

FERTiOLiVE — Low-Cost Smart Fertilisation System for Traditional Olive Groves



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Introduction

Soil fertility directly determines crop productivity and product quality. Yet in the traditional Mediterranean olive grove, close to 75% of the Portuguese olive area, fertilisation is decided without measurement. In Portugal, nutritional status is assessed by leaf analysis sampled in July [1], which requires travel, laboratory processing and a cost per sample, and the result arrives after the decision window has closed. For a two-hectare holding the method is unaffordable, so fertiliser is applied by habit: too much where the nutrient is already available, too little where it is not, and neither case is detected. Soil analysis on its own does not close the gap, because nutrient availability in the soil is not the same as uptake by the tree, being mediated by pH, electrical conductivity, texture, organic matter and cation interactions [2].

Objectives

The project has three objectives. The first is to establish a quantitative soil–leaf relationship for the traditional olive grove, derived from paired analytical profiles collected across three contrasting management systems and complemented by a historical analytical archive. The second is to develop predictive models that run locally on a microcontroller, compressed and quantised so that inference takes place on the device itself rather than in the cloud. The third is to deliver the resulting fertilisation recommendation in the field, without a permanent Internet connection, through a mobile application designed for users with limited digital literacy and validated with growers in real conditions.

Materials and Methods

Paired soil and leaf analytical profiles are collected in traditional olive groves under three management systems, conventional mineral fertilisation, abandonment and organic production and determined by reference methods: pH (ISO 10390), electrical conductivity, total nitrogen, available phosphorus and potassium, and moisture; leaf material by acid digestion with AAS or ICP-OES quantification. These are complemented by the digitised historical soil analysis archive of IPB and by established reference intervals [3]. The soil–leaf relationship is established through correlation matrices (Pearson, Spearman), regression and multivariate analysis. Neural network models are then trained, compressed and quantised for execution on a microcontroller [4].

The resulting system is organised in four layers. In the edge layer, a low-cost probe measures N, P and K in the soil; an ESP32 reads the probe and transmits over LoRa to a Raspberry Pi gateway, which buffers the readings. A second ESP32 applies pre-processing and normalisation and runs the two quantised networks in sequence: the first estimates nutritional status, the second converts that estimate into a fertilisation recommendation. The gateway reaches the mobile application over BLE or Wi-Fi, so diagnosis and recommendation are produced and consulted entirely within the holding. The backend layer REST API, central database and dashboard is reached only by opportunistic synchronisation when a connection happens to be available, and no field function depends on it.

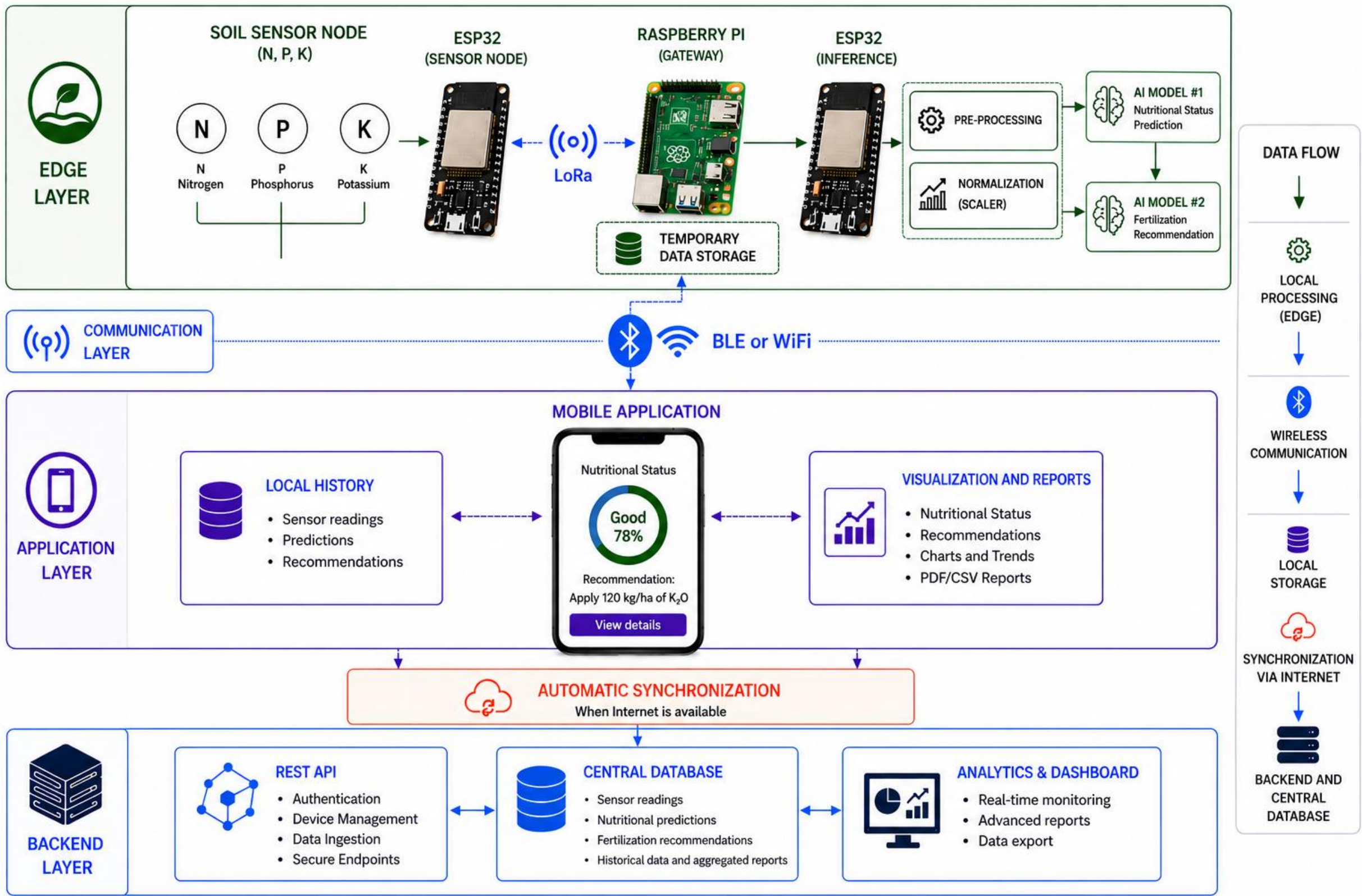


Figure 1 — System architecture: soil sensor node, LoRa transmission, local TinyML inference and mobile application

Expected Results

The solution will allow the nutritional status of each plot and the corresponding fertilisation recommendation to be consulted directly in the field, without an Internet connection. The information is generated locally from the readings of the sensor node installed on the farm, replacing the wait for laboratory results with an indication available at the moment the fertilisation decision is made. The complete solution: sensor node, microcontroller and low-cost application, is to be validated in a real-world setting and evaluated by at least 200 end users on traditional olive farms.

Conclusions

Demonstrating that foliar nutritional status can be inferred from soil parameters measured by a low-cost sensor node would make nutritional diagnosis accessible to farms that currently apply fertiliser without any measurement, replacing routine application with doses adjusted to actual needs. Moving diagnosis from the laboratory to the field is the practical prerequisite for European nutrient-loss reduction targets to reach the segment of the sector where most of the cultivated area is concentrated.

References

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