provides a scientific basis for landscape management and visitor services. Japan has established a nationwide autumn foliage forecasting system, predicting optimal viewing periods across regions using phenological models to guide visitor travel and scenic area operations, an experience worthy of reference and promotion.

7.3 Application of digitalization and intelligence in maple landscape planning

With the development of Geographic Information Systems (GIS), remote sensing technology, and artificial intelligence, the planning and design of maple landscapes are progressively transitioning towards digitalization and intelligence. Through high-resolution remote sensing imagery and drone aerial photography, the species distribution, leaf color dynamics, and health status of large maple forests can be rapidly acquired, providing data support for landscape assessment and optimization (Mu et al., 2022). Multispectral and hyperspectral remote sensing technologies can invert leaf anthocyanin and chlorophyll content, quantitatively assess red leaf color saturation, and identify early signs of abnormal coloration. Combined with visitor preference surveys and scenic beauty estimation models, designers can simulate the visual effects of different configuration schemes, achieving precise design. Through virtual reality technology, decision-makers and the public can experience autumn color landscapes firsthand during the planning and design phase, participating in scheme comparison and optimization.

Furthermore, IoT-based intelligent irrigation and maintenance systems can automatically regulate water supply based on soil moisture and meteorological conditions, ensuring healthy maple growth and extending the red-leaf viewing period. Soil moisture sensors monitor root zone water content in real-time; combined with weather forecast data, intelligent control systems can initiate irrigation before a drought occurs, avoiding premature leaf fall caused by water stress. For precious ancient maple trees, monitoring equipment such as trunk sap flow sensors and leaf chlorophyll fluorescence detectors can be installed to assess tree physiological status in real-time, promptly detecting anomalies and implementing maintenance measures. In the future, digital twin technology holds the potential to construct virtual maple landscape platforms, integrating real-time monitoring data with 3D landscape models to dynamically display leaf color change processes, aiding public engagement and cultural dissemination. Visitors can access real-time autumn foliage information via mobile apps to plan optimal viewing routes, while scenic area managers can use this data to regulate visitor flow and arrange events, further enhancing the comprehensive value and cultural influence of maple landscapes.

8 Concluding Remarks

The formation of maple leaf color is not caused by a single factor but is the result of the combined effect of genetic factors and environmental conditions. From a genetic perspective, certain genes and regulatory factors influence the production and content of chlorophyll, carotenoids, and anthocyanins, causing leaves to exhibit different colors such as green, yellow, or red. Simultaneously, external environmental conditions, such as light intensity and temperature, also affect the accumulation of these pigments and influence the expression of related genes. Therefore, the leaf color of the same maple tree may vary under different environmental conditions, and the pattern of color change may not be entirely consistent. Research also indicates that some artificial measures, such as girdling, can affect the pigment accumulation process and the expression levels of related genes, thereby causing changes in leaf color. In recent years, with the rapid development of molecular biology techniques, the understanding of the mechanisms underlying maple leaf coloration has deepened, providing a solid theoretical foundation for maple variety improvement and landscape application.

Research on the genetic mechanisms of leaf color has also promoted the development of ornamental plant breeding. Through multi-omics research methods, researchers have discovered many important genes and transcription factors related to pigment synthesis, such as MYB and bHLH. Simultaneously, studies have shown that gene duplication phenomena may also affect the stability of leaf color. The discovery of leaf color mutant materials and the application of molecular marker technology have provided new methods for breeding new varieties with specific leaf colors and the ability to exhibit changing characteristics in different seasons. Due to the rich genetic diversity in maple leaf color, through directional selection, various maple varieties with different color series, such as red series and yellow series, have been cultivated, further enhancing their ornamental value. With the maturation of gene editing technology and the improvement of genetic transformation systems, precise