water conservation monitoring methods have the problems of small data volume, poor timeliness, and high cost, which are difficult to meet the needs of large-scale and refined soil and water conservation management. Based on big data and IOT technology, this study constructed an intelligent detection platform for soil and water conservation monitoring and landscape ecological restoration, which realized real-time, dynamic, and comprehensive monitoring and analysis of soil erosion process, influencing factors, and restoration effect. In this study, a data-driven soil and water conservation evaluation model and a landscape ecological restoration strategy based on ecological priority were proposed by using multi-source data fusion, machine learning, and spatial analysis. The results of this study showed that the platform could effectively identify the type, degree, and distribution of soil erosion, evaluate the benefits and costs of soil and water conservation measures, and guide the planning and implementation of landscape ecological restoration. The results demonstrated that big data and IOT technology provided a new idea and tool for soil and water conservation monitoring and landscape ecological restoration, which was helpful to improve the scientificity, accuracy, and efficiency of soil and water conservation management, and promoted ecological civilization construction and green development. The soil erosion detection model proposed in this study would promote soil conservation and ecological restoration to a certain extent.

Keywords: big data; Internet of Things; soil and water conservation monitoring; ecological restoration.

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Introduction

With the continuous development of industry and economy, soil erosion has gradually become a major factor affecting human survival and development. According to statistics, the total area of soil erosion in China reached 3,700,000 km^2 in 2020, which accounted for about 40% of the country's land area. Soil erosion can lead to serious environmental problems, which may change the soil structure and affect the development of farming. Soil erosion is also the main cause of drought, flood, and sandstorms. The causes of soil erosion can be summarized into two aspects of uncontrollable natural factors and human activities. The natural factors included broken and unconnected terrain in certain areas due to its unique geographical environment, loosened soil, longtime heavy rain, and sparse vegetation [1, 2]. Soil erosion is fatal to the environment, which will destroy soil fertility and affect the growth of crops. Most of the land in China has suffered serious natural hazards with very fragile ecological environment and the declining of soil fertility. Water and soil erosion may also cause reservoir blockage, elevate the river course, *etc*., and the river carrying mud will continue to deposit, resulting in a gradual increase in the sediment in the riverbed and river course. For example, according to the current data, the water surface of Poyang Lake in Jiangxi province, China has decreased sharply with the riverbed being increased by nearly 5 meters every year. The continuous accumulation of sediment may also cause the river to hang above the ground, endangering the lives and health of people on both sides of the lake [3, 4].

With the advent of the information age, the amount of data is concentrated. To solve the problem of processing massive amounts of information, big data came into being. With its 4V characteristics, big data has a wide range of applications in data analysis and data processing. With the maturity of big data technology, big data has become a driving force for the development of information technology and has been widely used in various industries. The combination of big data and the Internet of Things (IOT) can realize intelligent monitoring, decision-making, and prediction, and therefore, promote modern business development. The IOT sensor can quickly transmit the massive amount of information received by the object terminal to the information processing center, and can realize the connections between people and things, and between things. The IOT technology covers many fields and has important applications in intelligent sensing and monitoring. The development of big data and the IOT provides an opportunity for soil erosion monitoring and ecological environment protection [5, 6]. Through big data and IOT, the ability of monitoring model is improved in accuracy, timeliness, and comprehensiveness. The intelligent ecological environment restoration model is constructed to fundamentally promote soil and water management and ecological environment protection and restoration. The observation station transmits the relevant information of water and soil loss to the water and soil loss processing platform through observation, and finally transmits it to the user. The user finally converts these data into tasks and then transmits them for the information processing and evaluation [7, 8].

The scope of water and soil loss is constantly expanding with increased speed. China is a large agricultural country, and agricultural development has brought about a certain degree of soil erosion. According to the statistics, soil erosion in rural areas is much higher than that in urban areas. The area of soil erosion in China is large, accounting for about 40% of the country's land area. Large areas of soil erosion have caused serious consequences, which hinders the development of farming and mining [9, 10]. The distribution of water and soil loss is also unbalanced in China. The water and soil loss in the northern part of country is higher than that in the southern part, and that in rural areas is higher than that in urban areas. Due to the low air humidity and loose and scattered soil in the northern region, soil erosion is more likely to occur. The large-scale soil erosion in China has caused serious river cut-offs. The lost soil was deposited on the riverbed, causing it continuously rising. Some rivers were seriously cut off [11]. The mechanism of soil erosion is complex. Due to the large geographical span of China, the soil erosion shows differences in the north and the south with different causes [12, 13]. The current soil and water conservation monitoring methods have many shortcomings, such as small amount of data, poor timeliness, and high cost, which are difficult to meet the needs of precise soil and water conservation management. The purpose of this study was to use big data and IOT technology to build an intelligent platform for soil and water conservation monitoring and landscape ecological restoration to realize real-time, dynamic, and comprehensive monitoring and analysis of soil erosion process, influencing factors, and restoration effects. The results of this study would improve the scientificity, accuracy, and efficiency of soil and water conservation management and promote the construction of ecological civilization and green development.

Materials and Methods

Study area

The geographic location of the studied area was Dingxi, Gansu, China, which is one of the eight key areas of soil and water conservation in China located in the intersection of the Loess Plateau, the Qinghai-Tibet Plateau, and the Western Qinling Mountains. It is a hilly and gully region of the Loess Plateau with alpine humid areas. The altitude of the area is 1,420 to 3,941 meters with the annual precipitation of 350 to 600 mm, and the annual average temperature of 7°C. The area of soil erosion accounts for 83.2% of the total land area. The main causes of soil erosion in this area are natural factors including topography, climatic conditions, soil properties, *etc*. and human factors including unreasonable farming methods, excessive reclamation, and deforestation. In order to control soil and water loss, the region has adopted the following strategies including a small watershed as a unit, a comprehensive management mode of unified planning for mountain, water, field, forest, and road, the implementation of the terrace construction, silt dam construction, water conservation forest construction, and other engineering measures, while the development of potato, Chinese herbal medicine, and other characteristic industries to improve the income of farmers.

Establishment of water and soil detection model

Soil and water testing and landscape restoration are two important links in soil and water conservation. The water and soil inspections are the premise of landscape restoration. A good water and soil detection model can quickly collect water and soil conservation information to transmit and process the water and soil conservation data and combine with other application systems to promote the development of water and soil conservation [14, 15]. The water and soil detection process are a process of collecting original data sets, but the traditional water and soil detection model has the problems of large data errors and slow processing, resulting in a long-term lag in water and soil detection. The optimization of the water and soil observation model can start from two aspects. One is to use technologies such as big data and the IOT to build a complete environmental tracking system through sensitive sensors to obtain more comprehensive, accurate, and accurate point-to-plane conversions. The second is to establish a model that can dynamically represent (spatial and temporal scales) changes in the land and water domain. The model in this study mainly started from the first aspect to use big data and the ability of the IOT to analyse and process massive data and the ability of the IOT to collect water and soil data in real time to improve the ability of water and soil observation from three aspects including sensitivity, timeliness, and accuracy. The model flowchart was shown in Figure 1 [16, 17]. The water and soil detection models currently used by most environmental enterprises are USLE and RUSLE with high accuracy and high calculation efficiency. However, these models all include less factors and ignored in the process of time. The model built through this study integrated multi factors in eight aspects (Table 1) [18, 19]. The specific model was shown as follows.

$$Q = S*W*E*R*T*V*N*M \tag{1}$$

By using the analysis and processing capabilities of IOT, detailed information on these eight types of data could be obtained. The specific IOT models used were as follows.

$$s_i \cdot G + e \cdot D_i \prod_{i^1 j} \frac{\mathrm{IO}_{i2}}{IO_{i2} - IO_{j2}} = D_i \cdot P_i \tag{2}$$

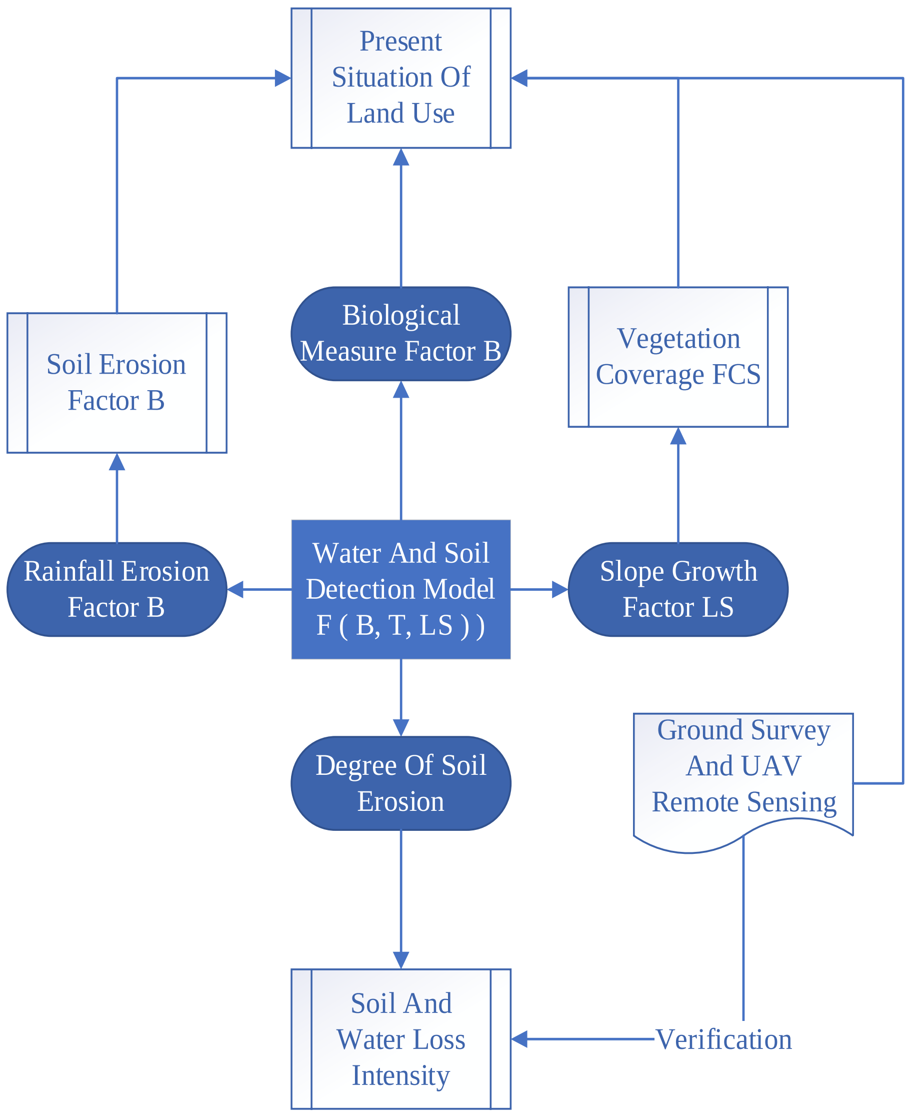

Figure 1. Water and soil observation model.

Table 1. Observation factors of soil and water observation model.

Project	Meaning	Concrete performance
S	Climatic factors	Torrential rain is the direct driving force and main climatic factor causing severe soil erosion
T	Ground slope	The greater the slope, the more serious the soil erosion
E.	Long slope type	The greater the slope length, the more serious the soil erosion
R	Slope of the rock formation	The slope of the rock formation also has an important effect on soil erosion
T	Vegetation	Vegetation can alleviate soil loss
V	Human action	Human activities such as arable land have complex effects on soil erosion
N	Soil structure	Different regions have different soil structures
M	Restoration works	Restoration works can promote soil and water conservation to a certain extent

where P_i was each type of data. D_i was data fusion that could reflect both vegetation and soil structure. IO_{i2} was multiple input ports. Generally, the data of water and soil observation system have multiple inputs and input ports, which will be normalized. $\frac{IO_{i2}}{IO_{i2} - IO_{j2}}$ was adopted in this study to ensure that the data obtained from different ports could be combined with each other $s_i \cdot G$ [20].

Formula (3) was used to fuse the acquired data to build a soil erosion assessment system, combining climate factors, ground slope, slope length and slope type, and other variables through a composite function *F* (*S*, *M*, *N*, *W* …). The specific order in Formula (3) was based on the weights of different factors [21].

$$F(S,M,N,W\ldots) = m_{t-1} \cdot S^{t-1} + M_{t-2} \cdot x^{t-2} + \text{L} + N_2 \cdot x^2 + W_1 \cdot x + m_0 \quad (3)$$

By improving the sensitivity of the model, the shortcomings of the traditional model could be significantly improved, thereby improving the accuracy of the observation model. The IOT remote sensing technology was applied to the water and soil detection model. The specific models were shown in Formulae (4) and (5).

$$D = \sum_{i=1}^{t} \frac{FD_{i2}}{FD_{i2} - FD_{j2}} Pu_{j_i}^{x_i} \quad (4)$$

$$DQ_{i1} = \left(x_j + Pr_{AIGi}\right) \cdot h\left(NM_i\right) + FCS \quad (5)$$

where *FD* was the input of the remote sensing port. $Pu_{j_i}^{x_i}$ was the integration of the variable *u* from the spatial scale and the time scale and improved the accuracy of remote sensing from multiple perspectives in both macro and micro perspectives. *FCS* was a redundant sequence of time slices. $h(NM_i)$ was a partial differential sequence [22].

Establishment of ecological restoration model

Using big data and IOT technology to build a smart ecosystem restoration system is a major trend to promote the development of ecological restoration. The smart ecosystem restoration system uses information technology to restore the ecosystem that has suffered or is currently suffering from soil erosion. The ecological restoration model of the ecological restoration model based on big data and IOT was shown in Figure 2 [23]. To build a complete big data and IOT ecological restoration model, two perspectives, decision-making and forecasting, were included in this study. Formula (6) collected ecosystem data and evaluated the ecosystem from multiple perspectives.

$$M(x) = \frac{1}{\sqrt{2\pi\theta^2}} e^{-(MIRE)^2/2F^2} \quad (6)$$

where MIRE was a series of soil and water evaluation indicators, including the soil and water loss evaluation indicators shown in Table 2 [24, 25]. Uncertainty was eliminated by performing mean square processing on the indicators in Table 2 to ensure the unity of units among the data. Formula (7) was applied for further processing of data, processing of redundant data, *etc*. while Formula (8) was the decision model and Formula (9) was the prediction model, respectively.

$$\frac{1}{\sqrt{G(x)}} e^{\frac{(x-h)^2 + (y-m)^2}{-2\theta^2}} \quad (7)$$

$$L(M(x),G(x),\theta) = G(M(x),G(x),\theta) / I(M(x),G(x),) \quad (8)$$

$$G(M(x),L(x),\theta) = \frac{1}{\sum rh^{MIRH}} \partial^{\frac{M(x)*L(x)}{-2\theta^2}} \quad (9)$$

where θ was candidate factors. $M(x)$ was domain knowledge. $G(x)$ was the data observed $L(M(x),G(x),\theta)$ through big data and IOT technology. $I(M(x),G(x),)$ was the decision set. $G(M(x),L(x),\theta)$ was the set of forecasts, r was the adjustment factor [26, 27].

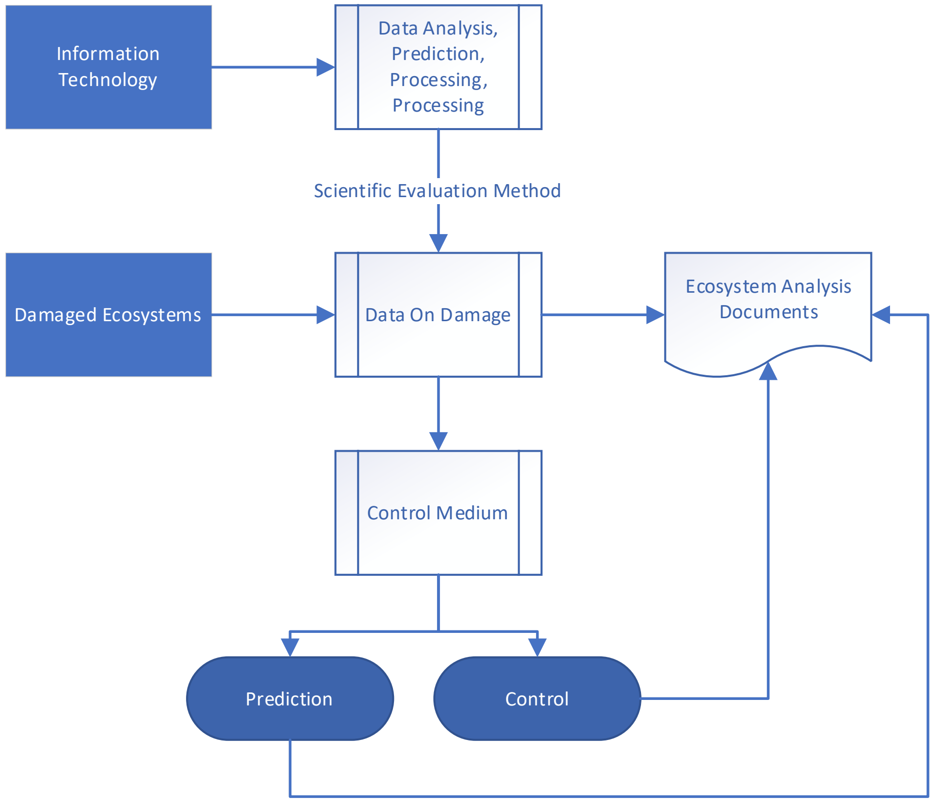

Figure 2. Ecological restoration model based on big data and IOT.

Table 2. Soil and water loss evaluation indicators.

Grading index of soil erosion degree	Ecological problem assessment indicators	Comprehensive evaluation index
Minority	Soil erosion sensitivity	Slope length slope factor
Mild	Soil erosion intensity	Surface vegetation cover factor
Moderate	Soil erosion	Recovery potential
Strength	Area ratio	Animal activity
Extreme strength	Rain erosion	Soil erosion mechanism
Severe	Soil erodibility	Consequences of soil erosion

Results and discussions

The artificial neural network evaluation demonstrated a linearized trend. All resulting data were shown in Table 3. The results demonstrated that, by using the artificial neural network for evaluation, the prediction accuracy rate was as high as 99.25%, indicating that the model constructed in this study was very usable, and the influence of outliers was slightly high, indicating that it was necessary to strengthen data preprocessing and improve input data accuracy, while the concentration and reliability were all excellent [28].

Table 3. Results of evaluation using artificial neural network.

Project	Value
Degree of reliability	99.25%
Outlier effect	18.2%
Concentration	75.369%
Prediction accuracy	79.8%

With the development of big data and IOT technology, all walks of life are transforming to informatization. By building a soil erosion information platform through big data and IOT, using IOT as the underlying structure, integrating the perception, dissemination, and processing of information, and accelerating the life cycle of information, the data information could be quickly transmitted to the information processing center, which would improve the timeliness of data analysis and decision-making. On the other hand, by collection of structural soil erosion data, establishment of a soil erosion database, and comparison of historical data with current data, the current situation of water and soil erosion could be reflected. Using big data as an information analysis tool, through data modeling, storage, utilization, *etc.*, a large amount of low-cost and only dense data can be converted to key information that reflects soil erosion. The combination of big data and IOT can help promote soil erosion informatization process. Compared to the traditional artificial methods, the soil erosion information platform showed advantages in timeliness, accuracy, and comprehensiveness of detection. Promoting the transformation of water and soil erosion management to informatization has become a major trend in soil and water conservation.

The assessment of water and soil loss is a time-consuming and laborious task. Traditional capacity assessment often has a certain lag, which makes it impossible for people to discover the problem of water and soil loss and solve it in time. The assessment of soil and water loss takes a long time, involves a lot of work, and is highly subjective. To overcome these problems, this study built a soil erosion assessment system based on big data and IOT technology, and comprehensively displayed the current status of water and soil erosion through scientific assessment methods and indicators. Through the cluster mining of the obtained data, the causes, influences, and changes of soil erosion in different regions were discovered. The performance of soil erosion in different regions was analyzed, and targeted solutions were formulated according to the special conditions of different regions [29].

With the development of information technology and the country's increasing emphasis on the environment, the use of big data and IOT technology to promote environmental restoration has become an important research field. Protecting the ecological environment is a vital matter for the development of the country. It is related to the economy and life and health. As the ecological environment problems represented by soil erosion become increasingly prominent, attention to ecological restoration must be paid because, once the ecological environment is damaged, it will become very fragile. IOT technology can be applied to intelligently monitor the soil condition, the growth of crops, the vegetation conditions in the area, and the river and bed conditions, *etc*.

Water and soil testing and ecological protection are two mutually reinforcing aspects. By constructing a water and soil protection model through this study, an intelligent detection system and an ecosystem intelligent restoration decision-making model were constructed by using big data and IOT technology, which promoted the model in the field of water and soil conservation in both data acquisition and specific measures and improved the ability of the monitoring model in accuracy, timeliness, and comprehensiveness. Using big data and the IOT to analyze and process massive data and the ability of IOT to collect water and soil data in real time could improve the abilities of water and soil observation in sensitivity, timeliness, and accuracy. This study applied big data and IOT technology to build a soil erosion information platform and a soil erosion assessment system, which would be helpful in formulating scientific ecological restoration strategies and promote the soil and water conservation monitoring and ecological restoration.

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