Deliverable D.3.01

Portable RFID tag reader/programmer

WP 3 – Integration of novel intelligent harvesting systems operating in mountain areas (hardware development/integration)

Task Number 3.1 - Intelligent tree marking and tree felling/hauling

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Statement of originality

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<th>Description</th>
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<tbody>
<tr>
<td>CA</td>
<td>Consortium Agreement</td>
</tr>
<tr>
<td>DM</td>
<td>Data Manager</td>
</tr>
<tr>
<td>GA</td>
<td>Grant Agreement</td>
</tr>
<tr>
<td>GA</td>
<td>General Assembly</td>
</tr>
<tr>
<td>OM</td>
<td>Operational Manager</td>
</tr>
<tr>
<td>PC</td>
<td>Project Coordinator</td>
</tr>
<tr>
<td>QRM</td>
<td>Quality and Risk Manager</td>
</tr>
<tr>
<td>SB</td>
<td>Stakeholders Board</td>
</tr>
<tr>
<td>TB</td>
<td>Technical Board</td>
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<tr>
<td>TL</td>
<td>Task Leader</td>
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<tr>
<td>WPL</td>
<td>Work Package Leader</td>
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Co-founded by the European Commission
WP 3 – Integration of novel intelligent harvesting systems operating in mountain areas
Deliverable 3.01 – Portable RFID tag reader/programmer
1 Selection of RFID technology

The definition of the appropriate hardware for RFID tag reading and programming is necessarily preceded by the selection of the specific RFID technology to be deployed. Radio Frequency Identification systems may differ for several technical or practical aspects, being the main one the radiofrequency used by the tag-reader devices. In the present chapter the criteria for selecting a specific RFID technology for the SLOPE work system is described. Furthermore, the most suitable models of RFID tags and the guidelines for their use in forest works is analyzed.
1.1 Selection of the technology

Radio Frequency Identification (RFID) technology is a general term used to describe a system which is able to transmit a unique identifier utilizing RadioWaves. The technology was born in the early 1970’s as a way to track hazardous nuclear material\(^1\). Nowadays this technology is used worldwide to identify and track any number of devices and elements.

The term RadioFrequency is used to describe electromagnetic waves ranging from a frequency of 30Hz to 300 GHz. RFID usually covers only a specific range of these frequencies, usually from 30Hz to 5.8 Ghz.

1.1.1 General considerations

Next figure shown a simplified version of a typical RFID system.

![Simplified RFID backscattering system](image)

**Figure 1** Simplified RFID backscattering system

First of all, the RFID reader sends an electromagnetic field using its antenna. If any RFID tag is inside the reading range of the field, it recovers energy from the EM wave to turn itself on. Next, the RFID tag sends a new RF wave of the same frequency but modulated to include the information inside the tag. The RFID reader receives this new modulated wave, and extracts the information.

Electromagnetic properties of any material near a tag and between the reader and the tag affect the performance of the RFID system. The system operation changes in two ways which can be referred to as the near field effect and the far field effect\(^2\). In theory, the near field effect occurs for both antennas of a radio system (reader antenna and tag antenna), but in practice the transponder has a

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\(^2\) Indisputable key Project (Project no. 34732). D4.10. Forest RFID Transponder and Reader Design.
simpler antenna and operates in varying and more challenging environments, whereas the reader assembly is rather fixed. Therefore, the near field effect should be considered to be relevant mainly for the tag antenna.

In the near field effect, the antenna properties are affected by the properties of a material brought near it. Any dielectric material near the antenna changes the electric field strength and distribution and results in a changed antenna feed impedance (detuning effect) and radiation efficiency (losses). The antenna feed impedance is optimized for a certain electric environment and any change from that results in a weakened power coupling between the tag antenna and the tag Integrated Circuit. To obtain perfect coupling of RF power and thus maximum read range, the impedance of the tag antenna $Z_{\text{ant}}$ and the impedance of the IC $Z_T$ should be complex conjugates of each other, which condition can be denoted as $Z_{\text{ant}} = Z_T^*$. The reflection of RF power due to impedance mismatch between the antenna and the IC can be denoted in terms of reflection coefficient $\rho$ and calculated from

$$\rho = \frac{Z_T - Z_{\text{ant}}^*}{Z_T + Z_{\text{ant}}^*}$$

Due to the reflection effect, the useful RF power coupled into the IC load, $P_{\text{in}}$, can now be calculated:

$$P_{\text{in}} = P_{\text{av}} \left( 1 - \left( \frac{Z_T - Z_{\text{ant}}^*}{Z_T + Z_{\text{ant}}^*} \right)^2 \right)$$

where $P_{\text{av}}$ is the maximum power available, obtained to the load in the case of perfect impedance match. We are here evaluating the system performance only in terms of the power coupled from the reader to the tag. It is acceptable, because the system is reciprocal in this sense, meaning that the same conditions apply for the signal scattered back from the tag to the reader. The complex impedance of the tag antenna can be divided into real and imaginary components:

$$Z_{\text{ant}} = R_r + R_l + j \cdot X_{\text{ant}}$$

where $R_r$ is the radiation resistance of the antenna, $R_l$ is the loss resistance of the antenna and $X_{\text{ant}}$ is the antenna reactance. In this equation, the real part of the antenna impedance consists of two parts: radiation resistance and loss resistance. The losses in the antenna and in the near environment of the antenna increase the loss resistance. Equations (1) and (2) help to find the right antenna impedance to minimize the detuning effect, but if the radiation efficiency of the antenna is poor, which is equivalent to the loss resistance being too large compared to the radiation resistance, their help is limited. To evaluate the near field effect as a whole, in terms of the factors affecting the performance of the tag, the effective
aperture $A$ of the antenna is a practical parameter. The effective aperture is the effective area from which the antenna captures the electromagnetic power radiated by the reader and transfers it to the IC load. The effective aperture of the transponder antenna can be written as:

$$A = \frac{\lambda^2 D}{\pi} \frac{R_T}{(R_0 + R_T + R_{\text{IC}})^2 + (X_{\text{IC}})^2}$$

where $\lambda$ is the wavelength and $D$ is the directivity of the tag antenna. The load impedance of the IC ($Z_{\text{IC}}$) is also here divided into real and imaginary parts, $R_T$ and $X_T$ respectively. We can now conclude that the effective aperture and thus the performance of the transponder are at their maximum when loss resistance $R_L$ is as low as possible and the impedances of the antenna and the IC load are complex conjugates of each other.

### 1.1.2 Main frequency ranges

The frequency of the electromagnetic wave is essential, since it has direct effect on the reading distance. Attenuation of electromagnetic waves follow the next equation:

$$L_{\text{att}}(dB) = 32.45 + 20 \cdot \log(D(\text{km})) + 20 \cdot \log(f(\text{MHz}))$$

Where the distance $D$ in introduced in km, and the frequency in MHz. In example, for 900 MHz (UHF) and a distance of 8 meters, the suffered attenuation is 49.5 db.

The frequency range are typically broken down into four different ranges:

#### 1.1.2.1 RFID LF

Low Frequency RFID tags work at 125KHz to 134 KHz. This frequency only allow working at very close contact, usually less than 1 cm. Typical applications for this technology are access control and livestock tracking. The main standards for LF animal-tracking systems are defined in ISO 14223, and ISO/IEC 18000-2.

#### 1.1.2.2 RFID HF

High Frequency RFID tags work at 13.56MHz. This frequency only allows working at close distance, in example 1-2 cm. The antenna for this frequency has a spiral...
type, the bigger the antenna the larger the reading distance. Usually it has a size similar to a credit card. Typical application for this technology are ticketing, payment, and data transfer applications.

There are several HF RFID standards in place, such as the ISO 15693 standard for tracking items, ISO/IEC 14443 A and ISO/IEC 14443 standards for MIFARE technology and the JIS X 6319-4 for FeliCa.

Near Field Communication NFC tags are a modification of RFID HF tags. NFC includes specific protocols for data exchange, being really used in contactless payments and other data transaction. The ECMA-340 and ISO/IEC 18092 are the main standards used in Near Field Communication (NFC).

### 1.1.2.3 RFID UHF

Ultra High Frequency RFID tags work at 868-902MHz. They are the standard for logistics and storage applications. Their frequency allows reading up to approximately 10 meters. The antennas have a dipole layout, and sizes usually below 11 cm wide.

The UHF frequency band is regulated by a single global standard called the ECPglobal Gen2 (ISO 18000-6C) UHF standard.

### 1.1.2.4 Microwave RFID tags

Microwave tags work at frequencies bigger than 900MHz. They have a very long reading range, i.e 200 meters. They are expensive and relatively big devices, because they need to incorporate a power source (battery) to be able to create microwaves, since a certain energy is required. This battery needs to be replaced once it is empty. They usually include other elements, like sensors, to measure and communicate different information.
1.1.3 **SLOPE RFID selection**

Main RFID characteristics are summarized in next table:

<table>
<thead>
<tr>
<th></th>
<th>LF</th>
<th>HF</th>
<th>UHF</th>
<th>Microwaves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td>125KHz to 134 KHz</td>
<td>13.56 M;Hz</td>
<td>868-902MHz</td>
<td>&gt; 902MHz</td>
</tr>
<tr>
<td><strong>Average reading range</strong></td>
<td>&lt;1 cm</td>
<td>2-5 cm</td>
<td>0-10m</td>
<td>0-100m</td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Estimative cost per tag</strong></td>
<td>&lt; 0.3€</td>
<td>&lt; 0.3€</td>
<td>&lt; 0.3€</td>
<td>&gt;3 €</td>
</tr>
</tbody>
</table>

For the SLOPE project, RFID tags will be used in different parts of the supply chain:

- **Tree marking.** A tag will be used to identify the tree. The tag needs to be placed and read. Since the tag is placed in the surface of the tree, it is easily accessible and can be read at very close distance (<1 cm)

- **Tree felling.** The tag needs to be read before the tree is cut down. In this situation the tags can be easily accessed and read at close distance (<1 cm)

- **Cable crane.** The tag needs to be red by the motorized cable crane. This is an automated reading, with no human user near the system. In this situation, the tree (and the attached RFID tag) cannot be too close to the crane because it could damage it. Trees and logs usually hangs at a minimum distance of 2 meters, so RFID tags need to be read at that distance. Therefore, a minimum reading distance of 2 meters is required.

- **Processor.** The processor will automatically read and integrate tags into the logs. The log will be grabbed and cut by the processor, and therefore tags can be read at short distance (<30cm).

- **Truck.** Finally the logs will be transported with trucks. Since the logs can be placed in different positions in the truck, not a specific and repetitive orientation and distance between a reader and the logs can be assured. At least 3-8 meters are needed.

Therefore, due to the requirements of the cable crane, the truck and partially the processor, UHF RFID technology has been selected for the project. Microwave technology could also comply with the reading range requirements, but microwave tags are considerably more expensive that UHF passive tags, and have a bigger size and therefore susceptible of receiving more hits and blows in field applications. This technology had been also selected and applied in the frame of the EU FP6 project “Indisputable Key”, for the development of a traceability system in timber logistics, where a dedicated pulping-compatible tag model was created.
1.2 Selection of the UHF RFID tag model

The basic structure of RFID tags is the transponder, a metallic element built in different shapes according to the purpose and the manufacturer, and the integrated circuit. These elements are fixed on a simple plastic tape structure (eventually with one adhesive surface for application), or protected and supported with different type of cases, according to the final application. Clearly the complexity of the final RFID structure is reflected in the size and the unitary cost.

As a first step the datasheets of a considerable number of UHF RFID tag models had been compared in order to identify the most suitable types for the specific purposes of the project, and in general for tree and log marking. Ideally a unique tag model should be used all along the whole timber supply chain, from tree marking to logs marking at the landing. This would lead to a great simplification in all the processes, and reduce the unitary cost of the tags, since a single model would be purchased in a larger quantity.

<table>
<thead>
<tr>
<th>Number</th>
<th>Manufacturer and name</th>
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<tr>
<td>1</td>
<td>Omni-ID; Exo 600</td>
</tr>
<tr>
<td>2</td>
<td>HID; Slimflex</td>
</tr>
<tr>
<td>3</td>
<td>Confidex; Ironside</td>
</tr>
<tr>
<td>4</td>
<td>Synometrix; SMLM-8200</td>
</tr>
<tr>
<td>5</td>
<td>Confidex; Ironside Micro</td>
</tr>
<tr>
<td>6</td>
<td>Confidex; Pino</td>
</tr>
<tr>
<td>7</td>
<td>Smartrac; Shortdipole</td>
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</tbody>
</table>
A selection of 7 tag models had been tested in marking operations on standing tree, gathering the opinions and suggestions of expert professionals. As a total 53 trees were marked traditionally (debarking) and with UHF RFID tags, simulating the actual procedure that an operator shall perform for visual and electronic marking in a unique operation.

For forest application a rough division can be made according to the application modality:

1) RFID tag models with hard shell, requiring a screw or rivet for application (tags 1, 3, 4 and 5);

2) RFID tag models with soft cover, allowing gluing or stapling (tags 2 and 7, partially tag 6).

The models grouped in 1) have a higher unitary price (above 1 €), are heavier, more protected and probably less sensitive to the dielectric influence of wood. On the other hand they require a common or electric screw driver and a longer operation for being applied on the standing trees. Furthermore they need steel screws for fixing on solid wood, and their presence may severely damage the sharp tools at the sawmills. Alternative resin-screws have been considered, but cannot be driven directly into the solid wood, requiring a time consuming pre-drilling. While the alternative to recover the RFID tags and screws at the end of the supply chain seems unfeasible from the practical and economic point of view. The tags of group 2) are lighter, simpler and with a unitary price around 0.2 €. The different configuration allows for a larger transponder size, which guarantees a longer reading distance. Furthermore if the plastic cover exceeds the transponder...
size, the tags may be simply stapled on the solid timber by means of a common mechanical stapler. This could be the system for fixing the RFID tags manually and automatically (with the processor). Commercial staples are made in aluminum, and have a very low unitary mass. Compared to steel screws, these have a negligible impact on the sharp tools of the sawmill and can be placed on the timber without main consequences.

The low cost, minimal impact and long reading range make the tag models of group 2) more suitable for a traceability system based on disposable items. Among these the tag model 7 (Smartrac Shortdipole), protected by a PET EVA plastic cover was initially selected as the best suited, and a first concept of SLOPE UHF RFID tag was developed.

![Figure 6 Concept of UHF RFID tag design for the SLOPE project](image)

Following the selection of the specific RFID tag type and protection, a further research was conducted, contacting RFID transponder manufacturers. In this second stage four RFID tag models were identified as suitable.

a) Smartrac Shortdipole Monza 5. A logistic dedicated model with long reading range. This is a very simple tag model basically constituted by the transponder and the relative die-cut applied in plastic colored stickers provided in reels. In order to make it suitable for the purposes of timber traceability this model was modified by applying a PET-EVA plastic cover with thermal treatment (110 °C).

b) Wintag Flexytag UHF D7040S. This tag model was selected because considered particularly suitable for the forest environment. In fact it is originally designed for
laundry uses, with a waterproof polyurethane cover (IP68) designed for maintaining the operative capacity at temperatures ranging from -40°C to 80°C as well as resistant to UV, acids and salt solutions.

c) Lab-ID UH 107. A tag model similar in size and purposes to the Shortdipole. Designed for long reading performances. The RFID tag was also adapted to outdoor use by mean of a PET-EVA plastic cover with thermal treatment (110 °C).

c) Lab-ID UH 424. Designed for item-level logistics and apparel applications. This tag was selected for the different measurements proportions compared to a) and c), while maintaining the long read range according to the manufacturer. A more squared tag could be easier to place on the tree and log butt end, with less risk of protruding from smaller diameter trunks. Furthermore it could be more convenient for storing in the cartridge of the processor head’s RFID tag applicator. This models as well was protected with a PET-EVA plastic cover.

<table>
<thead>
<tr>
<th>RFID tag model</th>
<th>Trasponder size (mm)</th>
<th>Overall size, including plastic cover (mm)</th>
<th>Reading range in laboratory conditions (m)</th>
<th>Average unitary weight (g)</th>
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<tr>
<td>Smartrac Shortdipole Monza 5</td>
<td>93 x 11</td>
<td>120 x 25</td>
<td>10</td>
<td>1.1</td>
</tr>
<tr>
<td>Wintag Flexytag UHF D7040S</td>
<td>47 x 13</td>
<td>64 x 45</td>
<td>2-3</td>
<td>4.9</td>
</tr>
<tr>
<td>Lab-ID UH 107/105</td>
<td>91 x 19</td>
<td>115 x 35</td>
<td>10-12</td>
<td>1.3</td>
</tr>
<tr>
<td>Lab-ID UH 423/424</td>
<td>56 x 34</td>
<td>80 x 50</td>
<td>8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Figure 1 main characteristics of the selected UHF RFID tags models

The 4 RFID tag models were compared in an outdoor reading test simulating the cable yarder detection of tag IDs as described in Annex 2. As a result, the model Lab-ID UH 107/105 proved to be the most performing in terms of reading reliability (number of effective readings) and reading range. Given this results, this model was selected as unique UHF RFID tag model to be deployed all along the SLOPE supply chain, from standing tree marking to timber logistics and yard management.

1.2.1 Tree marking with RFID tags - procedure

In collaboration with professional foresters a methodology for standing tree marking was defined. The procedure described in the box below is well integrated
with the operations currently made for tree marking. The execution is fast and requires an additional time of 30-60 seconds compared to the common practices (including tag reading). As a result the RFID tag is well fixed, protected and relatively hidden. This last aspect may be important against acts of vandalism which could lead to the removal of most of the tags.

![Figure 7 Operations for visual and electronic tree marking](image)

The reading simulation describe in Annex 2 proved that the position of the RFID tag on the tree is essential for an effective ID retrieval along the work processes. The RFID tag placed at breast height by the forester is not detectable by the cable yarder carriage, even if using a powerful circular antenna. This is mostly due to the position of the transponder, that would be perpendicular to the radio signal emitted by the reader. Thus, the original tag shall be replaced or coupled by the chainsaw operator with an additional tag fixed on the butt end of the tree felled.

This position is optimal for automatic reading by the carriage and the processor, and is also considered as favorable for the survival of RFID tags during the timber extraction activities. In fact in a properly planned and conducted cable crane extraction the trees are felled in a direction almost opposite to the position of the
cable line, with an angle facilitating the extraction of the tree. In this layout the operator fixes the tree by applying the chockers to the butt of the plant, which is lifted after a brief concentration. This position is suppose to reduce to a minimum the probability of impacts and frictions against the ground or wood residues.
Figure 8 Position of the UHF RFID tags on the butt of felled trees
2 Selection of the antenna/reader system

In this chapter the selection of the antenna + reader system is described. First of all, the operations that are expected from this equipment are listed. The state of the art related to this kind of devices is then explained and finally the equipment that has been selected is described together with the reasons that have motivated its election.

2.1 Objective of the Antenna+Reader system

For the purpose of the project regarding task 3.1 an antenna+reader set is required in order to allow the foresters and chainsaw operators to interact with the information which is linked to each tree.

The procedure is as follows: When the forester tags a tree, a RFID system will allow him to link the previously existing information of the tree (from the SLOPE forest recognition systems) to the specific tree, and also to add as much new information as he/she considers to enrich the systems.

Afterwards, the chainsaw operator will be able, also with a RFID system, to read all the information that the forester had included within the tag and, if appropriate, add more information to it or modify its content.

Thus the RFID system becomes a communication enabler between foresters and chainsaw operators since both of them will be able to read and write information at different moments to the RFID tag attached to the tree. Once the RFID tag is in place, the tree will be uniquely identify through the whole SLOPE platform.

2.1.1 State of the Art

As it has been already mentioned in the previous chapter, a set formed by a RFID UHF reader and an antenna are needed in order to meet the requirements of the project.

The RFID reader is a device which includes or can be connected to one antenna. It sends the primary RF wave, listens for the response from the tags near the antenna, and decodes the information included in the received RF wave. Also, the RFID reader can be used to write new information in the RFID tag.

There are several constructive variations for this device:

- Fixed Reader with integrated antenna. The reader and one antenna are integrated in a unique device.
• Fixed Reader with external antennas. The reader has 4 external parts where different antennas could be connected. This allows placing the antennas in specific pattern, for example in a portal, where the reader reads all tags that go through the portal.

• Portable reader with integrated antenna. Handheld readers are small and portable. The usually can send less energy than fixed readers, and therefore have a smaller reading range.

SLOPE Readers and antennas

All readers and antennas in the project will use UHF technology, in order to be compatible with UHF tags. For the specific application that concerns us at this part of the project, (tree marking), a portable handheld model with the antenna integrated seems to be the best choice.

There are plenty of devices in the market with such a description.

Table 1-1: Portable handheld RFID UHF readers

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
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<tbody>
<tr>
<td>R1240I - qID³</td>
<td>Fully integrated handheld UHF RFID USB/Bluetooth reader</td>
</tr>
<tr>
<td>R1170I - qID⁴</td>
<td>Is a handheld reader compliant with UHF RFID ISO 18000-6C/EPC C1G2 standards. The qIDmini has an integrated antenna suited for short to medium range applications with Bluetooth® communication interface. It is a perfect UHF RFID add-on for any Bluetooth® enabled host such as a PC, a smartphone, a PDA or a tablet. The reader is compatible with Windows XP/7, Windows CE/Mobile, Android, iPhone and iPad.</td>
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3 http://www.caenrfid.it/en/CaenProd.jsp?idmod=801
### Portable readers with integrated display

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
</table>
| IP30 Handheld RFID Reader<sup>5</sup> | EPCglobal UHF Gen 2, ISO 18000-6b, ISO 18000-6c  
RFID Frequency Ranges: 865, 915, and 950 MHz bands, supporting multiple regional configurations  
Bluetooth and USB configurations (model dependent) |
| ATID AT870<sup>6</sup> | 13.56 MHz HF and 868 MHz UHF RFID  
3.5” touch screen  
Windows CE 5.0 operating system.  
Dimensions: 146x74x26 mm  
Weight: 270-330 g (depending on options)  
Protection: IP54  
GPRS,  
GPS,  
Microsoft Windows Mobile 6.5 operating system.  
Dimensions: 27.3x11.9x19.5 cm  
Weight: 0.986 kg (including battery)  
Protection: IP64 |

As it can be seen in the table above, there are two types of handheld RFID readers, those that have been designed to be linked to a tablet or a smartphone through USB or Bluetooth which display is the interface of the reader for the user and those that have their own display as interface for the user.

On the other hand, the RFID tags stored in the backpack or pocket of the forester could interfere with the reading of the tag placed on the tree. This can be avoided in several ways. For instance the spare tags could be kept in a pocket-size metal container, making the transponders unavailable for reading. Alternatively the reader can be operated at low power in an almost contact-mode.

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5 http://www.intermec.com/products/ip30a/  
7 http://www.barcodesinc.com/pdf/Motorola/mc9190-z.pdf
2.2 Selected Equipment

The UHF RFID readers have been selected in this task. In general terms the same tool could be used by both the professionals, which have common operative requirements (light, easy to use, good), one model for the forester and another model for the chainsaw operator., nevertheless a differentiation was The is listed below:

R1240I qID

This is the reader selected for foresters. The main reasons are:

1. It provides **high development versatility, since it connects to any device via Bluetooth and has an android API for development.** This is especially relevant due to the fact that TREEMETRICS already had, (before starting the project), many applications developed for systems running with an Android operating system and great development skills for applications running on Android. Android solutions are a key technology within the project, and this readers will allow us to integrate the solution seamlessly in the SLOPE solution.

2. The **compatibility with tablets also allows a bigger display surface** than the one provided by the readers that have their own display. This becomes specially useful when, at a first glance and without spending too much time, the operator has to be able in the forest to read all the information linked to a tree. Also, Android tablets allow for an attractive and easy to use user interface.

3. The reader is physically adequate for forest applications. It is (i) **portable**; (ii) can be **attached to the arm** to leave the hands free; (iii) it has **low weight** of 180grs for the R1204I; and (iv) has an adequate **IP protection** (IP32), which could be further increased by mean of plastic covers and anti-shock protective cases.

4. **It has good RF power capabilities** (Programmable in 8 levels from 11 dBm (12.5 mW) to 28dBm (610mW)

5. The reader **can include a barcode reader.** Barcode is a technological alternative to RFID, and this reader will allow us to implement the technology if needed during the project development.
6. It is interesting for the project to keep the reader as a separate solution of the tablet, since some customers may not be interested in using RFID in tree marking steps.

**R1170I qID mini reader.**

This is the reader selected for chainsaw operators. The main reasons are:

1. Very limited weight (57 g) and size, to disturb as less as possible the chainsaw operator activity.
2. Limited reading strength, which allows to avoid accidental reading of the tags
3. Same Bluetooth compatibility as R1240I and same API, allowing easy development and integration.
4. Lower cost.
5. An adequate **IP protection** (IP32), and a size that allows the direct protection against shocks and main adverse factors (dirt, rain), for instance keeping the reader tied at the belt under the rain jacket when not in use.

### 2.3 High precision GPS

The Treemetrics Forest application currently links with a high precision GPS tracker (uBlox) to give you visual feedback on the map as to where the user is in real time. The GPS receiver can be positioned on the backpack, a shoulder or on the helmet in order to provide the maximum possible satellite visibility.

The main limitation of this system is the weight and the cable connection that can be a limitation during on field operations. For this reason has been evaluated the possibility to use an high accuracy external Bluetooth GPS devices.
The selected GPS devices should ensure an acceptable positioning under canopy cover and in real time positioning using code measure.

It is well known that the accuracy under these conditions cannot be higher than 2-3 meters. In order to ensure these edge accuracies some requirements are mandatory:

- GPS + GLONASS receiver;
- Support WAAS/EGNOS;
- Possibility to receive DPGS differential corrections.

Furthermore it even have to fill some other external constrains such as:

- Bluetooth connections;
- Light and portable receiver and antenna;
- Low cost;
- Android compatibility.

The selected GPS receiver considering all these features has been the Garmin GLO8

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2.4 Rugged tablet

The final part of the equipment for the on field tree-marking and felling is a tablet devices allowing running SLOPE applications and the interfaces with the previous devices abovementioned.

The main features of the portable devices for SLOPE are:

- Android operating system;
- Bluetooth connection;
- Large display;
- Ruggedized, anti-shock, water-resistant and dustproof case.
- Optional: powerful graphic card for supporting 3D SLOPE client

The unique available tablet on the market with these features is the Samsung Galaxy Tab active\(^9\) that has these main characteristics.

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2.5 General layout of the RFID reader/programmer hardware

The final layout of the UHF RFID reading/programming system is a set of tools interconnected via Bluetooth to a rugged Android tablet running the dedicated forestry application, which provides the interface for the operator, the memory storage for the database and its in-forest modifications. The application provides the georeferenced position of the operator, the visualization of the map and the dataset of the forest parcel to single tree level as well as the tool for linking the tags’ ID to the trees in the database. The same interface allows the forester to add further data regarding the trees already existing in the database, or add new trees or sections of trees.

In the following figure 12 the equipment for tree marking activity is depicted. All instruments are lightweight and easy to use. When not in use (e.g. while walking) the tablet may be easily stored in a jacket pocket in wintertime, while in summertime a frontal pouch may be used.

The equipment selected can be used also by the chainsaw operator. Nevertheless this must carry heavy equipment for the main activity (chainsaw, fuel, oil and safety gear). Furthermore the interaction with RFID tags is limited at this stage: the tag on the standing tree must be red before tree felling and the identified item on the database (virtual tree) associated to the new tag placed at the butt of the tree once it is felled. In case of on site bucking the same procedure and equipment will allow to add multiple tags per each original standing tree, as many as the final tree sections or logs. For this purpose the reader R1240i qID may be substituted with the smaller and lighter R1170i qID mini. In principle the chainsaw operator will not need to visualize any cartography related to the map.
(boundaries and trees to be felled were already marked in the previous step by the forester), thus the GPS is not necessary, and the tablet may be substituted by the service phone (always carried for security reason). A rugged Android smartphone fixed with an arm belt may provide the necessary interface with the UHF RFID reader without incurring in any hindering on the chainsaw operator work (figure 13).

Figure 12: Layout of the UHF RFID reader/programmer set: 1) RFID tag reader; 2) GPS antenna with Bluetooth connection to 3) tablet; 4) cartridge of UHF RFID tags shielded in a pocket (aluminum foil is enough); 5) stapler; 6) tree marking axe/stamp
2.6 Synchronization of the reader with forest database

Treemetrics Forest Application

Figure 13 Alternative equipment, particularly suited for the chainsaw operator (the picture depicts a lighter version of the set of the forester). The RFID tag reader and the smartphone on arm belt are indicated by red arrows.
The Treemetrics Forest Application is an Android based application used to plot and assess a forest. It has many features to aid in the assessment, such as GPS tracking, database connectivity, Bluetooth connectivity and the ability to mark notable trees. When you launch the app, the screen you’re greeted with a page that will allow you to load and download a forest and its related data. When you load a forest you’ll be introduced to the main portion of the application. Downloading a new forest requires the use of an email and password combination.

The application links with a high precision GPS to give you visual feedback as to where the user is in real time. This shows up in the form of a blue pointer on the mapper. The map is navigated by touch, clicking on a point will center the map around said point, with buttons to zoom in and out as needed. On the main screen there are also buttons at the top of the screen. They, respectively, are the Save, RTFI Bluetooth connectivity, ublox Bluetooth connectivity and additional options buttons. From this page you can also add new plots and also edit some of the details of your forest as shown in the screenshot below.

Figure 14: Left hand side – The starting page of the forest application. Right hand side is the Load Forest menu.

The application links with a high precision GPS to give you visual feedback as to where the user is in real time. This shows up in the form of a blue pointer on the mapper. The map is navigated by touch, clicking on a point will center the map around said point, with buttons to zoom in and out as needed. On the main screen there are also buttons at the top of the screen. They, respectively, are the Save, RTFI Bluetooth connectivity, ublox Bluetooth connectivity and additional options buttons. From this page you can also add new plots and also edit some of the details of your forest as shown in the screenshot below.

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After selecting a specific plot you get a view of the trees within the plot on the mapper, which are colour coded dots on the map, followed by a table in which you are shown the species, stocking, height pairs and diameters. You can click on each of the values in the table to edit them, updating your forest on the fly. You can also chose to add individual trees to the plot. This feature makes use of RFID tagging. While the scanner and tab are connected via bluetooth and on the Add Tree page, scanning with the scanner will populate the page’s fields with the RFID tag data. After that you can choose to add additional characteristics to the tree data.

Figure 15 Left hand side – Forest overview page. Right hand side – Forest data editor window.
This is a topside view of the RFID scanner, you power it on using using the power button (4). The trigger button button (5) is used to scan the RFID tag. The first LED (1), signifies power and battery level, (2) lets you know if your tablet and scanner are successfully linked and (3) is to let you know if the trigger button executed correctly, a green blink for yes, red for no.

**Figure 16** Left hand side – Selected Plot landing page. Right hand side – Add Tree window

**Figure 17:** Picture of the RFID scanner.
While on the Add Tree page of the application, scanning with the scanner using the procedure outlined above will populate the RFID fields with the RFID tag data.

**ANNEX 1 – Forest application operative instructions**

This annex presents the detailed instructions for operating the Treemetrics Application synchronized with the RFID tag reader and the GPS receiver. It will allow the forester to electronically mark the trees, linking the RFID to the corresponding field on the database. It will also allow to relate an RFID already existing on a tree to the new tag that will be necessary to place at the butt of the tree. Furthermore, in case of tree bucking in the forest, it will allow to add tags to each tree section or log.

**Task 1: Getting started**

Getting started with the app is very easy. Simply ensure you have Treemetrics’ Forests App install on your tab. Find the app icon on your tablet and click on it to begin.

1. **Open Treemetrics App on android device**

1. Click to open Treemetric’s Forest Application
Task 2: Downloading a Forest

Downloading new forests from the Treemetrics server is one of the larger features of the app. To download a forest you will need a login for Treemetrics services, this will be handled by Treemetrics and you’ll be given one if required.

Below are a series of screenshots and notes explaining the procedure for downloading a new forest.

2.0 Download forest from Forest Mapper

1. Click on the Download button

*Note: Internet is required for downloading forest

Advisable to be done before arriving at the forest
2.1 Enter Treemetrics account information

1. Enter User Name: user@treemetrics.com
2. Enter Password: ***************
3. Then click on the Connect button.

It’s important to note, not all usernames will be ending with @treemetrics.com. Treemetrics normally takes your regular work email as your username.

Ex.: johndoe@forestcompany.com
### 2.2 Select Forest to be surveyed.

1. **Select Forest** by clicking on the box adjacent to the forest’s name.

2. Click the **Download** button.

**Note:** Once a forest is downloaded, it will be stored on the device.
Task 3: Setting Up

Task 3 will be separated into two subtasks to make it more accessible. These will be

1. Loading the forest
2. Selecting a plot and plot data population

The numbering convention I’ll use on the screenshots will be 3.x.y, where x is the subtask and y is the step number for the subtask.

Ex: 3.1.2 would be Task 3, Loading a forest, Step 2
Task 3.1: Loading a forest

3.1.1 Load forest that has been downloaded

1. Click on the Load Forest button.
3.1.2 Select Forest

1. Select Forest by clicking on the Forest Name.
3.1.3 Connecting your RFID scanner

1. When you arrive on this page, click the RFID button in the top right to connect your scanner and device.

The tablet will confirm whether or not the device successfully connected in the top left corner.
3.1.4 Select Forest

The screen will automatically open on the inventory plan once the forest has been selected.

1. To edit project name and other information, click on the "Forest settings and species info" box (Dark green box located under the map screen).
### 3.1.5 Select Forest

1. Edit the forest name by clicking on the field provided.

2. You can set a standard *stocking plot radius* which will be automatically set for all plots. (see 4.3)

3. When completed, click on **Continue forest**.
Task 3.2: Selecting a plot and plot data population

3.2.1 Saving & Selecting Plots to Be Surveyed

1. Click on Save Symbol to save project (advisable to save regularly).

2. Select desired plot to survey by clicking on the plots name.

- **Block** = Area of Forest under analysis.
- **Strata** = Areas of similar composition and structure.
- **Plot** = A Representative portion of a Strata where measurements are taken.
3.2.2 Add Species that are present in the plot area

1. Click the add symbol.
3.2.3 Select Species

1. Select Species by clicking on the tree species name

NB: Steps 3.2.2 & 3.2.3 must be repeated for each species present within the plot.
3.2.4 Adding Data - Stocking (Stems Per Hectare)

1. Click on the Stocking field to add information.
3.2.5 Adding Data - Stocking (Stems Per Hectare)

1. Enter the number of stems counted within the plot.

2. Enter the Plot Radius.

3. Click the Save button once completed.
Task 4: Adding a tree and reading RFID tags

Task 4 will also be broken into multiple parts due to length and complexity. These sections will be

1. TLS Scan
2. Adding a tree
3. Scanning a RTFI tag

We’ll be using the same naming convention for these steps as above.

NB: Steps 4.1.x are only necessary if you’re doing a TLS scan, if not, just skip straight ahead to 4.2
Task 4.1: TLS Scan

4.1.1 TLS Scan Details

1. Click on the **Scan Details** field to add scan information.
4.1.2 Enter Scan Info

1. Enter Scan number (found on the top left corner on Scanner screen).

2. Set Notable tree boundary. This is the distance inside which dead and second species will be marked.

3. Scanner offset is the angle at which the scanner is facing at the start of the scan. This is recorded using the Trimble LaserAce (RangeFinder mode - refer to field procedures).

4. Offset will automatically be added when taken using LaserAce.
4.1.3 Adding offset

1. This screen will automatically show after recording the offset.

2. To save the offset, click Yes.

*Offset is used to determine where the dead and second species are located within the scan.*
Task 4.2: Adding a tree

4.2.1 Adding a tree

1. Click on the Add Tree button.

This is what the previous page looks like while populated with trees. If you’re not doing a TLS scan this should be populated for you.
### 4.2.2 Tree Information Page

1. Populate the data fields present (with the exception of the RFID field)
2. Ensure that the “Distance” field has a value of at least 2m (this is because trees are normally added after a scan and a tree should be at least 2m from the scanner)
Task 4.3: Scanning a tag

4.3.1 Scanning a tag

1. Simply put your cursor in the RFID field and scan the tag and the field should be populated automatically.

If the field is already populated, you will receive a prompt asking if you would like to overwrite the tag in the field. Simply pick whichever option is correct for your situation.
Possible Scenarios:

Replacing a tag:

1. If you need to replace a tag on a tree, simply follow the steps like normal until you get to step 4.2.1.

2. When at this page, find the tree in which you wish to replace the RFID tag in the array and click its name under the “Edit” column.

3. You’ll be brought back to the “Add Tree” page for that tree (with its fields populated).

4. Take the old tag off of the tree, and replace it with the new one.

5. Select the RFID field and scan the tag.

6. You’ll be prompted to ask if you’d like to overwrite the field or not, click yes.

7. Ensure to click the save button.

Manual cutting a log:

1. If you need to cut a tree into logs manually (chainsaw operator) then place a tag on a tree, simply follow the steps to place/replace a tag on a tree for each log cut.
ANNEX 1 – UHF RFID tag reading test

The SLOPE project relies on UHF RFID tags for the AutoID of trees and logs throughout the timber supply chain, from forest to sawmill. UHF RFID tags are attached and read by different means, manually in the forest and automatically when extraction and bucking machines handle and transform the trees in logs.

Among the several work phases, the most challenging from the RFID detection point of view seems the operation of reading UHF RFID tags attached to the trees hanging from a cable yarder carriage. In this operation the tags will be generally at a considerable distance from the antenna (2-4 meters) and in constant movement due to the displacement of the carriage and the freedom to swing of the hanging load.

For this reason, the RFID tag models selected in the previous steps of task 3.1 were tested simulating the work conditions of suspended loads typical of cable yarding extraction.

A suspending structure was fixed on a security bridge within the facilities of CNR-IVALSA in Florence at a height of 12 meters above the ground level. A long range circular polarized antenna (860-960 MHz) was installed protruding from the metal structure and orientated towards the ground and the hanging log. The antenna was connected to a R4300P ION UHF long range reader run via PC with Windows CAEN Easy Control system. The reader settings were adjusted for an effective power of 1977 mW considering the gain and loss of the antenna and cable respectively.

A log produced from a freshly felled tree (*Picea abies*) was used for the tests. The crosscut surface was refreshed by chainsaw just prior to start the test, in order to fix the tags on wood fibers with the maximum possible moisture content. This expedient aimed at working in the most unfavorable conditions, i.e. with the maximum possible back signal reduction due to the dielectric constant for the
deployed log (size may be a further factor, but due to weight limits a log with a diameter of 20 cm and 155 cm length).

The log was fixed with metal choker and chain, but as a hanging cable a synthetic rope was used instead of steel cable. This last solution was necessary again for weight limits due to the manual maneuvering of the load.

The log was suspended at variable distances from the antenna (a = 100, 200, 300 and 400 cm) and RFID tag reading were performed with still and moving log (swinging).

On the log’s upper butt end was fixed the main RFID tag tested, while at a distance of 130 cm, corresponding to breast height, a second tag was placed, simulating the tag used to mark the standing tree. This tag was always the same in all tests: model Shortdipole.

The quality of the received signal was evaluated in terms of Received Signal Strength Indicator (RSSI) expressed in dBm. This is a value used in radio telecommunication for measuring the power of the received signal. In RFID applications this parameter is used for measuring the power of the signal received from the UHF RFID transponder. The higher is the RSSI value, the stronger is the signal received and thus the better the performance of the tag model (note: in the given application the RSSI value is returned as a negative figure). Each reading cycle had a duration of 5 seconds, and was replicated 10 times.

The average air temperature and moisture content during the tests was 24 °C and 15% respectively. Due to the particular position the site was constantly exposed to moderate wind or breeze.
Results show clear differences in the reading performance of the tested tags (Figure 14). Models 1 and 2 are by far the most performing, with a maximum RSSI value of -587.5 and -537.2 respectively. Particularly the model 2 (Lab-ID UH 107/105) is the only one that can be detected by the reader at the maximum distance of 4 meters.

The dynamic condition of the log has a clear influence on the reading quality: on one hand it reduces the strength of the signal, but on the other it allows for longer reading range. This is probably due to the fact that a moving load (and tag) incurs in a wide variation of angles with the emitting source (antenna) thus increasing the possibility to have for a moment an optimal angle for returning the signal to the receiver. On the other hand the movement seems to dilute the signal strength, which, when present, is better perceived in still condition.

The RFID tag placed on the trunk surface (over bark) simulating the tag placed on the standing tree was never visible for the reader, even when the actual distance between transponder and antenna was 2.3 meters. Tag model 1 in radial position could be red at 3 meters, thus the outcome should be explained with the different orientation of the transponder, which is parallel to the radio signal emitted by the antenna. This result confirms the necessity to add a tag at the butt end of the felled tree in order to maximize the readability of the RFID tag with the intelligent machines developed within the project.
Results indicate that reading RFID tags on the trees hanging from the cable yarder carriage is possible, particularly when this is moving. The maximum result in this operation, and probably in any other logistic application can be achieved with tag 2, which has a return signal particularly powerful. Further tests are necessary for understanding its behavior in bulk reading, such as a truckload of tagged logs.

Figure 3 Detail of the test layout. The red arrow indicates the position of the protruding antenna.
<table>
<thead>
<tr>
<th>Tag model</th>
<th>Distance (cm)</th>
<th>Swing</th>
<th>RSSI main tag (dBm)</th>
<th>SD</th>
<th>N. reading</th>
<th>RSSI control tag (dBm)</th>
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Figure 4 Results of the reading test. RFID tag models: 1) Smartrac Shortdipole Monza 5; 2) Lab-ID UH 107/105; 3) Wintag Flexytag UHF D7040S; 4) Lab-ID UH 423/424. NOTE: RSSI values in negative figures, the higher value indicates the stronger signal.