Early Detection of Branch Failures in Ficus retusa Trees
El Hamma Garden

Flora

June 25, 2025

Report submitted for
IdeaGen
at the School of Artificial Intelligence,
ENSIA

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Abstract

The historic El Hamma Garden is more than a park — it's a place of memory, beauty, and identity for generations of Algerians. Its towering *Ficus retusa* trees, some over a century old, are living monuments that shape the garden's character and charm. But these same trees have become a silent threat. In recent years, **branches have fallen without warning**, causing serious injuries — and even claiming lives.

The garden's caretakers face a painful challenge: these trees are too majestic to prune without harming their natural beauty, yet they have no reliable way to know when a branch might fail. Signs of internal decay or fungal infection often go unnoticed until it's too late, and relying on the naked eye alone has proven tragically insufficient.

This project offers a much-needed breakthrough: a smarter, safer way to monitor and assess the risk of falling branches — **before they fall**. It is the **first solution of its kind ever developed for El Hamma**, combining practical observation and data-informed assessment to help protect both the trees and the people who walk beneath them. With this initiative, we hope to prevent further tragedies, preserve the garden's legacy, and bring peace of mind to every visitor.

1 Introduction

The El Hamma Garden in Algiers is not just a botanical park — it is a cultural and historical landmark, visited by thousands of people each year. Among its most iconic features are the Ficus retusa trees, known for their immense branches, thick canopy, and stunning aesthetic presence. These trees have stood for decades, providing shade, beauty, and identity to the garden. However, as time passes, they are beginning to pose an alarming danger.

Recent years have seen an increase in sudden branch falls, some of which have resulted in serious injuries and even death. These incidents are not only tragic — they are preventable. The garden's team faces a difficult challenge: the branches are too large and structurally complex to prune without advanced planning, yet no technical solution currently exists to help assess whether a branch is at risk. Relying solely on the naked eye, experts often miss internal decay, fungal infection, or structural stress until it's too late.

To address this, we propose a smart, AI-driven system that can analyze visual indicators of risk and help staff detect failing branches before they fall — preserving both the beauty of the garden and the safety of its visitors.

2 Problematic

What happens when the very trees that symbolize life, peace, and history become a threat to the people walking beneath them?

In recent years, the majestic *Ficus retusa* trees of El Hamma Garden — towering giants that have stood for decades — have started to pose a growing danger. Without warning, large and heavy branches have fallen, sometimes in areas filled with **families, tourists, and children**. These incidents are not isolated. **Tragically, some of them have led to serious injuries, and even deaths.** What was once a place of peace and beauty is now overshadowed by a **silent and deadly risk**.

The staff in charge of maintaining these trees are caught in a difficult situation. These trees are **too large, too old, and too iconic** to simply cut down or prune aggressively without damaging the garden's charm and heritage value. But at the same time, they have **no reliable method to know if a branch is going to fall**. Visual inspections are limited — **fungal growth, internal decay, and structural weakness are often invisible** until it's too late.

This lack of early detection puts both the trees and the public at risk. Despite the seriousness of the situation, **no solution has been implemented yet** in the garden to address it. With each passing season, the risk increases — and so does the **urgency for action**.

This project proposes the **first intelligent system ever designed specifically for this problem in El Hamma Garden**. More than just a technical challenge, this is a matter of **human safety, cultural preservation, and responsibility**. **It's time to give the people who protect these trees the tools they need — and the peace of mind they deserve**.

Figure 1: Fallen Branch

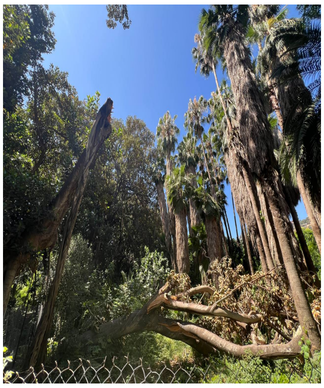

Figure 2: *
Ficus branch failure in 22-06-2025

Figure 3: Real-world challenges faced in El Hamma Garden

3 Background

The issue of unexpected branch failures in large, old trees is a serious concern in public spaces, especially in botanical gardens like El Hamma. Here's what makes this problem so critical and unique:

- **What is branch failure?**
  It refers to the sudden fall of tree branches due to hidden weaknesses such as internal decay, fungal infections, or structural stress. These failures can happen without warning and may be life-threatening in crowded public areas.

- **Why is *Ficus retusa* at risk?**
  These majestic trees are known for:
  - Their **enormous size** and heavy limbs,
  - Their **aesthetic and historic value**,
  - Their tendency to develop **internal rot or fungal issues** that are invisible from the outside.

- **Why El Hamma Garden?**
  El Hamma is home to some of the oldest and largest *Ficus retusa* in the region. The garden plays a major cultural and ecological role in Algiers. However:
  - Several **branch fall incidents** have already been recorded.
  - **Fatal accidents and serious injuries** have occurred.
  - No preventive system is in place to detect failures in advance.

- **Current detection methods are limited:**
  - **Visual inspection** is the main method used by staff — but it cannot detect internal decay or fungal growth.
  - Advanced methods like *sonic tomography, resistance drilling, or pull tests* exist, but:
    * They are **expensive, invasive, or complex**.
    * They require **expertise and equipment** not readily available at the garden.

- **Why this project matters:**
  - There is **no solution currently in place** for El Hamma.
  - The trees are **too valuable to prune or remove** without valid reasons.

  - A **non-invasive, affordable, and scalable system** is urgently needed to:
    * Keep visitors safe,
    * Preserve the beauty and heritage of the garden,
    * Support decision-making for maintenance teams.

- **Our Approach:**
  - Focus on **visible indicators** of internal failure:
    * Bark texture changes,
    * Fungal growth,
    * Canopy dieback.
  - Develop a **localized early detection framework** tailored to El Hamma's specific context and needs.

No advanced or affordable solution has been implemented yet in El Hamma.

Figure 4: trees showing large branches leaning at dangerous angles.

4 Methods

The project followed a structured approach combining fieldwork with predictive modeling:

1. **Expert-Guided Tree Inspections:** A large number of Ficus retusa trees in El Hamma Garden were visually inspected in collaboration with botanical and forestry experts. Particular focus was placed on recently fallen branches, leaf discoloration, fungal patterns, and structural attachments.

2. **Data Collection:**

   - High-resolution photographs were taken of branches, trunks, and infected areas.
   - Measurements were recorded, including branch diameter (just outside the collar) and trunk diameter (above and below the attachment point).

3. **Observation Findings:**

   - Many trees showed signs of fungal infection and internal decay.
   - Branches fell mainly due to excessive weight that exceeded the structural capacity of the trunk to hold them.
   - No quantitative method was in use to estimate or predict when a branch might become hazardous.

4. **Formula Development:** Based on literature review and real-world data, a stress prediction formula drawing on Kane & Smiley's model (2008).

5. **Leaf Analysis:** To identify tree health status, a computer vision model (CNN) was trained to classify leaves as healthy or infected using a labeled dataset. Accuracy and performance were evaluated, and the output was incorporated into the risk classification system.

Tools used: forms, camera documentation, and structured Excel sheets. Future phases may include smart analysis or expert systems.

5 Proposed Solution

5.1 Theoritical Side

To address the inability to quantify branch failure risk, we designed a two-level assessment framework based on established arboricultural research and adapted it to the context of *Ficus retusa*.

5.1.1 Diameter Ratio Risk Classification

- The **Diameter Ratio (DR)** is calculated as:

$$DR = \frac{d_{branch}}{d_{trunk}}$$

  where:

  - d_{branch}: branch diameter (cm), measured just outside the branch collar.
  - d_{trunk}: trunk diameter (cm), average of measurements above and below the branch attachment point.

- Based on research by Kane & Smiley (2008), we apply the following risk levels:

DR Range	Risk Level	Action Required	Failure Mode
$DR \geq 0.70$	CRITICAL	Immediate removal/support	Flat surface/Embedded
$0.50 \leq DR < 0.70$	HIGH	Maintenance within 30 days	Mixed
$0.30 \leq DR < 0.50$	MODERATE	Monitor quarterly	Ball and socket
$DR < 0.30$	LOW	Annual inspection	Ball and socket

5.1.2 Branch Breaking Stress Estimation

To calculate the mechanical stress on a branch:

$$\sigma = \frac{P \times L \times \cos(\theta)}{\frac{\pi d^3}{32}}$$

Where:

- σ: Estimated breaking stress (MPa)
- P: Load force (kN)
- L: Distance from attachment point to load (m)
- θ: Angle between branch and vertical (degrees)

- d: Inside-bark branch diameter (m)

Species-based stress regression:
Kane & Smiley provide predictive formulas:

- Red Maple (conservative): $\sigma = 94.8 - 76.3 \times DR$
- Sawtooth Oak: $\sigma = 181 - 152 \times DR$
- **Recommended for Ficus retusa (conservative)**:

$$\sigma_{estimated} = 95 - 76 \times DR$$

5.1.3 Leaf Analysis (Optional Future Module)

Future improvements will include:

- Use of captured images of leaves to detect fungal or viral infections.
- Visual markers such as discoloration, spots, or deformation may be integrated into a classifier model.
- This will further support early risk identification before structural symptoms appear.

5.2 Practical Side:Application Walkthrough

This section presents a step-by-step tour of theFolly mobile application. The goal is to demonstrate how the user interacts with the app — from opening it, locating a tree, submitting measurements, to viewing risk assessment results.

Each step is accompanied by interface illustrations to help visualize the flow.

Step 1: Launching the App

Upon launching, the user is greeted with an interactive map interface showing the layout of El Hamma Garden.

Step 2: Selecting a Tree

The user taps on a specific tree marker on the map. This opens a new page dedicated to that tree's information.

Step 3: Entering Branch Information

Users enter the required measurements: branch diameter, angle, length, and estimated load. This data is used to calculate mechanical stress.

Step 4: Assessing Risk

After clicking the “Assess Risk” button, the app calculates the risk level using built-in formulas and shows a result widget with:

Step 5: Viewing Saved Assessments

All past assessments are stored under the ”Latest Assessments” tab, allowing users to track history over time.

Optional: AR-Based Measurements

Users can also opt to use Augmented Reality (AR) for measuring branch length and angle by pointing their smartphone camera.
This feature improves accuracy and reduces the need for physical tools such as calipers or angle meters.

6 Future Requirements

FUT-01: Tree Signal-Based Monitoring (FUTURE)

- Develop a non-invasive system to monitor tree health by capturing bio-signals (electrical, acoustic, or vibrational) from within the tree structure.

FUT-02: Decorative Sensor Cable Network (FUTURE)

- Implement an aesthetically integrated cable system that wraps around the tree branches and trunk.
- These cables would serve a dual purpose:
  - As visual enhancements that blend naturally with the garden's historical charm.
  - As embedded signal capture devices that monitor internal stress levels and signal conductivity changes over time.
- The cables could be designed to collect real-time physiological indicators (e.g., sap flow, impedance variations) and be connected wirelessly to the system.
- This solution is entirely non-destructive and supports long-term, live monitoring.
- Feasible with future hardware availability and funding for development.

FUT-03: Vibration-Based Diagnostic Tool (FUTURE)

- Introduce a portable vibration sensor tool that emits low-frequency waves into branches and listens for echo patterns.
- This technique can:
  - Detect internal decay or hollow zones within thick limbs.
  - Identify early structural weaknesses that are not visible from the outside.
- Can be used during periodic inspections by simply placing the device against the bark.
- Similar technology has been used in trunk tomography and could be miniaturized.
- Requires specialized sensors not currently in possession, but the approach is technically viable and scalable.

Conclusion

The early detection of branch failures in heritage trees such as the *Ficus retusa* at El Hamma Garden is not merely a technical problem — it is a matter of public safety, cultural preservation, and environmental responsibility. The proposed Flora Tree Safety System brings a novel, intelligent, and non-invasive approach to this challenge, combining artificial intelligence, stress analysis, and field inspection tools into one unified platform.

Through this SRS, we have outlined a clear vision of the system's goals, architecture, functional features, and potential future extensions. The solution is practical, grounded in arboricultural science, and designed for real-world use by garden staff and authorities. By offering actionable insights and risk classification, it empowers decision-makers to act before tragedies occur — not after.

Moreover, the roadmap for future development shows promising directions for expanding the system's capabilities through AR measurements and signal-based diagnostics. These innovations could elevate tree health monitoring to an entirely new level, blending technology seamlessly with nature.

In sum, this system stands as a first-of-its-kind digital guardian for trees that have stood for centuries — a guardian that watches silently, calculates wisely, and protects both nature and people with precision.

Flora Team

Acknowledgements

We thank the ENSIA mentors, El Hamma staff, and our fellow participants in IdeaGen for their support and insights.

A Appendices

Figure 5: Interactive Map Interface

Figure 6: Tree Selection Page

Figure 7: Measurement Input Form

Figure 8: Risk Assessment Output

Figure 9: latest statistics

Figure 10: AR Measurement Feature (Experimental)

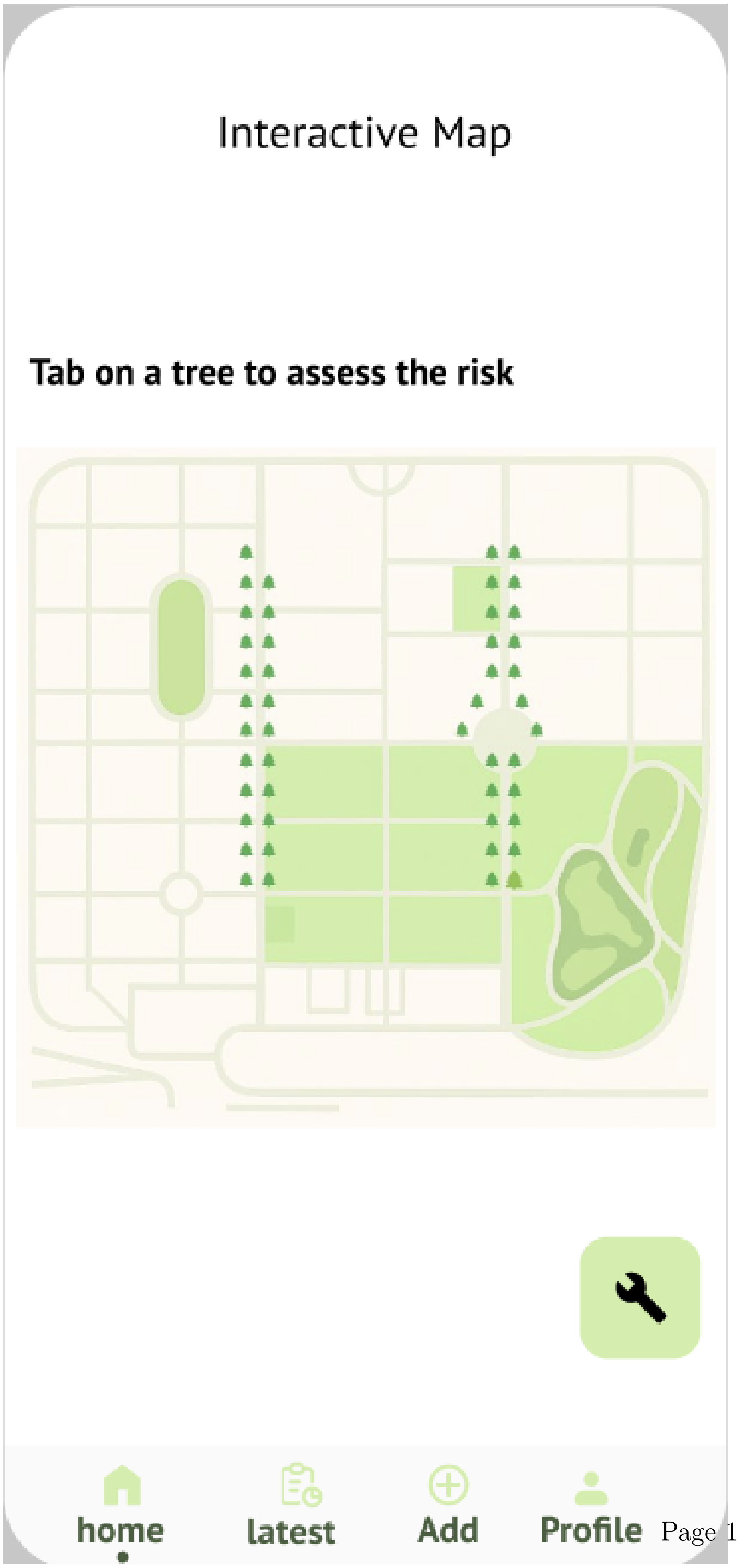

Figure 5: Interactive Map Interface – Users can select trees

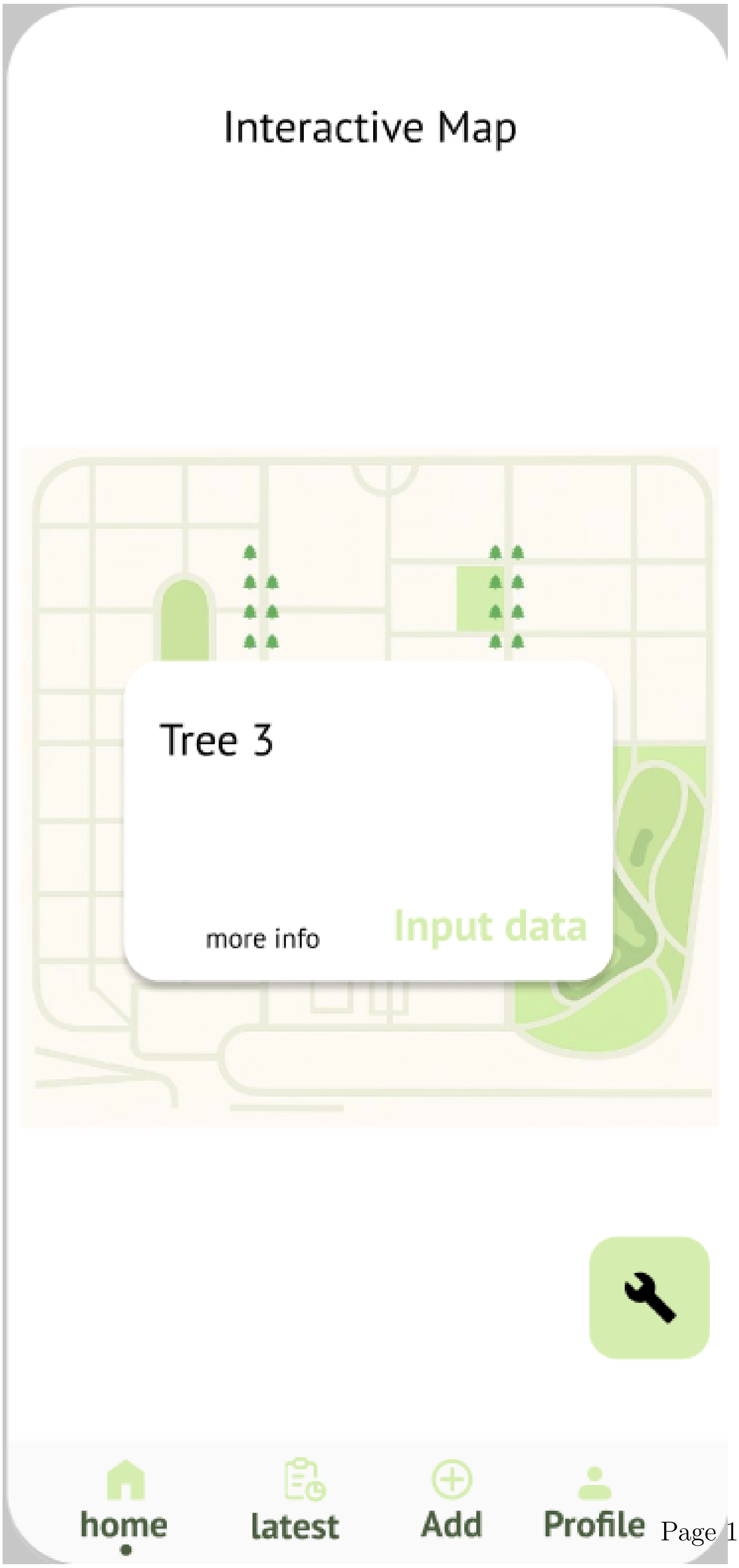

Figure 6: Selecting a specific tree from the garden map

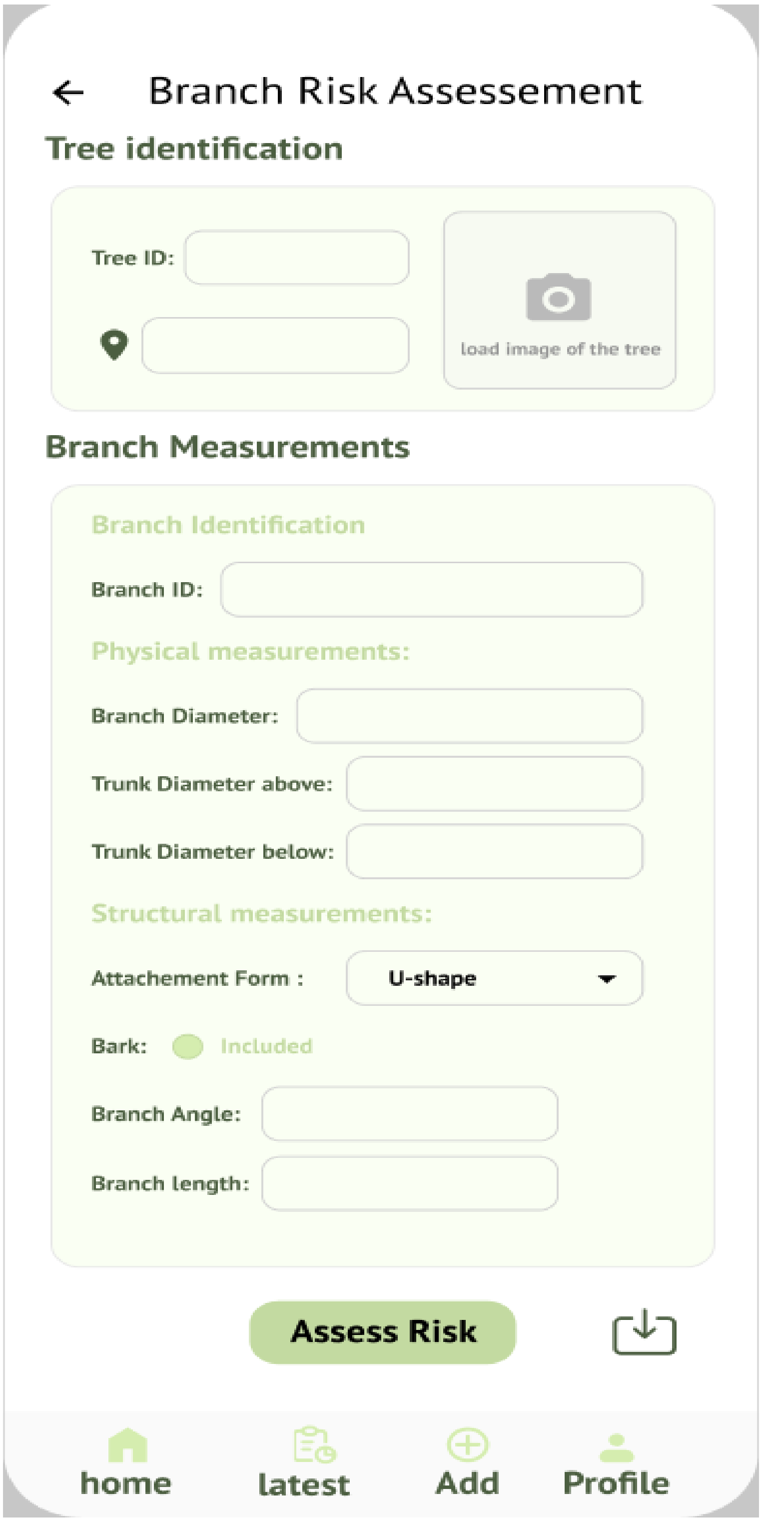

Figure 7: Input form to record branch diameter, angle, etc.

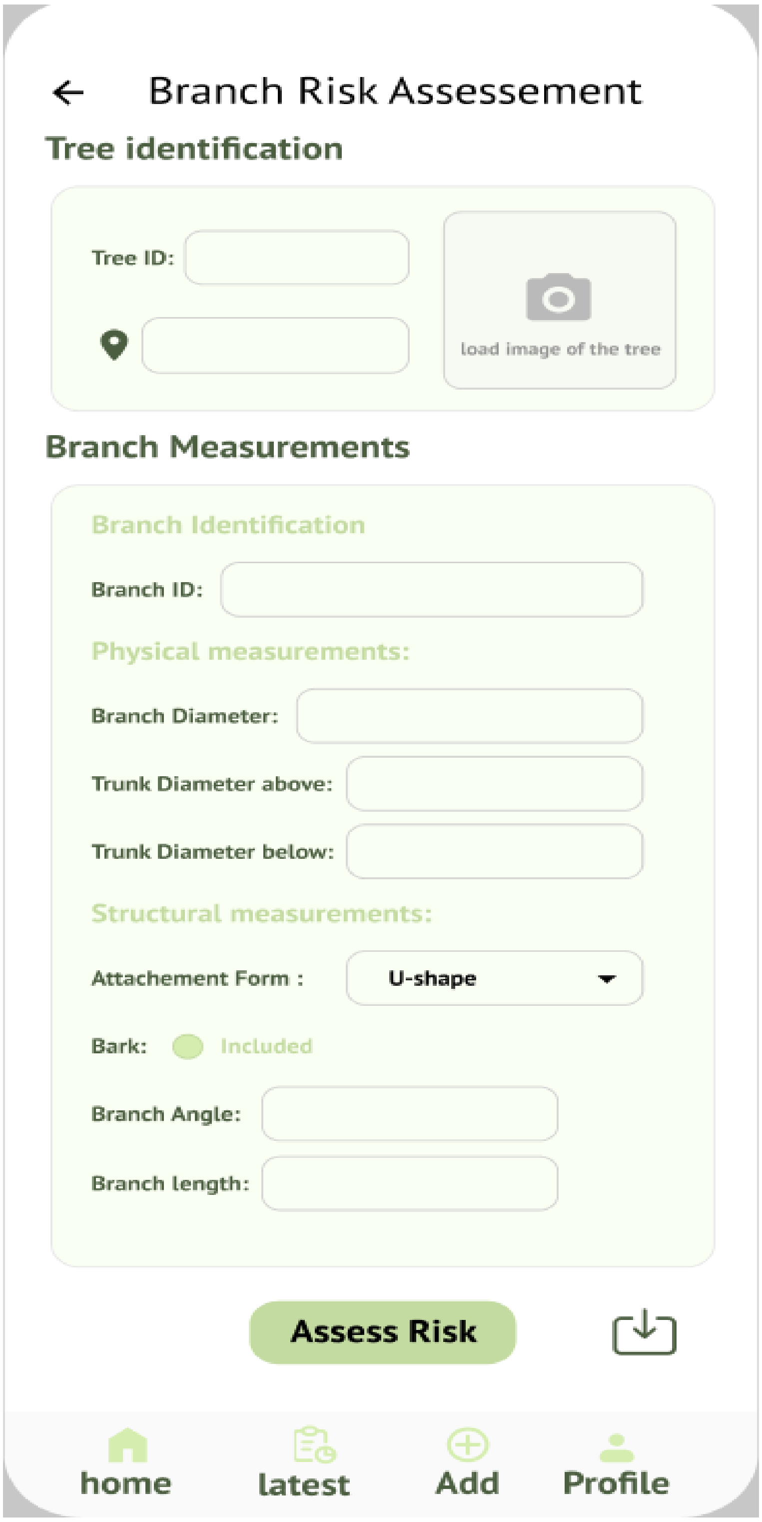

Figure 8: Assessment result showing stress, DR, and action

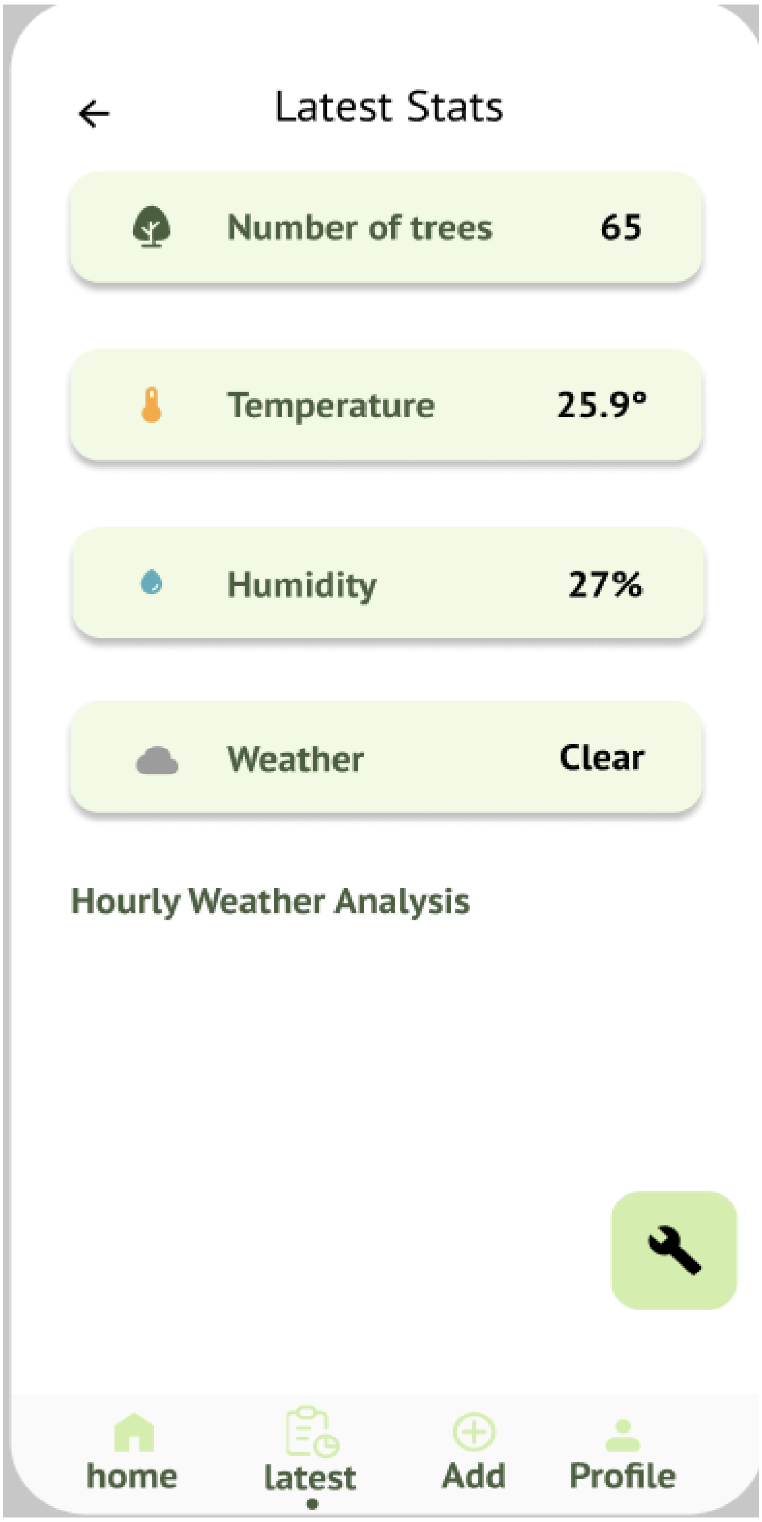

Figure 9: List of latest statistics

Figure 10: Measuring branch size and angles using AR

References

[1] Kane, B. Smiley, E.T. (2008). "Failure Mode and Prediction of the Strength of Branch Attachments." Arboriculture Urban Forestry, 34(5), 308-316.