hyperspectral measurements with synchronous ground traits such as biomass, SPAD, or morphological indicators, and that improve performance further by fusing spectral, texture, and phenotypic variables (Wu et al., 2025). Spatial layers should also be included, because machine learning linked with GIS and soil information can map suitable cultivation zones and rapidly organize medicinal plant growth conditions at regional scale, which is directly relevant for Zhejiang's heterogeneous production environments (Roopashree et al., 2024).

6.2 Machine learning-based prediction of growth performance

For growth-performance prediction, the case study should model biomass, vigor, and relative growth rate using supervised learning algorithms trained on integrated temporal and environmental features. Evidence across plant systems shows that machine learning handles complex functional associations in biomass prediction well, especially when datasets include weather, soil, and agronomic variables rather than image features alone. Ensemble methods are often strong performers in such settings, and agriculturally important predictors repeatedly include temperature, precipitation, slope, elevation, and other environmental drivers that can be measured or inferred for medicinal plant fields (Figure 2) (Cacho et al., 2023).

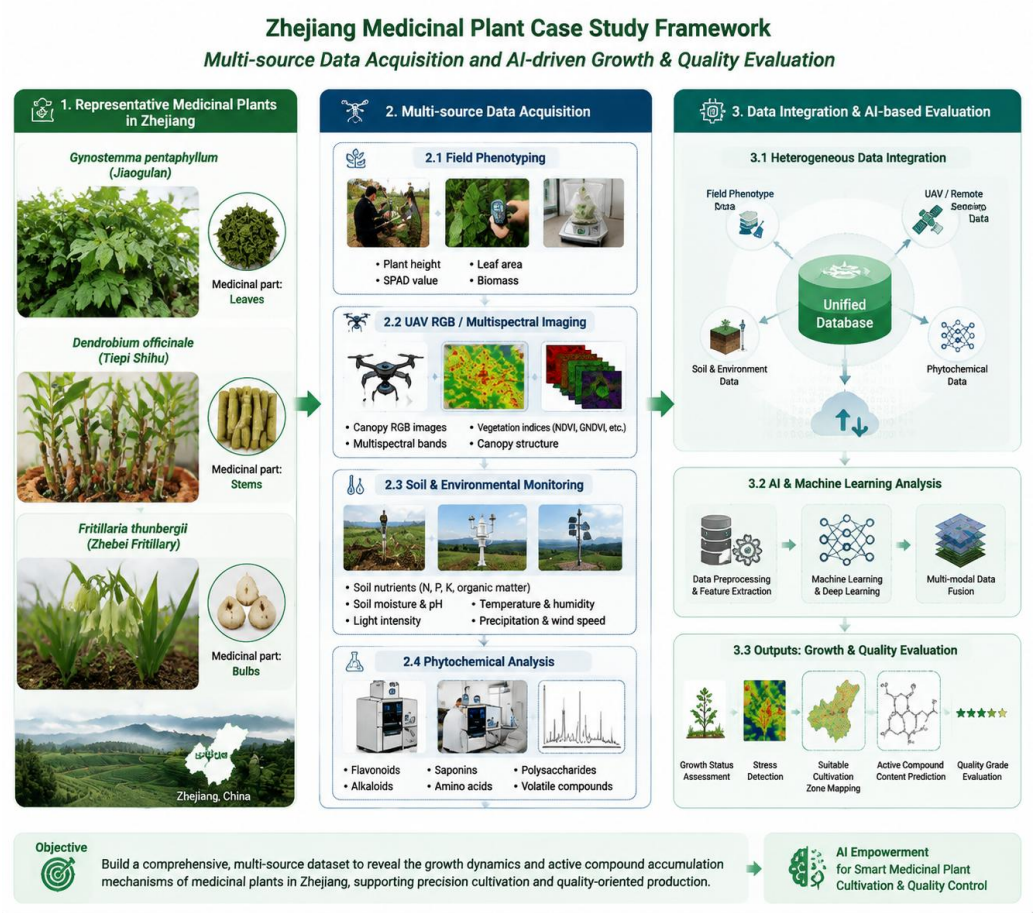

Figure 2 Representative medicinal plant selection and multi-source data acquisition framework for Zhejiang case studies

At the same time, medicinal-plant-specific evidence supports non-destructive and early prediction workflows.Hyperspectral and deep learning approaches have estimated SPAD and biomass in *Lamiophlomis rotata* with good accuracy, while feature fusion improved prediction over single feature types, indicating that Zhejiang medicinal plants would benefit from models that merge spectral and phenotypic descriptors (Wu et al., 2025). Time-resolved prediction is also valuable because early models can identify low-yield batches well before harvest and enable corrective intervention, as shown by cultivation studies where final biomass was predicted by day 8 and process adjustment increased yield by 54.1%.

6.3 Prediction of active compound accumulation and quality optimization

Prediction of active compound accumulation should be based on integrated chemical, biological, and