Application of Refined Meteorological Observation Data in Agricultural Production

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Abstract The entire process of agricultural production is directly constrained by meteorological factors, and conditions such as temperature, precipitation, light, and humidity determine crop growth rhythms, final yields, and agricultural product quality. Traditional meteorological observation stations are sparsely deployed, and data have broad spatial representativeness, which can only reflect the average meteorological conditions of the region and cannot capture the microclimate differences between field plots, making it difficult to support the development needs of precision agriculture. Refined meteorological observation relies on automatic monitoring stations in farmlands, remote sensing inversion, grid numerical simulation and other methods to achieve small-scale, high-frequency, and multi-factor continuous monitoring, which can accurately depict the dynamic changes of micro meteorology in the field. In this paper, the core characteristics of refined meteorological observation data are summarized. Combines practical production scenarios such as agricultural sowing, field management, disaster prevention, irrigation and plant protection, this paper systematically elaborates on its application path, analyzes the current practical obstacles to its implementation, and proposes feasible optimization strategies, in order to provide practical reference for meteorological data to empower modern agriculture and ensure stable grain production.

Key words Refined meteorological observation; Agricultural production; Precise planting; Agricultural meteorological services; Disaster prevention and control

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Meteorological conditions are an indispensable core natural condition for agricultural production, and various meteorological disasters and periodic climate fluctuations have always been key factors restricting stable agricultural production and income growth. Under the traditional production mode, farmers rely on their agricultural experience to arrange farming, irrigation, pesticide application, harvest and other agricultural activities. However, their predictions of short-term meteorological changes in the local area are lagging behind, and their response measures are passive when encountering sudden disasters such as late spring cold, drought, short-term heavy rainfall, hail, *etc.*, which can easily lead to large-scale production reduction. With the promotion of rural revitalization and agricultural modernization, large-scale planting, facility agriculture, and water-saving agriculture continue to be popularized, and the demand for meteorological service accuracy in agricultural production continues to increase. The spatial distribution of conventional national meteorological observation stations is relatively sparse, and the frequency of updating observation data is limited. There is a lack of refined observation information such as temperature, humidity, soil moisture, and accumulated temperature at the plot scale. Extensive meteorological services are no longer suitable for the needs of refined planting management. The refined meteorological observation system is based on high-density field monitoring equipment, integrating satellite remote sensing and regional numerical forecasting products, reducing the meteorological monitoring scale to village and plot levels, achieving minute-level element updates, and fully covering all meteorological indicators required for crop growth. It has important practical significance for enhancing agricultural disaster prevention and reduction capabilities, saving water and soil resources, and stabilizing grain production capacity by fully tapping into the value of refined meteorological observation data, and promoting the deep integration of meteorological information with the entire agricultural production process.

1 Core characteristics of refined meteorological observation data

1.1 Refinement of spatial scale Traditional meteorological observation stations have a wide coverage area, and observation data at single station only represents the climate characteristics of a large area. Local meteorological differences among mountains, depressions, and contiguous farmlands cannot be reflected. The refined observation network is equipped with dedicated monitoring terminals in farmlands, fruit and vegetable greenhouses, and characteristic planting bases, reducing the distance between observation units. It can distinguish the differences in temperature, precipitation, and light under different plots and terrains, accurately reflect the microclimate in the field, meet the data needs of precise management by household and plot, and provide basic data support for the precise climate

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zoning of county-level crops[1].

1.2 High frequency of time update Traditional observations often use daily and hourly data, which makes it difficult to capture short-term and sudden meteorological processes. The precision monitoring equipment for farmland can continuously collect data minute by minute, and track short-term meteorological changes such as sudden temperature rises and drops, short-term heavy precipitation, and nighttime low temperatures in real time. It can greatly shorten the interval between meteorological information updates, reserve sufficient disposal time for disaster warning and agricultural dispatch, and support the implementation of short- and medium-term dynamic prediction business for agricultural meteorological disasters[2].

1.3 Specialization of observation elements Compared with general meteorological observations, agricultural precision monitoring adds special indicators such as soil temperature and humidity, crop canopy temperature, field evaporation, effective accumulated temperature, frost free period, *etc*. The data dimensions are in line with the physiological growth laws of crops. There are significant differences in the threshold requirements for meteorological conditions among different crops and growth stages. Diversified observation indicators can provide targeted data support for agricultural management by category and period, and can also construct soil moisture simulation and growth prediction models suitable for field crops.

2 Practical application of refined meteorological observation data in agricultural production

2.1 Supporting precise management and protection of crops throughout their entire growth period There are fixed meteorological suitable intervals for each growth stage of crops, including sowing, emergence, tillering, flowering, grouting, and maturity. Insufficient accumulated temperature, insufficient light, and abnormal temperature can all delay crop growth and reduce seed setting rate. By relying on long-term and refined ground temperature and air temperature monitoring data, it is possible to accurately calculate the annual effective accumulated temperature, initial frost date, and final frost date in the region, determine the suitable sowing window period, and avoid problems such as rotten seed due to low temperature in early spring and forcing ripening due to late autumn frost. In the middle and later stages of crop growth, continuous monitoring of the temperature difference between day and night and air humidity in the field can dynamically assess the risk of heat and cold damage, and guide growers to take prevention and control measures such as film insulation, greenhouse ventilation and cooling, and shading protection. For large-scale planting bases, integrating years of refined meteorological data can analyze regional climate resource endowments, optimize the planting layout of grain crops, economic crops, fruits and vegetables, reasonably match crop varieties that are suitable for maturity, and fully utilize light and temperature resources to improve land output efficiency. Based on refined meteorological time series data at the township level, the prediction model for crop phenology and maturity period can also be constructed to achieve accurate prediction of mature harvest time at the plot level.

2.2 Realizing precise prevention and control of agricultural meteorological disasters in different zones Drought, floods, low-temperature freezing damage, and severe convective disasters have strong local characteristics. Traditional large-scale meteorological warnings lack pertinence for plot, and the allocation of disaster prevention resources is prone to redundancy or shortage. Refined meteorological observation data can accurately locate disaster prone areas, predict the intensity of disaster development, and provide differentiated disaster prevention guidance for different land parcels. In response to drought disasters, drought levels are classified based on soil moisture, evaporation, and real-time precipitation data, and mild, moderate, and severe drought plots are distinguished. Farmers are guided to carry out drip irrigation and sprinkler irrigation in different areas to avoid water resource waste caused by indiscriminate irrigation throughout the region. When encountering short-term rainstorm, gale, hail and other severe convective weather, high-frequency monitoring data can lock risk farmland in advance, timely push early warning information, guide farmers to dredge field drainage channels, strengthen greenhouse, and quickly harvest mature grain, oil, fruits and vegetables. Before the arrival of low temperature frost in spring and autumn, relying on real-time monitoring of low temperature at night, key areas for anti freezing should be designated, and practical suggestions such as smoking, foliar spraying, and covering with insulation film should be pushed to effectively reduce the scale of disaster losses. Relying on multi-source refined meteorological data for disaster rolling prediction, it can significantly enhance the foresight and targeting of agricultural meteorological disaster prevention.

2.3 Guiding water-saving irrigation and optimizing the allocation of water and soil resources The total agricultural water consumption accounts for a relatively high proportion of the national water use, and the traditional flood irrigation mode causes significant water resource loss. The timing and amount of irrigation lack scientific basis. By combining refined meteorological data with soil moisture monitoring, a calculation model for crop water consumption can be constructed to dynamically calculate the field water surplus and deficit. The system collects real-time factors such as temperature, relative humidity, sunshine duration, and wind speed, and calculates the total amount of evapotranspiration in farmland. Overlaying short-term precipitation forecast data, it accurately determines irrigation timing and single irrigation water volume, and provides quantitative water supply according to demand. This model can not only eliminate the impact of soil water shortage stress on crop growth, but also avoid problems such as soil waterlogging, root rot, and secondary salinization caused by excessive irrigation, which is in line with the development requirements of green water-saving agriculture and reduces the cost of planting and irrigation. A soil moisture simulation scheme based on microclimate factors in the field can further improve the precision of irrigation water quantity calculation.

2.4 Standardizing crop protection and harvesting operations to improve the quality of agricultural products The outbreak of pests and diseases in the field is highly correlated with meteorological conditions. High temperature, high humidity, and continuous rainy and cloudy environments are highly likely to induce fungal diseases and piercing-sucking insect pests. Refined continuous monitoring of temperature and humidity in the field can accurately predict high-risk periods for pests and diseases, provide preventive pesticide application reminders in advance, guide farmers to choose sunny and windless periods for plant protection operations, improve pesticide utilization efficiency, and reduce agricultural non-point source pollution caused by blind pesticide application. During the mature harvest stage of crops, relying on refined weather forecasts, continuous suitable harvesting and drying periods are designated to avoid grain germination and mold growth caused by rainy weather, ensuring the quality of grain, fruits, and vegetables. At the same time, the refined meteorological dataset accumulated year by year can review the correlation between climate conditions and yield, quality, providing data basis for the revision of standardized planting regulations and the delineation of high-quality production areas for characteristic agricultural products. Relying on big model technology for deep mining of massive time-series meteorological data, it can promote the shift of agricultural management from empirical judgment to intelligent decision-making[3].

3 Existing problems in the application of refined meteorological observation data in agriculture

3.1 Insufficient adaptability of data products to agricultural scenarios The existing refined meteorological output products are mostly general meteorological element values, and there are relatively few customized analysis products for different crops such as rice, wheat, fruits and vegetables. The professional threshold for raw monitoring data is relatively high, and it has not yet been converted into agricultural operation guidelines that farmers can directly execute. A large amount of high-precision monitoring data is only in the collection and storage stage, making it difficult to translate into production benefits.

3.2 Weak supporting facilities for grassroots agricultural meteorological services There are gaps in the deployment of monitoring stations in remote planting areas and mountainous farmland, and some old monitoring equipment has insufficient transmission stability, resulting in frequent data gaps. Grassroots villages and towns lack dedicated agricultural meteorological technicians, and ordinary farmers lack the professional ability to interpret meteorological monitoring data. The single channel for pushing meteorological warning and agricultural guidance information results in delays in delivering information to farmers, weakening the actual effectiveness of data services.

3.3 Insufficient fusion and sharing of multi-source monitoring data Meteorological observation, soil moisture, crop growth, and pest and disease monitoring data belong to different supervisory units, and the data exchange mechanism between departments is incomplete, resulting in prominent data silos. Single meteorological data cannot fully reflect the comprehensive production conditions of farmland, and the ability to integrate and analyze multi-source data is insufficient, making it difficult to build an integrated and full-chain agricultural meteorological intelligent research and judgment system, which restricts the further improvement of meteorological service accuracy.

4 Optimization measures for promoting the implementation and application of refined meteorological observation data

4.1 Developing scenario based meteorological service products by category Based on the growth characteristics of regional dominant crops, a differentiated meteorological suitability model is constructed to transform the original refined monitoring data into simplified agricultural tips, covering suitable sowing periods, irrigation reminders, pest and disease prevention window periods, disaster grading and disposal plans, optimal harvesting periods, and other content. It should customize exclusive meteorological service products for grain, facility fruits and vegetables, and economic trees to reduce the threshold for farmers to use data. By integrating and analyzing multidimensional observation data with meteorological big models, personalized service content suitable for different planting subjects can be generated in batches.

4.2 Improving the grassroots farmland monitoring network and service system It should fill in the gaps in the deployment of monitoring stations in remote farmland and mountainous planting areas, regularly inspect and update field monitoring terminals, and ensure continuous and stable data collection. Meteorological data application training for grassroots agricultural technicians should be regularly carried out to enhance their frontline technical guidance capabilities. Relying on multiple channels such as rural broadcasting, village-level WeChat groups, intelligent agricultural machinery terminals, and field bulletin boards, simple agricultural meteorological information is pushed, to connect the key links of meteorological services to the grassroots level. Referring to the concept of refined agricultural climate zoning in counties, it should optimize the layout of monitoring stations according to the area, to enhance the overall representativeness of the observation network.

4.3 Building a multi-source agricultural data fusion and sharing platform It should coordinate the monitoring resources of meteorological, agricultural and rural, natural resources and other departments, establish a sharing platform for regional agricultural meteorological big data, and connect the transmission channels of meteorological, soil, crop, pest and disease monitoring data. An intelligent analysis model is built based on data fusion technology, realizing the transformation from single element monitoring to comprehensive production risk prediction, and forming a modern agricultural meteorological service system that integrates monitoring, analysis, warning, and guidance.

5 Conclusion

Refined meteorological observation data is the core data resource for developing precision agriculture and ensuring food security. It can effectively compensate for the shortcomings of traditional extensive meteorological services and play a key supporting role in crop management during growth period, meteorological disaster prevention, water-saving irrigation, plant protection and harvesting. At present, the application of refined meteorological data in agriculture still faces practical problems such as insufficient product adaptability, weak grassroots service capabilities, and low degree of multi-source data fusion. In the future, it is necessary to continuously improve the high-density meteorological monitoring network in the field, deepen the deep integration of meteorological data with agricultural production scenarios, improve the operational mechanism of grassroots agricultural meteorological services, fully unleash the application value of refined meteorological data, and rely on digital meteorological services to promote the sustainable development of agricultural modernization.

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