

OPERATION MANUAL

for the

Yara N-Sensor

Software release 4.5



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Preface

The Yara N-Sensor is a responsible and carefully developed tool for the detection of in-field variability in agricultural crops and variable rate application of farm inputs on-the-go. Because of the multitude of crops, grown in different production systems, on various soils, and under countless climatic conditions, Yara disclaims all warranties, express or implied, as to the accuracy of the information gathered by the tool and takes no liability for management decisions based on this information. When using the Yara N-Sensor and its related software modules the user accepts that he will take full responsibility for agronomic decisions.

We carefully select the materials and components used in the production process of the Yara N-Sensor. Therefore, we cannot accept any liability for any damages to Yara N-Sensors and other objects of legal protection caused by the use of accessories and spare parts not delivered by Yara. Neither can Yara take over any liability for improper use and application of the Yara N-Sensor, nor for any procedures not described in this manual.

We have a policy of constant product improvement and reserve the right to discontinue or to modify product specifications, models or designs without previous notice.

Safety notes



A proper utilisation and a trouble-free operation are only possible in case of a competent and specialised installation. A faulty installation, any system modifications, as well as the use of accessories and spare parts not delivered by Yara, can lead to malfunctions and cause damages to the Yara N-Sensor as well as personal and property damage; Yara does not take over any liability for these damages.

Any person responsible for the operation, must observe the safety regulations. This has to be assured by the operator of the Yara N-Sensor for every single case.

Furthermore, the operator must assure that all safety regulations for add-on parts or peripheral parts, which do not belong to the Yara N-Sensor, are known to the persons responsible for the operation.

Arbitrary modifications at the Yara N-Sensor are not allowed due to safety reasons. A non-observance of this results in a loss of any warranty claims and may lead to unpredictable dangers for persons or properties. In case of repair procedures, only original parts of the manufacturer must be used.

1 Preface

1.1 Scope of this document

This manual describes the *operation* of the N-Sensor software. It does not cover hardware nor software *installation* issues. If there are questions regarding installation please contact your local service partner.

As the software handles various platforms (terminals, operating systems, GPS receivers, variable-rate controllers) there may be various platform- or device-specific settings. Contact your local service partner for support.

1.2 Prerequisites

To successfully operate the N-Sensor, make sure that the following hardware and software has been set-up properly:

- N-Sensor mounted on the vehicle and connected to power supply
- GPS receiver mounted on the vehicle and connected to power supply
- Variable-rate controller mounted in the cabin, connected to power supply and fertilizer distributor
- Terminal computer (panel PC) mounted in the cabin and connected to power supply
- N-Sensor, GPS and variable-rate controller connected to the terminal computer
- N-Sensor software installed and pre-configured on the terminal computer
- N-Sensor internally calibrated

2 N-Sensor user interface

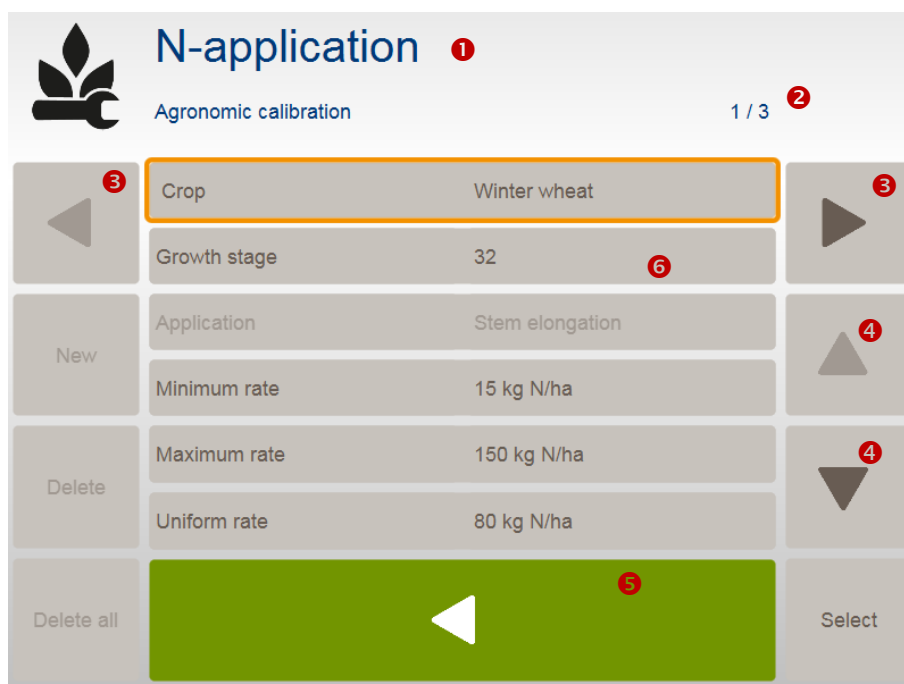
2.1 Screen layout

Depending on the screen layout (portrait or landscape, aspect ratio) and resolution the layout of the menus and screens looks slightly different, but the functionality is all the same. For clarity, all screenshots in this manual are shown in 4:3 landscape format.

2.2 Menu navigation

Generally, the menu structure and the size of the buttons is designed for N-Sensor operation by touching the screen with bare fingertips, even on small displays.

All menus are consistently composed of the same elements:



- ❶ Menu heading
- ❷ Page number and number of pages in the selected menu
- ❸ Flip menu pages back and forth
- ❹ Move one menu item up or down. If at the top/bottom of the page, automatically flip to previous/next page
- ❺ Return to previous menu
- ❻ Individual menu items (Max. 6)

Every menu consists of maximum 6 individual menu items. To access a certain item, first use the arrow left/right buttons (❸) to navigate to the respective page in the menu. Then either use the up/down buttons (❹) to select the desired item or click the item directly.

Depending on the type of menu item a sub-menu will open or you will be asked for numeric or alphanumeric input:

The screenshot displays a user interface for entering the nitrogen content in fertilizer. At the top, there is a leaf icon and the title "N-content in fertilizer". Below the title, the valid range is specified as "Valid range: 0.1 - 100.0 %". The main input area shows a numeric keypad with the current value "25.0 %". The keypad includes arrow keys (2), a backspace key (3), a clear key (4), and "OK" and "Cancel" buttons. The "OK" button is highlighted in green.

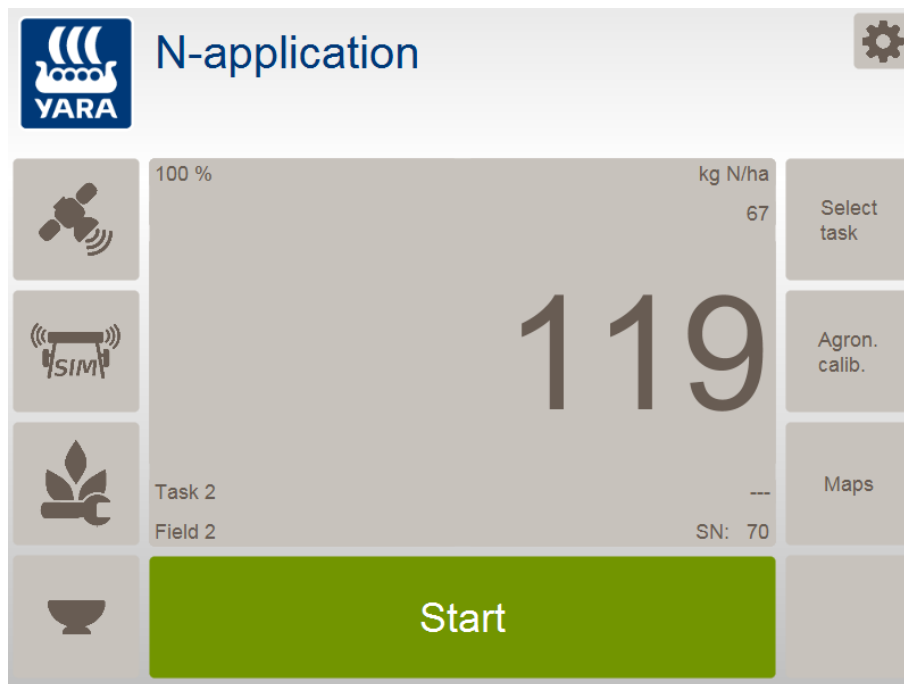
Numbers (or text in case of an alphanumeric keypad) can be entered by directly pressing the respective buttons, by using the arrow keys (2) to navigate to the desired digit and pressing *Select* or by typing the number on the hardware keyboard (if available). Use the backspace (3) and clear (4) buttons to correct.

The *Ok* button is greyed out if the entered number is outside the valid range (1).

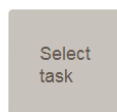
3 Quick start example

This section describes the standard way of operating the Yara N-Sensor. It can also be seen as a step-by-step introduction to first-time users. For this example it is assumed that the N-Sensor is operated in the standard *N-application* operation mode and that the software is set up as described in the *Installation Instructions* (separate document).

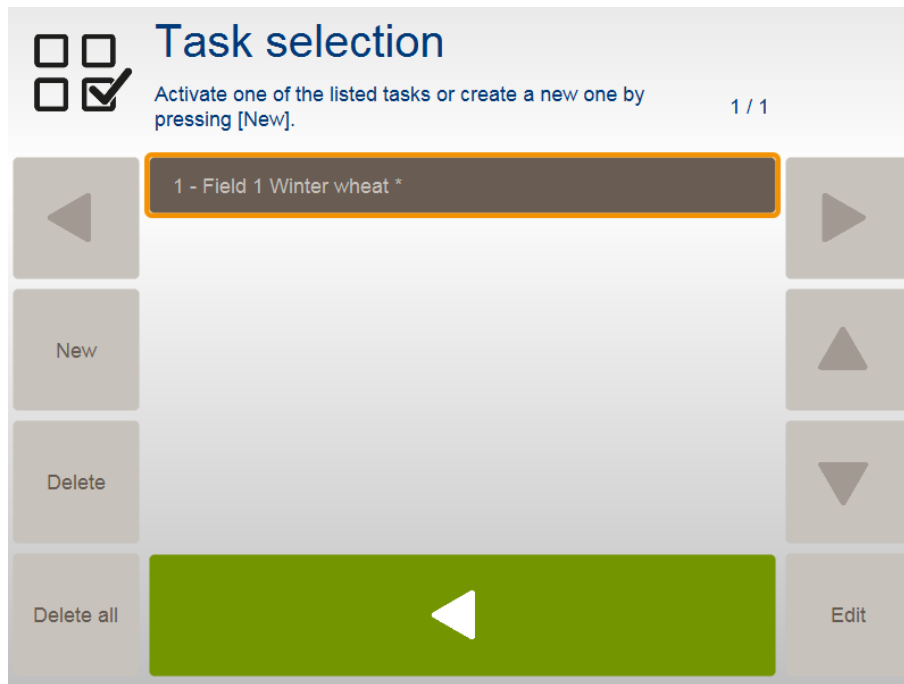
After program launch, the work screen (as described in section 4) will be displayed:



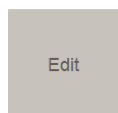
Initially the N-Sensor is in standby mode, i. e. it does not yet communicate to the spreader/sprayer and it does not yet log any data.



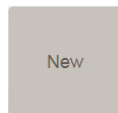
First, choose *Select task* and switch to task management:



At this point, new tasks can be created and filled with additional information about field names, field sizes and customers. By default, a first task is available and selected.



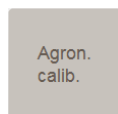
To edit the task and enter a task name, press the *Edit* button.



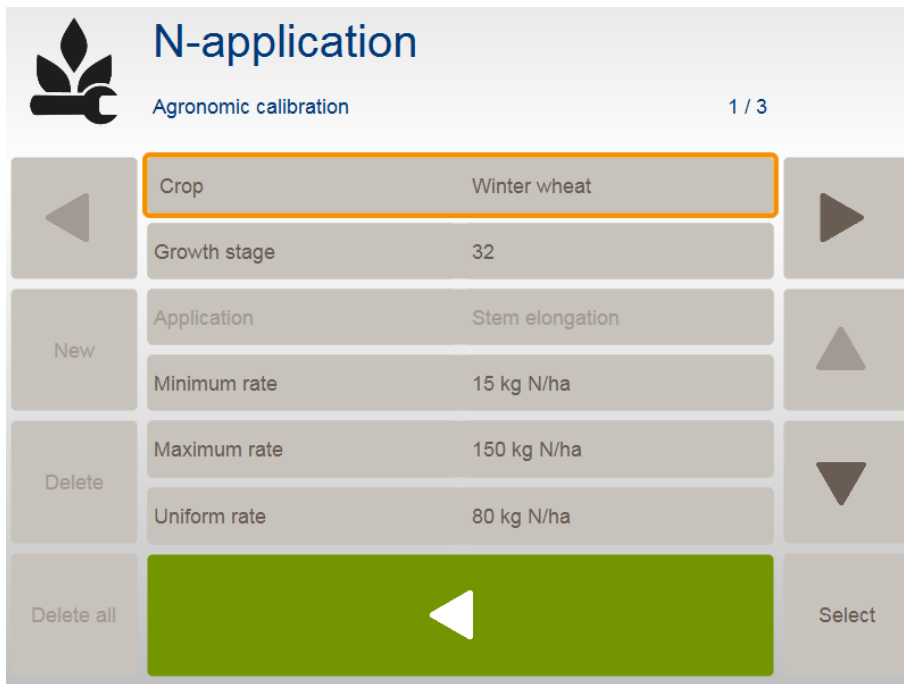
Press *New* to add a new task, if desired.

P

Press *Ok* to return to the work screen. The task number and the name of the field will be displayed in the bottom left.



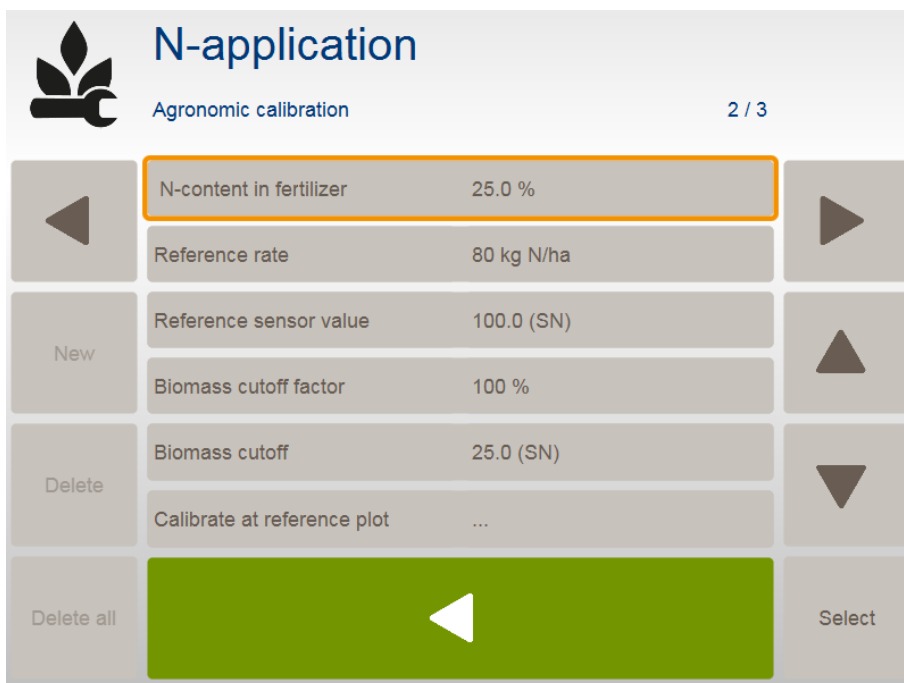
Next, choose *Agron. calib.* to enter the agronomic calibration menu:



Enter the appropriate settings for the field.

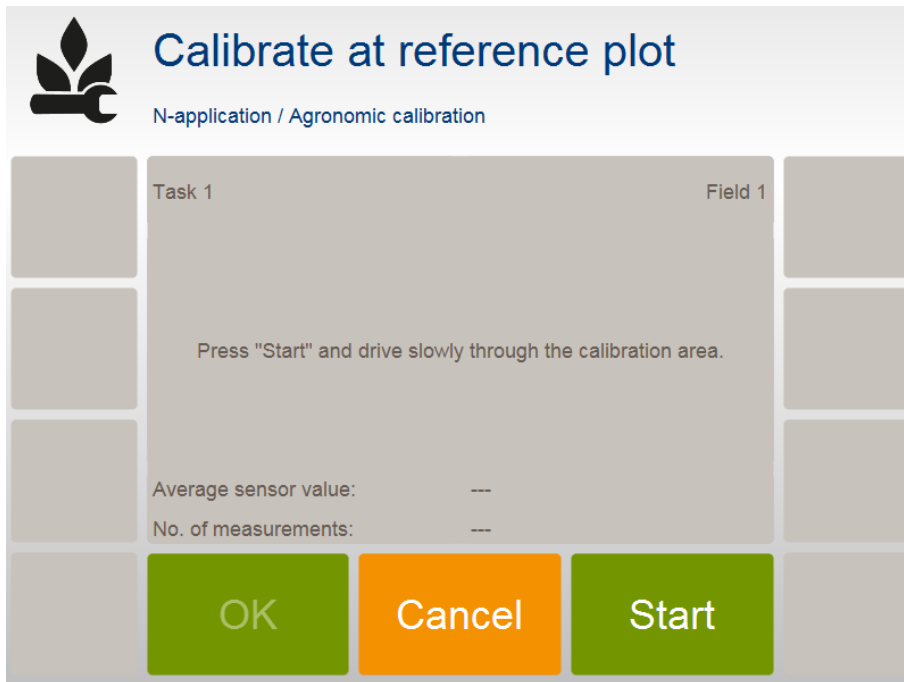


When finished, press the arrow right button to navigate to the second page of the menu:

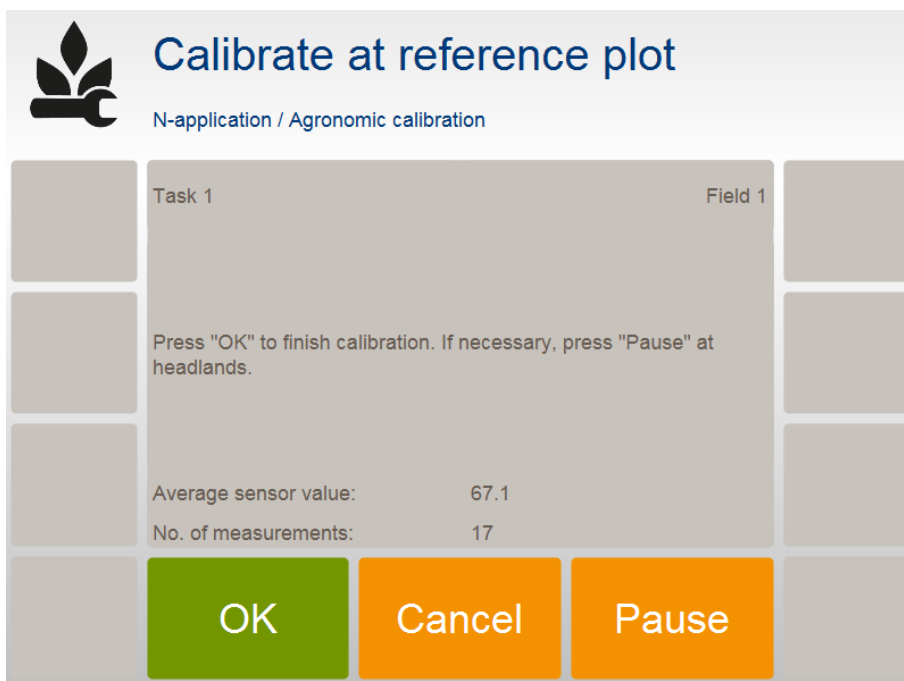


Enter the *N-content in fertilizer*. Leave the remaining menu items unchanged for the time being.

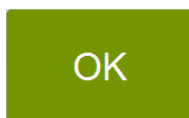
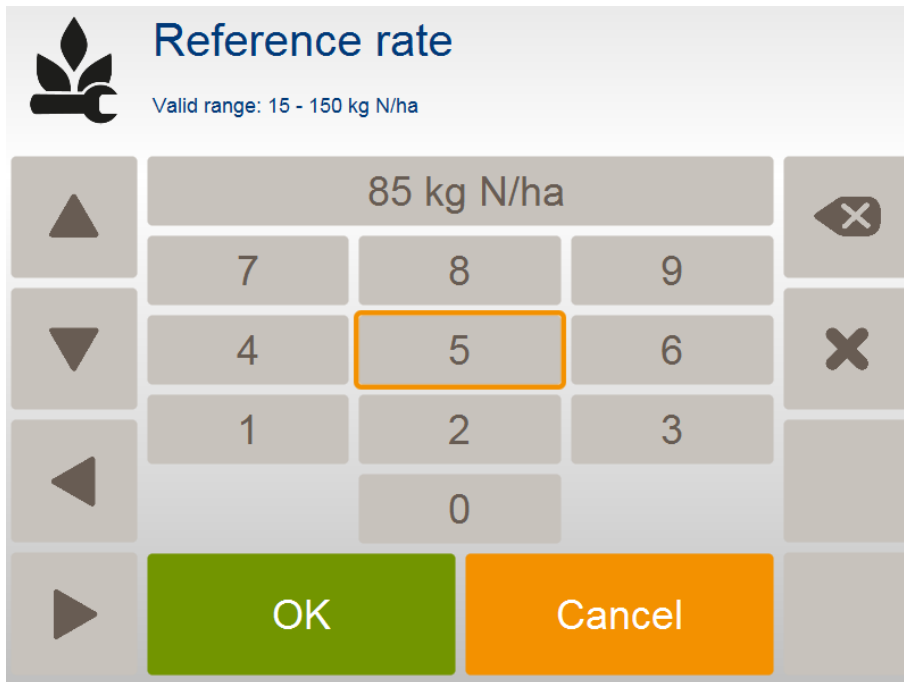
Press *Calibrate at reference plot*.



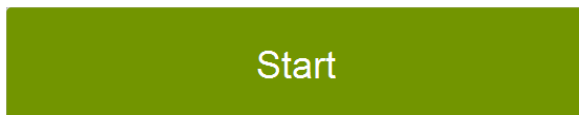
Start Drive to the calibration area in the field. Press *Start* and drive slowly through that area to collect an average N-Sensor reading:



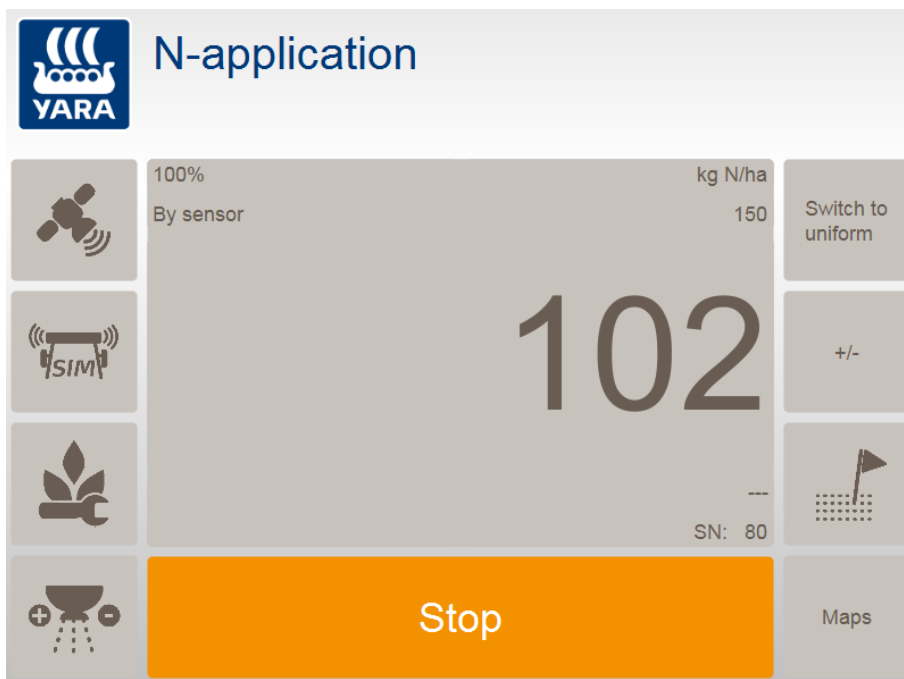
OK When finished, press *Ok* again and enter the desired application rate for that calibration area:



Press *Ok* and *Back* to return to the work screen.



The N-Sensor is now ready for operation. Drive to the beginning of the field and start the system by pressing the *Start* button:



The system will now start to communicate to the spreader/sprayer and it will log all data to the selected task.

Apply all fertilizer to the field as usually done without the N-Sensor. In particular, in the headlands open and close the spreader through the spreader controller as usual. Leave the N-Sensor running and do not press *Stop*.

If fertilizer has to be refilled or at a break press *Stop* to pause data logging. N-Sensor application can be continued at any time by pressing *Start* again.



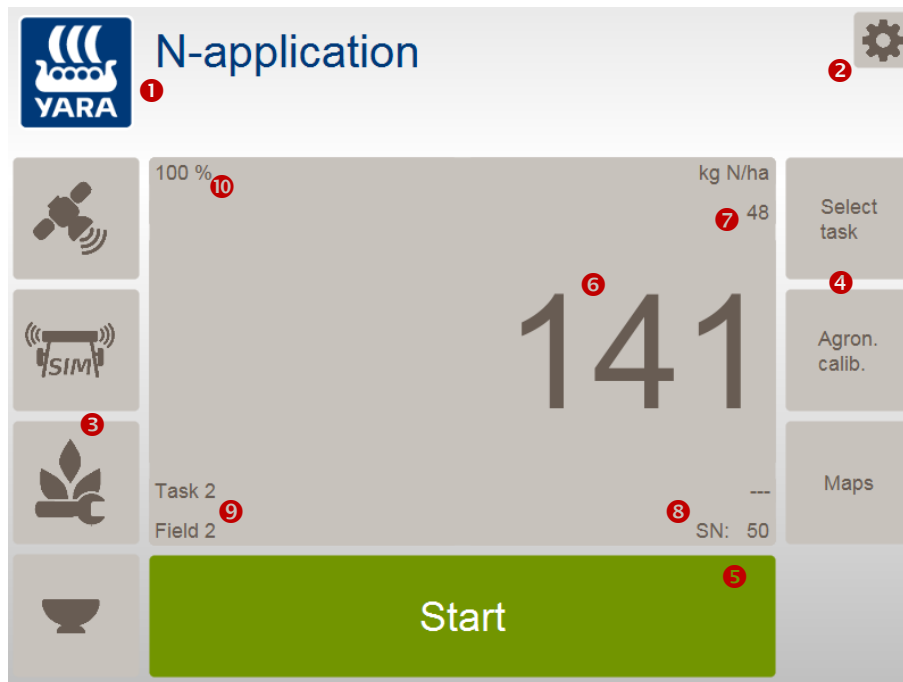
Stop

When finished with the field, press *Stop*. To proceed with the next field, select a new task and repeat the steps as above. When finished with all fields, remove the

usb-stick or copy the N-Sensor log files from the working directory for further processing.

4 The work screen

When the N-Sensor program is started, it will first display the work screen. This screen contains all relevant information that is required for successful operation of the N-Sensor. Depending on the selected operation mode (see section 6), the work screen may look slightly different from what is shown below, but the general structure will be the same.



If the work screen is empty or if certain elements are missing check the separate *Installation Instructions* manual first.

If configured properly, the work screen should display:

- ❶ **Operation mode title and logo:** The current operation mode is displayed as menu header. For standard N-Sensor operation, make sure *N-application* is selected. Refer to section 6 to choose operation modes.
- ⚙️ **System setup:** Press this button to change configuration settings.
- 📶 **Status icons:** Status icons are arranged on the left side of the work screen. Every module may display one dedicated icon. See section 4.1 for more detailed information.
- 📁 **Main menu:** In the main menu on the right all settings and selections can be made for normal operation.
- ▶️ **Start/Stop button:** Use the *Start/Stop* button to toggle between standby and active mode. Only in active mode rates are transmitted to the fertilizer distributor and logged to the N-Sensor log-file. If the button is greyed out and a padlock is displayed as a status icon, the system requires a proper software license code for unlocking. Contact your local service partner in this case.
- 📊 **Current application rate:** The application rate that is currently being calculated from the sensor reading and/or the prescription map. This rate will be sent to the spreader controller and will be logged in the N-Sensor log-file as soon as the *Start* button is pressed. Be aware that the rate unit may depend on the operation mode.

For standard N-Sensor operation the rate is always displayed in kg *nitrogen* per ha, whereas the spreader controller receives and displays a *product* rate.

- ⑦ **As-applied rate:** If the spreader reports back an as-applied rate this rate is displayed here.
- ⑧ **Sensor value:** The sensor value (SN value) as currently measured by the N-Sensor is displayed here.
- ⑨ **Task information:** The task information line displays the current task number together with the name of the field associated to this task.
- ⑩ **Manual adjustment:** Indicates manual adjustments that are made to the N-Sensor recommendation during operation.

4.1 Status icons

Status icons are arranged on the left side of the work screen. Depending on the individual setup, different types of status icons may be present. By default, information is provided about GPS, N-Sensor, agronomic properties and spreader/sprayer connection. Generally grey icons indicate proper operation while icons on a yellow or red background indicate that the respective module requires attention. Clicking on an icon generally opens the diagnosis screen for the respective device.

4.1.1 Positioning service (GPS)



GPS connected: The GPS receiver is connected and a valid signal with at least standard GPS quality is received.



No GPS connection: The connection to the GPS receiver is lost. Either the receiver itself is not working properly or the connection itself is faulty. Check power supply and wiring of the receiver.



No GPS signal available: The GPS receiver is still connected, but it cannot process valid positioning information. Probably the receiver is shaded from the satellites by buildings, trees or the vehicle itself.

In case no GPS signal is available, the system will continue to work normally, but it will be impossible to process a map of the respective part of the field. Furthermore, if prescription maps are used, default rates are applied depending on the application mode.

4.1.2 N-Sensor



N-Sensor working properly: The N-Sensor is connected and it produces valid data.



No N-Sensor signal available: The connection to the N-Sensor is lost. Either the N-Sensor is not working properly or the connection itself is faulty. Probably the N-Sensor is not powered properly. The N-Sensor will be reconnected automatically as soon as it is available again.

If this problem persists, the alarm *Invalid sensor data* will be issued (see section 4.4.1) and the system switches to the uniform rate predefined in the *Agronomic calibration* menu.

If this icon only pops up from time to time and for less than a second it can be ignored.



Bad N-Sensor data: The N-Sensor is physically connected, but no valid N-Sensor data can be processed. Contact your local service personnel if this icon does not disappear after a few seconds.



N-sensor data temporarily invalid: (passive N-Sensors only) The N-Sensor data is temporarily invalid because it is adjusting to new irradiance conditions. It is normal that this icon shows up temporarily for a very few seconds, in particular at changing irradiance conditions.



Simulation mode: The N-Sensor runs in simulation mode. In this mode, the N-Sensor program can be run without a real N-Sensor connected. This mode is mainly intended for demonstration and testing purposes. *No real application must be done with this icon on the work screen!*



Low light level: For passive N-Sensors, the actual irradiance is too low to receive a suitable signal from the N-Sensor optics. As soon as irradiance conditions improve, the icon will disappear automatically.

For active N-Sensors, this icon indicates that a too low amount of artificial light is reflected into the N-Sensor optics. A reason for this may be dirty optics or that the distance between the sensor heads and the crop canopy is too high.

If this problem persists, the alarm *Invalid sensor data* will be issued (see section 4.4.1) and the system switches to the uniform rate pre-defined in the *Agronomic calibration* menu.



Sensor over-range: (active N-Sensor only) Too much light is reflected back to the N-Sensor optics. Usually this icon appears because the distance between the sensor head and the crop canopy is too short.

If this problem persists, the alarm *Invalid sensor data* will be issued (see section 4.4.1) and the system switches to the uniform rate pre-defined in the *Agronomic calibration* menu.



Low solar elevation: (passive N-Sensor only) The current solar elevation is below 25° above the horizon. As long as enough light is available, the system continues to work, but accuracy may be reduced and recommended rates may drift over time. It is strongly recommended to finish N-Sensor work as soon as possible.

When this occurs the first time the warning *Solar elevation below limit* (see section 4.4.2) will be shown.

4.1.3 Agronomic calibration



Agronomic calibration: A valid agronomic calibration is loaded and operates normally. Click on this icon to display a summary of the current agronomic settings.



Low crop density: (Selected operation modes only) The current N-Sensor reading is below the preset biomass cutoff value (see section 6.1). As obviously other factors than nitrogen affect the crop growth in this area, the application rate is reduced. In the extreme cases only the minimum rate may be applied.

For proper operation, this symbol should appear only on a small fraction of the whole area. If it displays regularly (i. e. on more than 10% of the field area), the selected *Growth stage* or the *Biomass cutoff* setting may be wrong.



Sprayer warning: (Potato haulm killing / potato fungicide operation mode only) The current recommended application rate is too low for the sprayer to adapt accordingly. If possible, increase the speed of the vehicle.



License required: The padlock icon indicates that the system does not have a valid license. It cannot be started until a valid license code has been entered. To enter the code select *License* at the end of the *Agron. calib.* menu. The 8-digit license code can be obtained from your local service partner.

4.1.4 Spreader/Sprayer



Standby: The spreader/sprayer is in standby mode, i. e. no application rates are exchanged.



Variable-rate application ongoing: The N-Sensor software continuously communicates to the spreader/sprayer and sends variable application rates.



Uniform rate: (flashing) The N-Sensor is currently applying a uniform application rate either because the *Uniform* button has been pressed in the work screen or because of an error condition which forced the system to apply uniformly. Press *By Sensor* again on the work screen to return to sensor-controlled application.



No valid data from spreader controller: The N-Sensor software does not receive back any valid data from the spreader/sprayer controller. Either the controller is not working properly or the connection itself is faulty. Probably a wrong communication protocol has been selected.

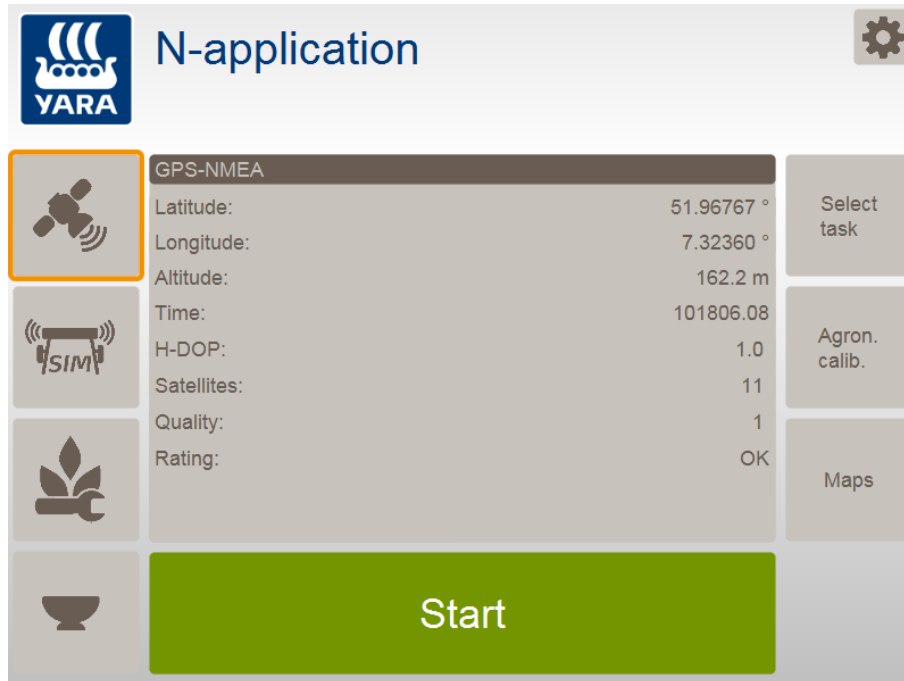
If this problem persists for a couple of seconds, the alarm *Spreader communication failure* (see section 4.4.3) will be issued and the application is stopped automatically.

If this icon only pops up from time to time and for less than a second it can be ignored.

4.2 Diagnosis screens

Diagnosis screens can be displayed for all devices and modules by clicking on the respective status icon. A yellow frame will appear around the the icon. To close the diagnosis screen, press the same icon again.

4.2.1 Positioning service



Latitude, Longitude: Current geographical latitude and longitude (in decimal degrees) as received from the GPS unit.

Altitude: Current altitude (m) as received from the GPS unit.

Time: UTC (HHMMSS format) as received from the GPS unit.

H-DOP: Accuracy of the position fix. Lower numbers correspond to better accuracy.

Satellites: Number of satellites currently used for positioning

Quality: GPS quality parameter (1: standard GPS, 2: DGPS, 4/5: RTK)

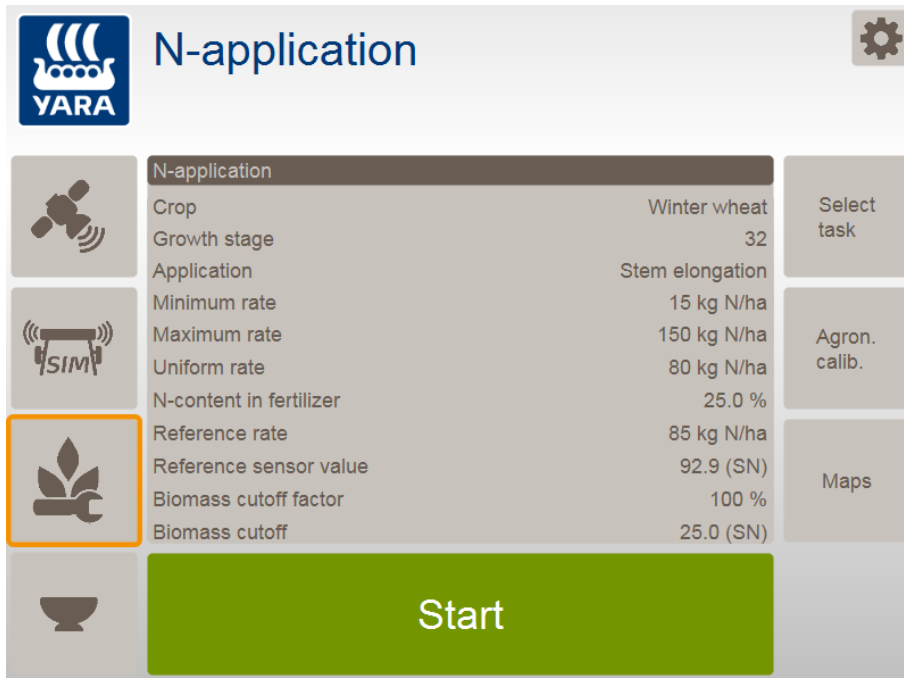
Rating: Connection status (OK / invalid data / no data)

4.2.2 N-Sensor



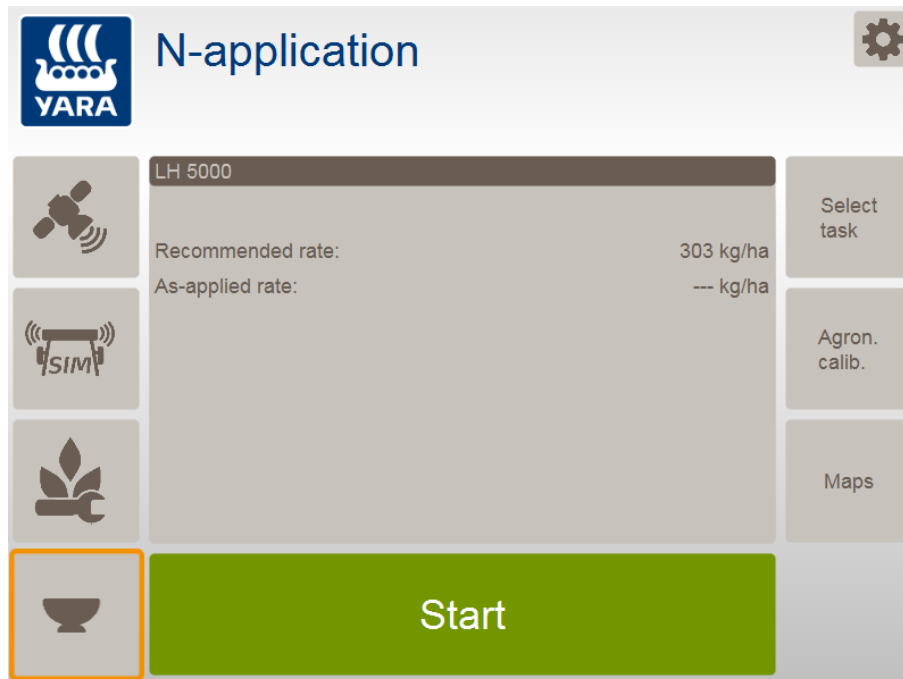
Layout and content of the N-Sensor diagnosis screen depend on the type of N-Sensor (active/passive) that is currently being used.

4.2.3 Agronomic calibration



The diagnosis screen of the agronomic calibration summarizes all settings that are relevant for the selected operation mode. Content and layout varies depending on the operation mode.

4.2.4 Spreader/Sprayer



The content of the spreader/sprayer diagnosis screen depends on the type of the selected rate controller. Generally it at least contains information about the current *Recommended rate* and *as-applied rate* as returned by the controller.

Note that at this point all rates are in units of product rates (i. e. kg/ha or l/ha instead of kg/ha N).

4.3 Start and stop buttons



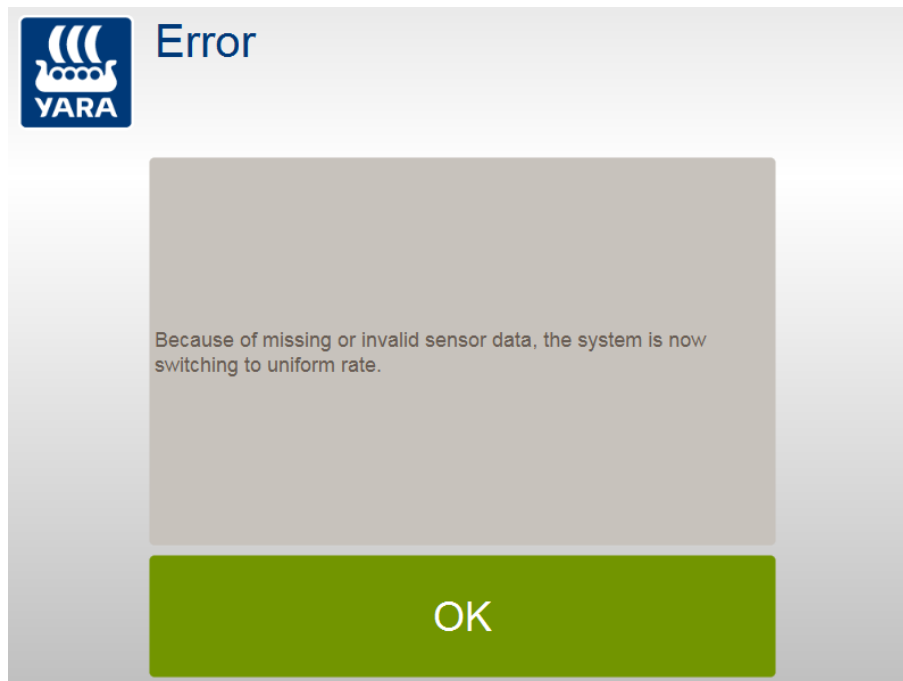
Start: Press the *Start* button to start the variable-rate application. Application rates are continuously transmitted to the controller and data is logged.



Stop: Press *Stop* to stop the variable-rate application. The system stops sending rates to the controller and it stops logging data.

4.4 Alarms and warnings

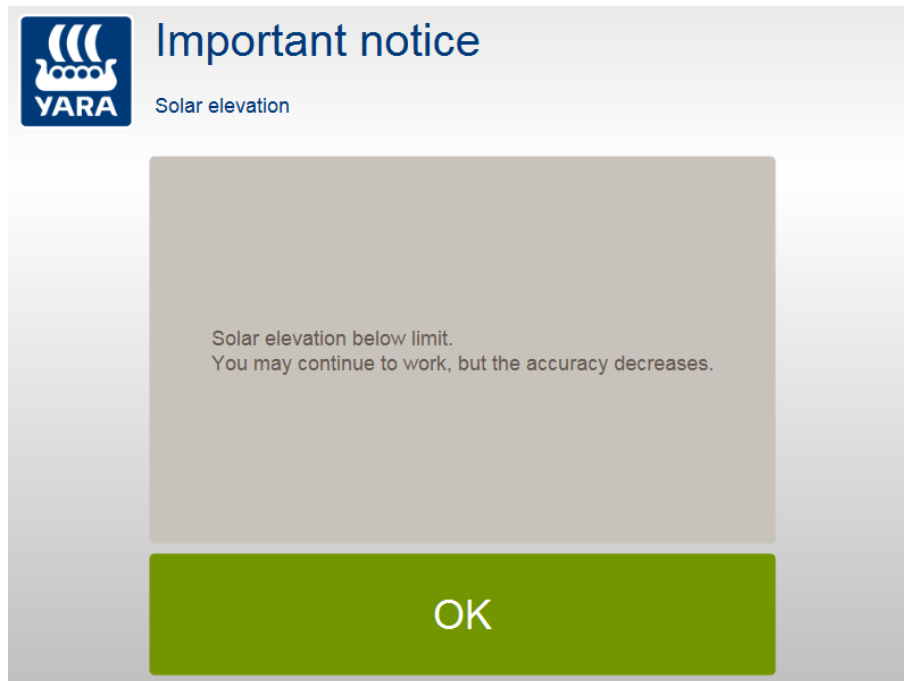
4.4.1 Invalid sensor data



If the data from the N-Sensor is invalid or missing at all, the system automatically switches to uniform rate. Typically the reason for this warning is insufficient light for measurement or connection problems to the N-Sensor. More details can be found on the N-Sensor icon on the work screen (see section 4.1.2) and the diagnosis screen.

Note that the system will not automatically switch back to sensor-controlled application rates, even if the cause of the problem has disappeared. Instead, press the *By sensor* button on the work screen to manually return to sensor-controlled application as desired.

4.4.2 Solar elevation below limit

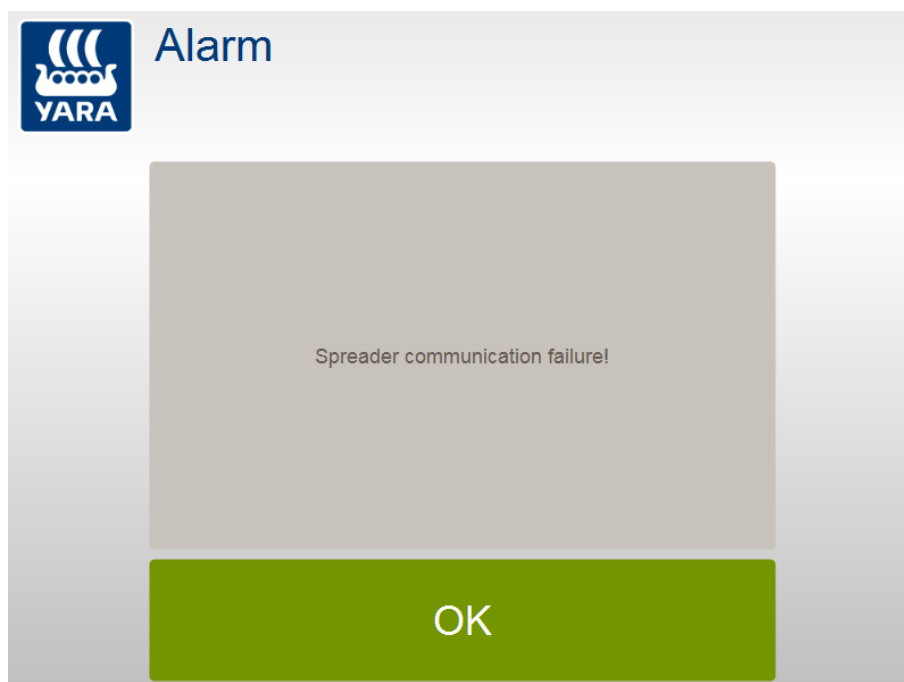


(passive N-Sensors only)

The current solar elevation is below 25° above the horizon. As long as enough light is available, the system continues to work, but accuracy may be reduced and recommended rates may drift over time. It is strongly recommended to finish N-Sensor work as soon as possible.

After pressing OK, the low light level icon (see section 4.1.2) will be displayed on the work screen.

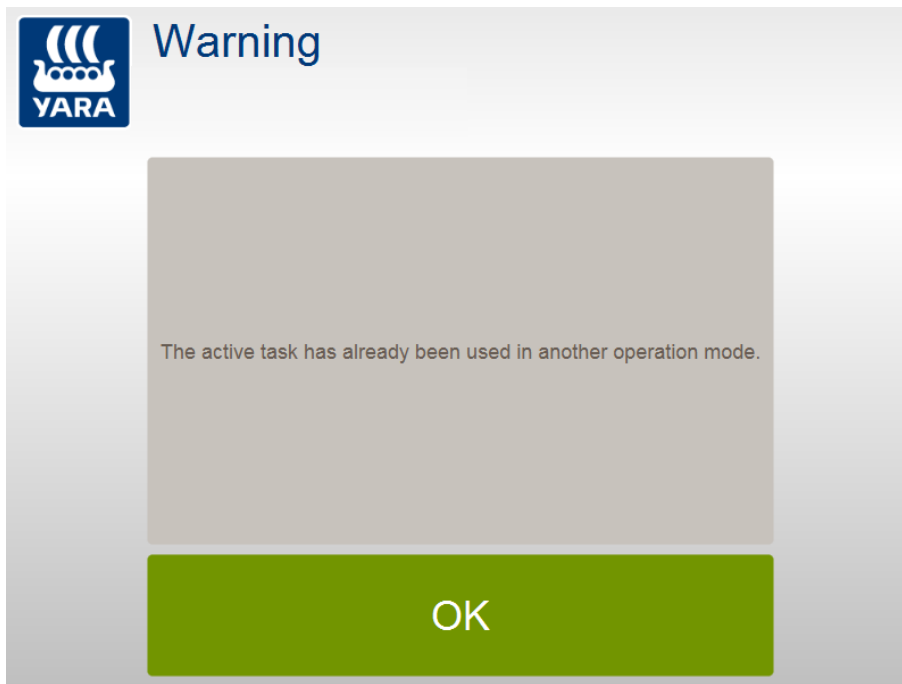
4.4.3 Spreader communication failure



The connection to the spreader or sprayer is lost. Probably the controller is not working properly or it is set up wrongly. The system will automatically switch to standby mode and stop data logging and stop sending application rates.

To avoid this warning, the *Unidirectional only* option may be checked in the configuration menu of the spreader/sprayer controller. With this option checked, no warning will be generated at all, but as-applied rates will not be logged and the connection to the spreader/sprayer will not be monitored.

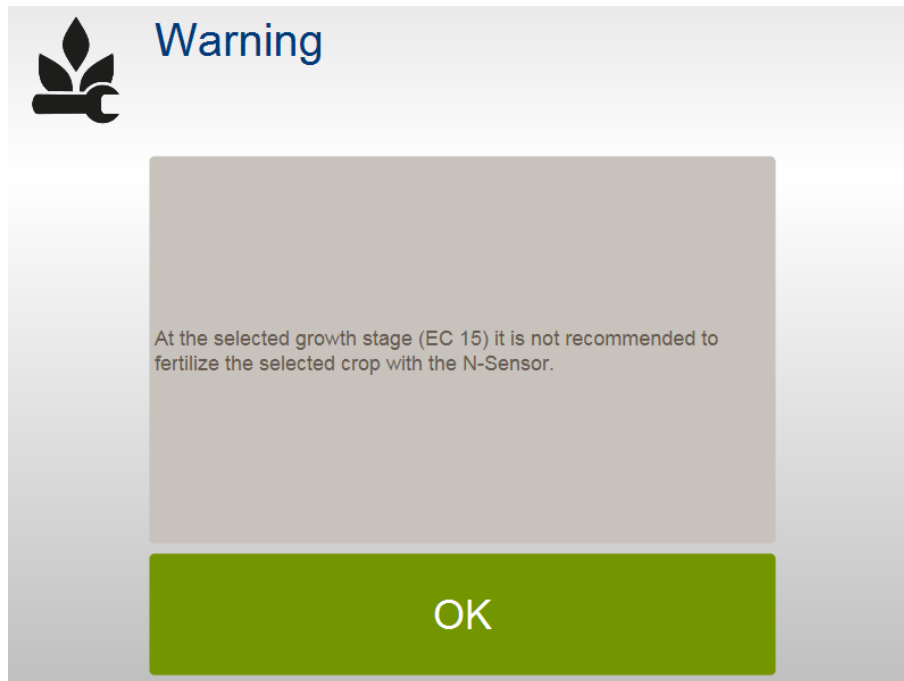
4.4.4 Wrong operation mode



The selected task already contains data which has been acquired using a different operation mode (see section 6). It is not possible to store data from different operation modes into one single task.

Select a new task or select a task that was started with the same operation mode.

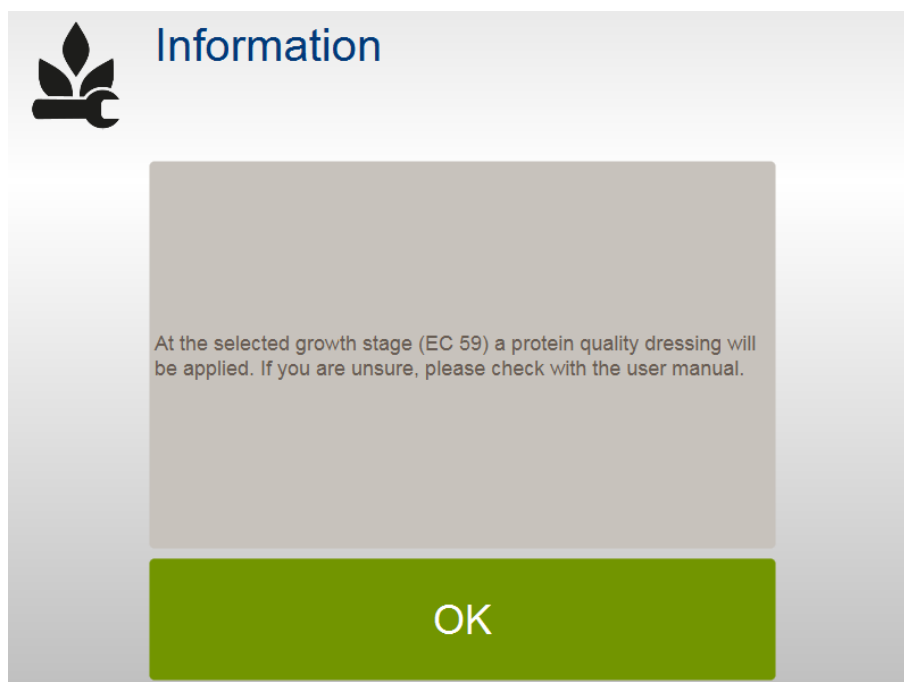
4.4.5 Wrong growth stage



An agronomic calibration function is not available for the selected combination of *Crop type* and *Growth stage*. This warning is displayed immediately after crop type and growth stage have been entered in the agronomic calibration menu.

Regardless of the warning message, the system will work using the most suitable agronomic calibration function.

4.4.6 Protein quality dressing

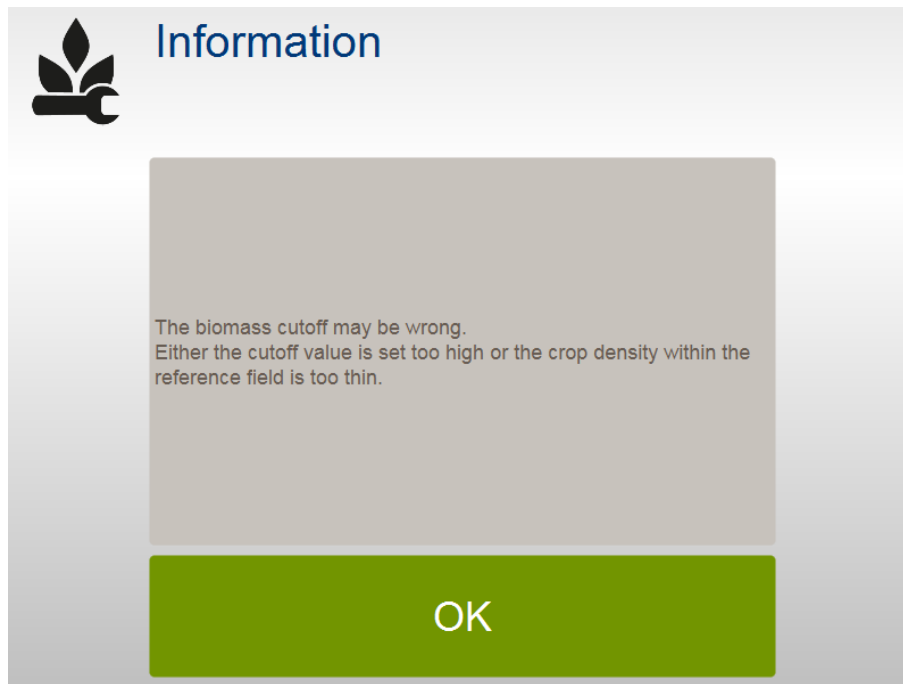


In cereals, at growth stages between EC 59 and EC 69 a protein quality dressing will be applied. In general, the agronomic calibration function is opposite to the "normal"

calibration functions at earlier growth stages. Application rates will increase with increasing N-Sensor readings, whereas at earlier stages rates generally decrease with increasing readings.

You should be aware of this principal difference and make sure that a protein quality dressing is really required.

4.4.7 Biomass cutoff

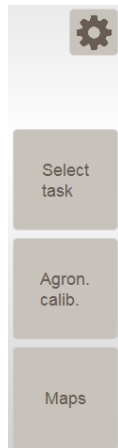


(N-application only) The average sensor value on the reference area is close to or lower than the *Biomass cutoff* entered in the *Agronomic calibration* menu.

The cutoff value should be reduced or another, more representative reference area should be chosen.

4.5 Main menu

Generally, all required settings and operations are controlled through the main menu bar in the right corner of the work screen. The layout of the main menu bar changes whenever the *Start/Stop* button is pressed. In standby mode, the main menu bar is used for general setup, task selection and agronomic calibration:



Setup: Configure the spreader/sprayer, the N-Sensor, the GPS receiver and the program itself. Details can be found in the separate *Installation Instructions*.

Select task: Enter task management to create, modify and select tasks. This menu should be entered once before a new field is started.

Agronomic calibration: Enter field-specific agronomic calibration parameters. This menu should be entered once before a new field is started.

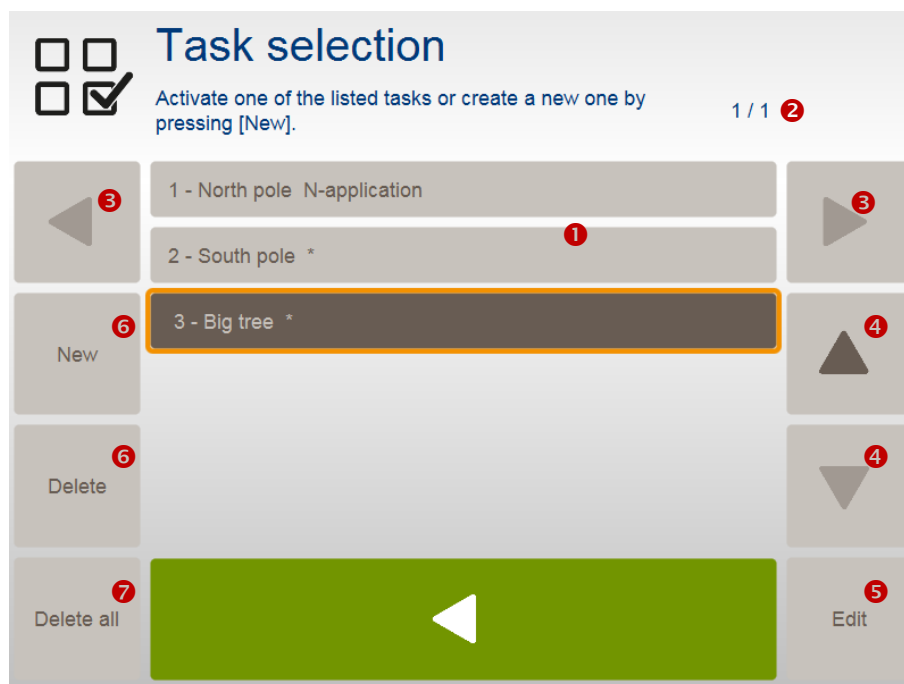
Maps: Toggle between the standard work screen (see section 4) and the map preview (see section 7).

5 Task management

Generally, the N-Sensor can handle an unlimited number of individual tasks, whereas usually one task should correspond to one field. Each task can be regarded as a storage location for N-Sensor data. Tasks are numbered and contain general field information (i. e. field name, field size, crop type etc.) together with a link to the corresponding N-Sensor log-file where all recorded data are stored. In addition, prescription maps (sometimes referred to as “raster maps”) can be attached to a task optionally. All task data, log files and prescription maps are stored in the *Data directory* as selected in the *Setup* menu.

Tasks can be prepared either on a desktop PC through third-party software or “on the fly” by filling in the menu entries in the *Task selection* menu. In the simplest case, nothing needs to be prepared or filled in; just a task number has to be selected.

To enter the task management, press the *Select task* button in the main menu bar. Usually, this menu is entered once on each individual field before N-application is started.

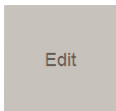


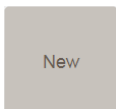
- ❶ **Task list:** The task list contains all available tasks with their task number, field name and operation mode. New (unused) tasks are marked with an asterisk (*).
- ❷ **Page indicator:** If the task list contains more than 6 tasks, they will appear on additional pages.
- ❸ **Page navigator:** use the arrow left/arrow right buttons to flip between individual menu pages.
- ❹ **Task selection:** Use the arrow up/arrow down buttons to select a certain task from the list. Alternatively directly click on the desired task in the list.
- ❺ **Task editor:** Click this button to modify the selected task.
- ❻ **Add/remove tasks:** Use the *New* and *Delete* buttons to add or remove individual tasks. Note that if tasks are removed both the task information and the log file is deleted; any prescription map linked to that task will not be removed.

- 🔗 **Remove all tasks:** Pressing this button will erase all available tasks at once. Note that prescription maps will not be removed, even if they are linked to the tasks.

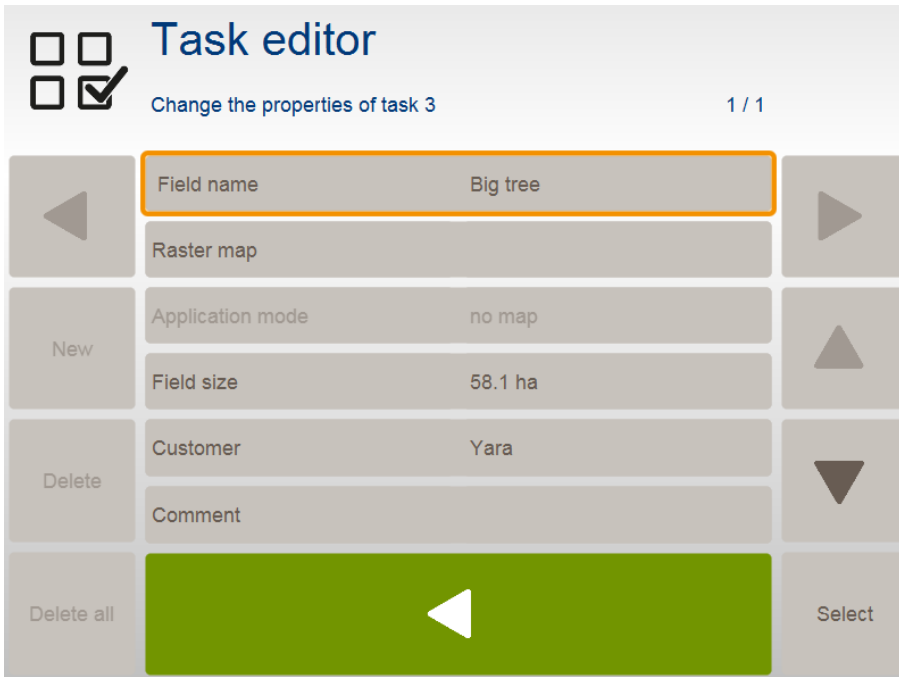
The task that has been last selected when the *Back* button is pressed will be used for data logging. The corresponding task number is displayed on the work screen together with the field name.

5.1 Enter task information

 To enter task information, either edit an existing task or

 press the *New* button to create a new task.

The *Task editor* window will open:



Field name: The name of the field will be assigned to the task and will be shown on the work screen. It will also appear in the file name of the log file.

Raster map: Optionally, a raster map can be assigned to the task. See section 8 for more information. This option is only available if at least one raster map is physically present in the *Data directory*.

Field size: Note that the field size entered here is for information only; it does not affect the N-Sensor application itself. However the value is stored in the log file and may be used by the processing software for map creation.

Customer: The customer information will be stored in the log file and may be used by the processing software. For the N-Sensor operation itself it is not required.

Comment: The comment field may be used to exchange information between the operator in the field and the person in charge of data processing. Again any information entered here will be stored with the task data and the log file.

Whenever alphanumeric text needs to be entered (i. e. field name, customer and comment), a software keyboard pops up:



Text can be entered by either pressing the alphanumeric buttons directly or through the arrow and *Select* buttons. A hardware keyboard is not supported.

6 Operation modes

The N-Sensor can be operated in different operation modes, also referred as agronomic calibrations. These modes determine the agronomic content of the N-Sensor and basically translate N-Sensor readings into meaningful application rates.

Availability and visibility of certain operation modes depends on the local setup of each individual N-Sensor. Typically, the following modes are available:

N-application: Default module for nitrogen application in many crops grown under non-water limiting conditions. An in-field reference calibration (i. e. using the Yara N-Tester) is required.

Target rate application: Standard module for nitrogen application in many crops grown under non-water limiting conditions. The user needs to provide the desired overall (average) nitrogen rate; the Yara N-Sensor will then redistribute that rate according to its site-specific measurements.

Absolute calibration (oilseed rape): The nitrogen recommendation is derived directly from the N-Sensor reading and some general settings to be entered by the user. No in-field calibration (like with the standard *N-application* module) is required. This module is designed for oilseed rape under western/central European conditions only.

N-Sensor scanning: N-Sensor readings are collected, but no application rate is being calculated nor communicated to the spreader/sprayer. Use this module for acquiring an N-Sensor map for information only or if the application is planned at a later date.

Base application: Application according to a prescription map only. N-Sensor readings are collected, but are not taken into account for the recommendation.

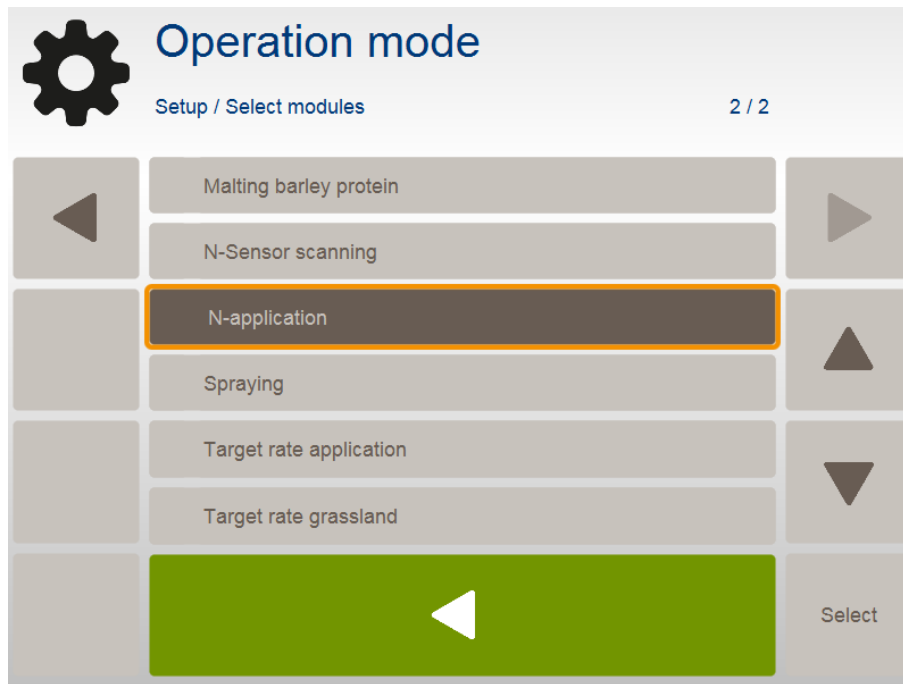
Potato fungicide: Variable-rate application of various types of fungicides to potatoes. This module has been developed by PRI Wageningen.

Potato haulm killing: Variable-rate application of potato desiccants. This module has been developed by PRI Wageningen.

Malting barley: Variable-rate application of nitrogen in malting barley under Swedish conditions. This module has been developed by Lantmännen, Sweden.



To select an operation mode, from the *Setup* menu choose *Select modules*, then *Operation mode*:



Choose the desired operation mode and successively press *Back* twice to return to the work screen. Check that the name of the module is correctly displayed in the header of the work screen.

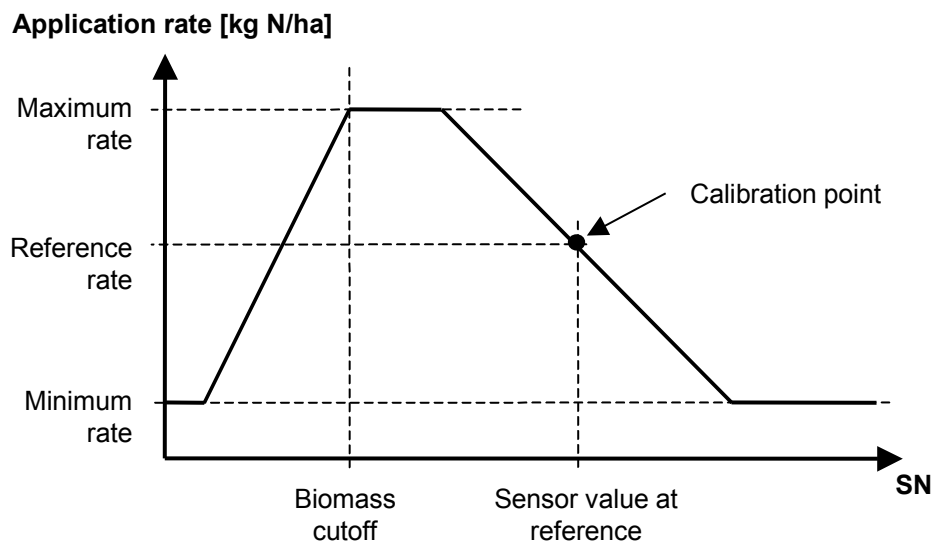
Note that a valid license must be present for the selected mode. License codes are available from the local N-Sensor distributor and must be entered in the agronomic calibration menu of the respective module.

In the following sub-sections the most relevant agronomic modules are briefly described.

6.1 N-application

The *N-application* operation mode is the default mode to use the N-Sensor for site-specific nitrogen application. It provides a relative calibration, i. e. application rates are changed up and down from a user-selectable baseline. To determine this baseline, the user is supported by the agronomic calibration procedure (see below).

The basic principle of the calibration curve is shown below:



Generally, application rates decrease with increasing sensor values SN, i. e. the better the crop is developed and the more nitrogen has already been taken up by the plants, the lower the application rate will be. However, the rate is clipped to a user-selectable minimum and maximum rate. If the crop is extremely bad, the sensor value drops below a threshold level (*biomass cutoff*) and rates will again be reduced to avoid over-fertilisation in areas where the crop is obviously suffering from other problems than nitrogen deficiency. This biomass cutoff level is dependent on crop type and growth stage and will be automatically preset by the program. However, it is possible to manually change this value to adapt to local conditions.

While this general pattern is similar for oilseed rape, potatoes and maize at all relevant growth stages and for cereals until flowering, late cereal applications (typically at growth stage between 59 and 69) will be treated differently. These applications will automatically be treated as protein applications to achieve a certain level of protein concentration in the grain. Consequently, the system will react with increasing application rates at increasing sensor values in order to achieve a uniform concentration of nitrogen in the crop stand. You should be aware of this different approach when selecting a cereals crop at the respective growth stages. However, a warning message will be displayed as a reminder.

6.1.1 Agronomic calibration

Agron.
calib.

To enter the agronomic calibration menu, press the *Agron. calib.* button on the main menu bar in the work screen. Usually, this menu is entered at the beginning of the field after a task has been selected:

N-application
Agronomic calibration 1 / 3

	Crop	Winter wheat	
	Growth stage	39	
New	Application	Booting	
	Minimum rate	15 kg N/ha	
Delete	Maximum rate	150 kg N/ha	
	Uniform rate	80 kg N/ha	
Delete all	▶		Select

Crop: Select the crop type to be fertilized. A sub-menu will pop up to choose from the list of available crop types.

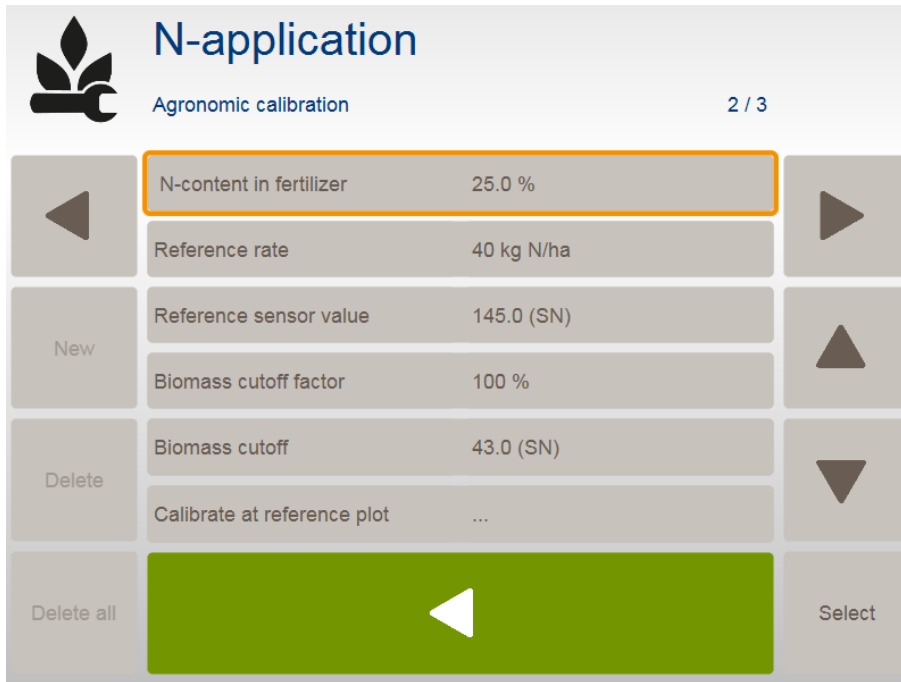
Growth stage: Select the current growth stage of the crop to be fertilized. The growth stage is entered as decimal code (EC) between 0 and 99. Depending on the selected crop, the type of application is displayed in brackets behind the growth stage. The warning “wrong growth stage” will be displayed if a N-Sensor controlled nitrogen application is not recommended.

Application: (Cereal crops only) Displays the type of application dependent on the selected growth stage. Normally this menu item is greyed out and cannot be changed. For growth stages 37 to 51 however you can decide between a standard booting application and a protein dressing with inverse recommendations.

Minimum rate: The minimum rate that is recommended by the N-Sensor. Note that the final application rate may be less if the -10% button is pressed during operation or if a prescription map is used. For optimum performance, the minimum rate should not limit the N-Sensor variation too much. The default minimum rate is 0 kg N/ha, allowing the N-Sensor to apply no fertilizer at all if indicated by the crop.

Maximum rate: The maximum rate that is recommended by the N-Sensor. Note that the final application rate may exceed this limit if the $+10\%$ button is pressed during operation or if a prescription map is used. For optimum performance, the maximum rate should not limit the N-Sensor variation too much. The default maximum rate is 120 kg N/ha, allowing the N-Sensor to apply a high rate if indicated by the crop.

Uniform rate: The uniform rate is regarded as a standard rate that will be applied when the user explicitly switches to uniform rate or in case the system cannot process a regular rate. Therefore the uniform rate should be a reasonable, good average for the field.



N-application
Agronomic calibration 2 / 3

	N-content in fertilizer	25.0 %	
	Reference rate	40 kg N/ha	
New	Reference sensor value	145.0 (SN)	
	Biomass cutoff factor	100 %	
Delete	Biomass cutoff	43.0 (SN)	
	Calibrate at reference plot	...	
Delete all	▶		Select

N-content in fertilizer: This number is used as conversion factor between nitrogen rates and product rates. In N-application operation mode, all rates within the N-Sensor program are in nitrogen units, but the application device requires product rates.

Reference rate: The application rate assigned to the reference area. Normally, it is not required to explicitly enter this value, as it will be automatically set during the *Calibrate at reference plot...* procedure.

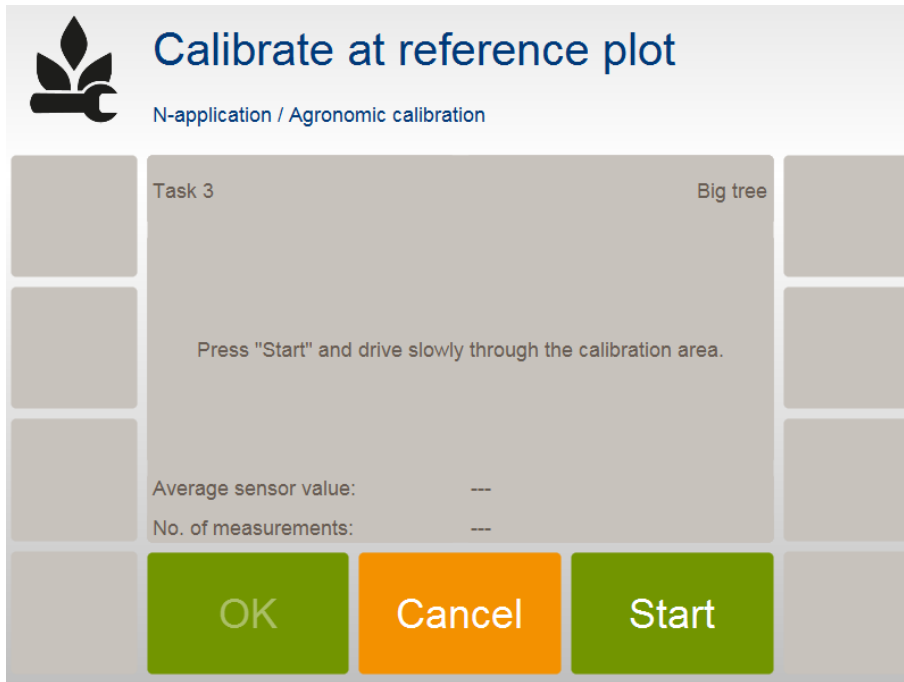
Reference sensor value: The average sensor value from the reference area. If the current sensor value is equal to this value, the reference rate (see above) will be applied. Normally, it is not required to explicitly enter this value, as it will be automatically set during the *Calibrate at reference plot...* procedure.

Biomass cutoff factor: The *Biomass cutoff factor* allows to generally increase or decrease the *Biomass cutoff* (see below) by a certain factor. Under default condition the default setting (100%) should not be changed.

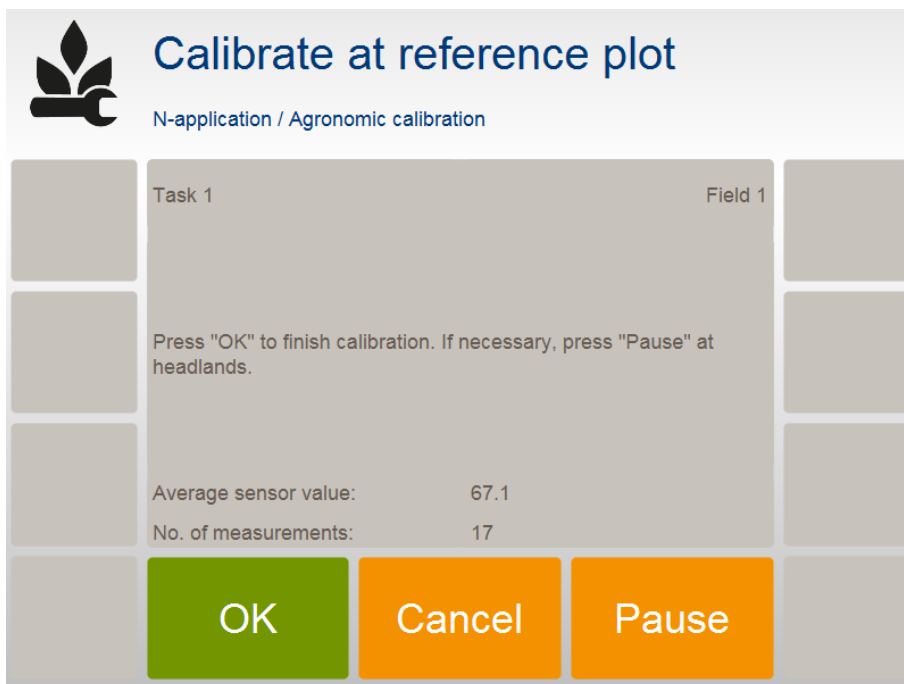
Biomass cutoff: If the sensor value is lower than the *Biomass cutoff* (multiplied by the *Biomass cutoff factor*), the crop density is regarded as too low to apply the full nitrogen rate. Instead, the rate will be reduced with decreasing sensor value. On the work screen, the “low crop density” icon is displayed. Depending on crop type and growth stage, default biomass cutoff values are set automatically. Therefore under default conditions it is not necessary to change this value.

Calibrate at reference plot: Enter the automatic on-field calibration procedure (see below). This procedure is started with the system on the so-called reference area of the field. The reference area should be a small, approximately 30 m long part of one tramline with normal crop conditions. The tractor is driven slowly across this area while sensor values are continuously taken. At the end of the calibration area, the average reading is calculated. Finally, the driver assigns the desired application rate to this reference value. Both values are then automatically taken as *Reference rate* and *Sensor value at reference rate*.

When the *Calibrate at reference plot...* button is pressed, the following menu is displayed:



Start With the vehicle entering the calibration area, press *Start* and pass the area slowly. The sensor starts to measure continuously and the average reading together with the number of measurements can be followed on the screen:



Note that the calibration data is already logged to the selected log file. For this reason it is strongly recommended to select the task number *before* the calibration is done.

Pause If necessary, data acquisition can be paused at any time using the *Pause* button.



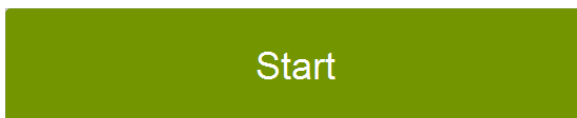
Press *OK* just before the end of the calibration area is reached. The total number of measurements should be above 20 to achieve a good average.

The image shows a digital input screen titled "Reference rate" with a leaf icon and a wrench icon. Below the title, it says "Valid range: 15 - 150 kg N/ha". The current input is "85 kg N/ha". A numeric keypad is displayed with the number "5" highlighted in an orange box. At the bottom, there are two buttons: a green "OK" button and an orange "Cancel" button.

The system now asks for the application rate to be assigned to the reference area. Preferably, use the N-Tester[®] to determine this rate. Alternatively, any other method that provides a good recommendation for the reference area can be used. Note that this rate always refers to the reference area only; *it is not necessarily equivalent to the average recommendation of the whole field!*

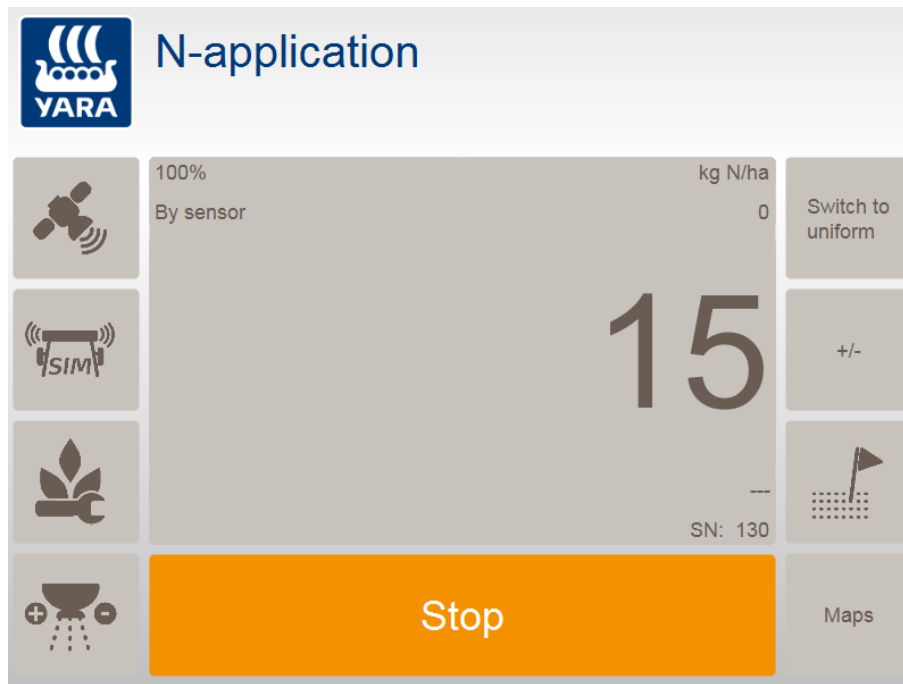
After the reference rate has been entered, the system automatically transfers the reference rate and the average Sensor reading to the agronomic calibration menu and switches back to the work screen. The system is now calibrated agronomically and ready for operation.

6.1.2 Operation



data logging.

With the N-Sensor properly set up and calibrated, N application can be started on the field. On the work screen press the *Start* button to begin fertilizing and



The main menu bar changes and the *Stop* button appears. Calculated application rates are continuously sent to the spreader controller and all relevant data is logged to the log-file that is linked to the selected task. The main menu bar displays the following options:

Switch to uniform: Pressing the *Switch to uniform* button changes the application rate to the predefined setting made in the *Agronomic calibration* menu. In this case, the “uniform” icon is displayed to remind that the rates are not based on the N-Sensor reading.

+/-: This button changes the menu to allow for manual application rate changes in steps of +10% and –10%. The change factor is displayed in the top left corner of the work screen.

Markers: If this button is pressed the menu changes to the marker menu, which allows to set and delete three markers independently from each other. If markers are set, the respective area will be marked in the log data output and in the map printout, respectively. This option may be helpful to identify specific areas within the field during fertilizer application.

Maps: If pressed, a map of the area processed so far is displayed together with the current position of the vehicle. If a prescription map is available, this will also be displayed. The sensor-controlled variable rate application is continued. For more information see section 7.

Usually, the system should be started at the beginning of the field and should continue to operate throughout the whole field. The *Stop* button is only pressed to pause operation within the field, i. e. in order to refill fertilizer. In the headlands, the N-Sensor keeps running. The fertilizer distributor is operated as without the N-Sensor connected, i. e. it is closed and opened in the headlands as usual.



When the field is completed, press the *Stop* button to deactivate the system. You may now continue with another task on another field as described in section

5 or remove the data stick and process the log-file(s).

6.2 Target rate application

The *Target rate application* operation mode is very similar to the *N-application* operation mode (see section 6.1). The mode has been designed to apply a predefined target rate on the field, i. e. to locally redistribute a predefined rate according to the N-Sensor readings. If used properly, the average application rate on the whole field will be approximately equal to the target rate.

In contrast to the standard *N-application* mode a separate in-field calibration is not required. Instead, the system automatically calibrates itself when the first tramlines are fertilized. This may lead to some inaccuracy at the very beginning when only a few datasets have been acquired. However, the accuracy will continuously improve the more area has been covered.

6.2.1 Agronomic calibration

Agron.
calib.

To enter the agronomic calibration menu, press the *Agron. Calib.* button on the main menu bar in the work screen. Usually, this menu is entered at the beginning of the field after a task has been selected:

The screenshot shows the 'Target rate application' menu with the following settings:

Field	Value
Crop	Winter wheat
Growth stage	37
Application	Booting
N-content in fertilizer	25.0 %
Minimum rate	0 kg N/ha
Maximum rate	150 kg N/ha

At the bottom, there are two main buttons: 'Start calibration' (green) and 'Cancel' (orange). A 'Select' button is also visible on the right side of the bottom row.

Crop: Select the crop type to be fertilized. A sub-menu will pop up to choose from the list of available crop types.

Growth stage: Select the current growth stage of the crop to be fertilized. The growth stage is entered as decimal code (EC) between 0 and 99.

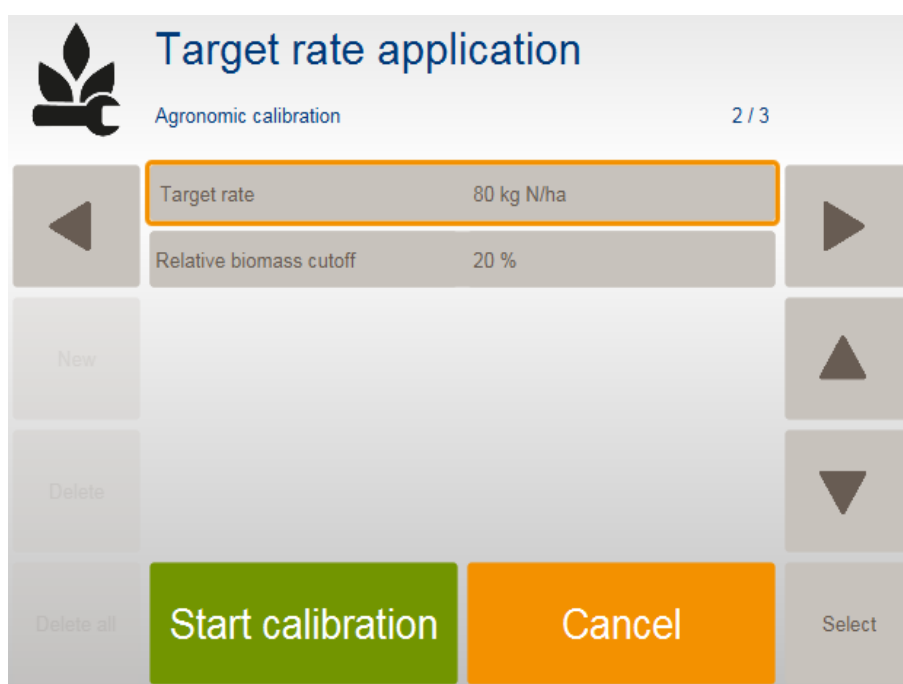
Application: (Cereal crops only) Displays the type of application dependent on the selected growth stage. Normally this menu item is greyed out and cannot be changed. For growth stages 37 to 51 however you can decide between a standard booting application and a protein dressing with inverse recommendations.

N-content in fertilizer: This number is used as conversion factor between nitrogen rates and product rates. In target rate application operation mode, all rates within

the N-Sensor program are in nitrogen units, but the application device requires product rates.

Minimum rate: The minimum rate that is recommended by the N-Sensor. Note that the final application rate may be less if the -10% button is pressed during operation or if a prescription map is used. For optimum performance, the minimum rate should not limit the N-Sensor variation too much. The default minimum rate is 0 kg N/ha, allowing the N-Sensor to apply no fertilizer at all if indicated by the crop.

Maximum rate: The maximum rate that is recommended by the N-Sensor. Note that the final application rate may exceed this limit if the $+10\%$ button is pressed during operation or if a prescription map is used. For optimum performance, the maximum rate should not limit the N-Sensor variation too much. The default maximum rate should be at least 120 kg N/ha, allowing the N-Sensor to apply a high rate if indicated by the crop.



Target rate: The rate to be applied to the whole field on average. This rate is also the standard rate that will be applied when the user explicitly switches to uniform rate or in case the system cannot process a regular rate.

Relative biomass cutoff: If the current sensor value is lower than the given percentage of the average sensor value, the crop density is regarded as too low to apply the full nitrogen rate. Instead, the rate will be reduced with decreasing sensor value. On the work screen, the “low crop density” icon is displayed. A default value of 50% should be applicable to most conditions.

Start calibration

Press *Start calibration* to reset the internal calibration parameters and return to the main menu. This button must be pressed to confirm the settings and start the automatic calibration. If the *Cancel* button are used to return to the main menu, the calibration is not reset and the target rate will not apply.

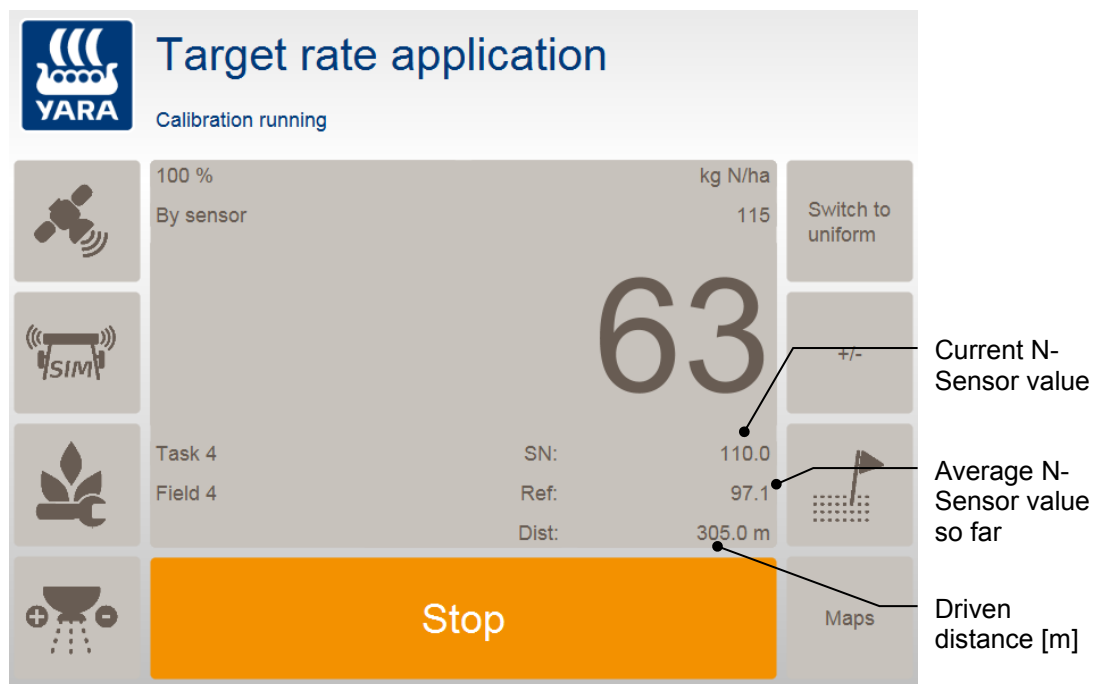
6.2.2 Operation

Start

Once the agronomic calibration has been completed, the system is ready for application. When the *Start* button on the work screen is pressed, the system will

immediately start to apply the target rate. At the same time sensor readings are collected to continuously recalculate the actual field average and the application rates may deviate from the target rate whenever the current sensor reading is different from the actual average.

On the work screen, the distance driven (*Dist*) and the average N-Sensor value (*Ref*) are displayed continuously. The distance is calculated from the GPS data. If no GPS is connected, a standard speed of 3 m/s is assumed.



Uniform: Pressing the *Uniform* button changes the application rate to the predefined setting made in the *Agronomic calibration* menu. In this case, the “uniform” icon is displayed to remind that the rates are not based on the N-Sensor reading.

+/-: This button changes the menu to allow for manual application rate changes in steps of +10% and –10%. The change factor is displayed in the top left corner of the work screen.

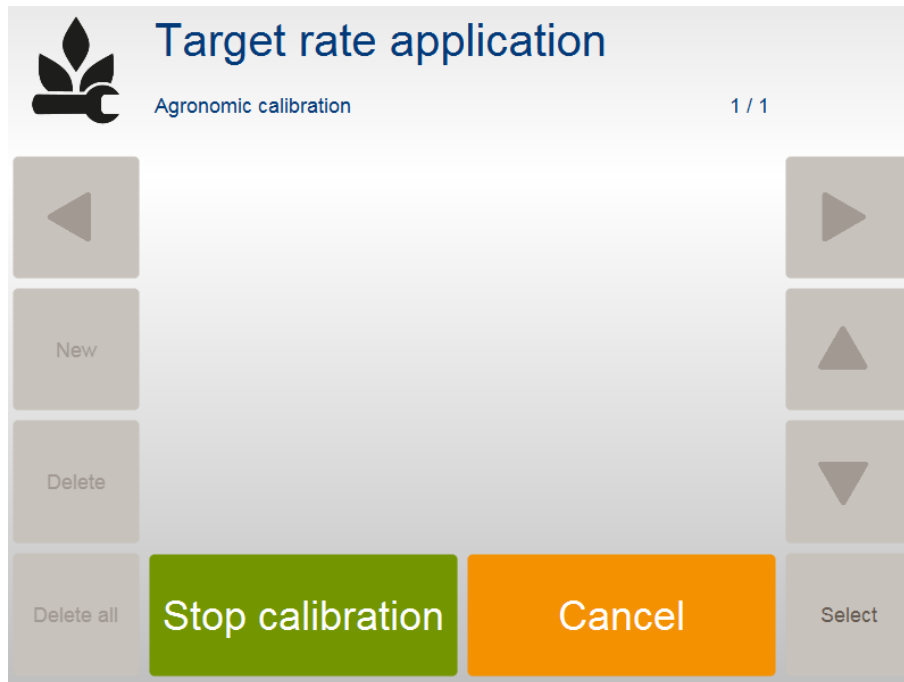
Maps: If pressed, a map of the area processed so far is displayed together with the current position of the vehicle. If a prescription map is available, this will also be displayed. The sensor-controlled variable rate application is continued. For more information see section 7.

Markers: If this button is pressed the menu changes to the marker menu, which allows to set and delete three markers independently from each other. If markers are set, the respective area will be marked in the log data output and in the map printout, respectively. This option may be helpful to identify specific areas within the field during fertilizer application.

Usually, the system should be started at the beginning of the field and should continue to operate throughout the whole field. The *Stop* button is only pressed to pause opera-

tion within the field, i. e. in order to refill fertilizer. In the headlands, the N-Sensor keeps running. The fertilizer distributor is operated as without the N-Sensor connected, i. e. it is closed and opened in the headlands as usual.

The continuous recalculation of the average N-Sensor reading can be stopped at any time within the field. To do so, press *Stop* on the work screen first, then *Agron. Calib.* and *Stop calibration*. (see below).



After that, the reference N-Sensor value will remain unchanged until the agronomic calibration menu is entered again and until *Start calibration* is pressed again.



When the field is finally completed, press the *Stop* button to deactivate the system. You may now continue with another task on another field as described

in section 5 or remove the data stick and process the log-file(s).

6.3 Base application

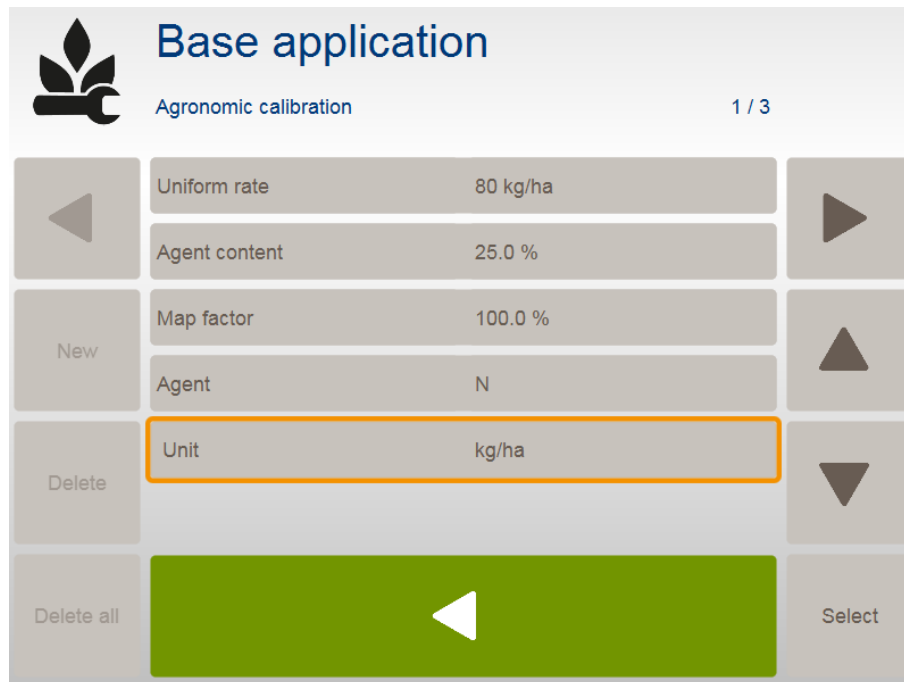
The *Base application* operation mode can be used to apply various agents (not only nitrogen) from a prescription map. In this mode, the application rate is solely based on the map; sensor readings are dismissed. However, sensor values are still acquired and stored to the log file for later processing and visualisation.

6.3.1 Map selection

In *Base application* operation mode it is mandatory to link a prescription map to the task. See section 8 for details.

6.3.2 Agronomic calibration

To enter the agronomic calibration menu, press the *Agron. Calib.* button on the main menu bar in the work screen. Usually, this menu is entered at the beginning of the field after a task has been selected.



Setting	Value
Uniform rate	80 kg/ha
Agent content	25.0 %
Map factor	100.0 %
Agent	N
Unit	kg/ha

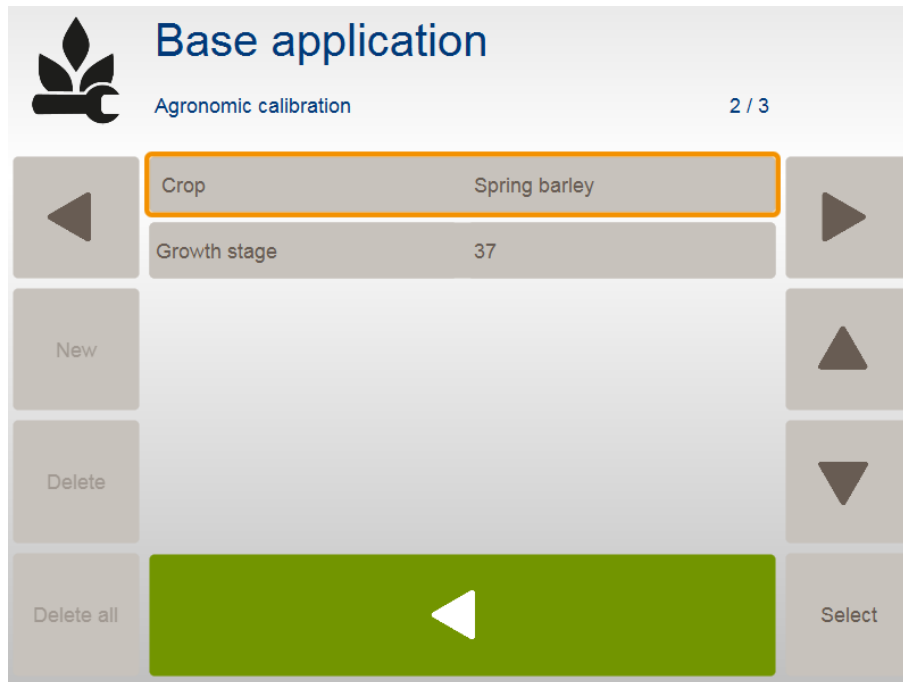
Uniform rate: The uniform rate is regarded as a standard rate that will be applied in case the system cannot process a regular rate because of GPS failure or if the vehicle is outside the prescription map. Therefore the uniform rate should be a reasonable, good average for the field.

Agent content: This number is used as conversion factor between agent rates and product rates. All rates within the N-Sensor program are in agent units, but the application device requires product rates.

Map factor: Use this option if you only want to apply a fraction of the prescription map-value. All application rates will be multiplied with this value. This may be particularly helpful if you want to split the application from one map into several years. In this case you may i. e. apply with a value of 33% in three consecutive years.

Agent: The type of active ingredient to be dispensed. This setting is stored with the log file for documentation purposes, but does not affect the behaviour of the system at all.

Unit: The physical unit of the application rate, either kg/ha or l/ha. The setting does not have any impact on the behaviour of the system; it is only displayed in the work screen for convenience and it is logged for documentation purposes.



Crop: Select the crop type to be fertilized. A sub-menu will pop up to choose from the list of available crop types.

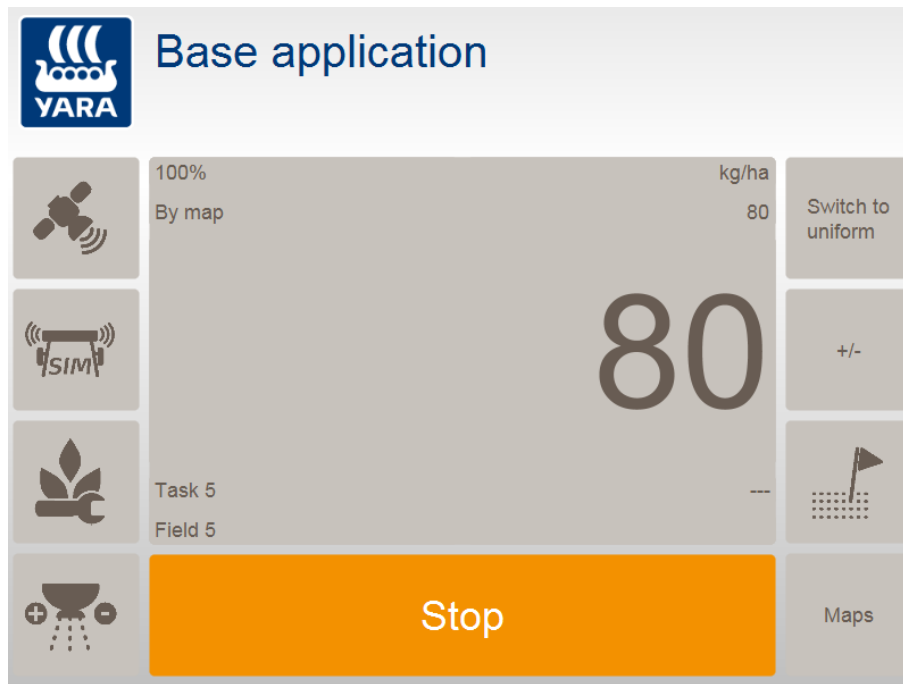
Growth stage: Select the current growth stage of the crop to be fertilized. The growth stage is entered as decimal code (EC) between 0 and 99.

Note that the *Crop* and *Growth stage* settings do not affect the application rate at all, however they are used for record-keeping and for logging the correct SN value in case an N-Sensor is connected. Therefore it is strongly recommended to choose the proper settings here.

6.3.3 Operation



On the work screen press the *Start* button to begin map-based variable-rate fertilizing and data logging. The main menu bar changes and the *Stop* button appears. Calculated application rates are continuously sent to the spreader controller and all relevant data is logged to the log-file that is linked to the selected task.



The main menu displays the following options:

Uniform: Pressing the *Uniform* button changes the application rate to the predefined setting made in the *Agronomic calibration* menu. In this case, the “uniform” icon is displayed to remind that the rates are not based on the prescription map.

+/-: This button changes the menu to allow for manual application rate changes in steps of +10% and –10%. If rates are manually changed, the change factor is displayed above the application rate.

Maps: The prescription map is displayed with the current position of the vehicle and the current application rate at that point in the map.

Marker: If this button is pressed the menu changes to the marker menu, which allows to set and delete three markers independently from each other. If markers are set, the respective area will be marked in the log data output and in the map printout, respectively. This option may be helpful to identify specific areas within the field during fertilizer application.

Usually, the system should be started at the beginning of the field and should continue to operate throughout the whole field. The *Stop* button is only pressed to pause operation within the field, i. e. in order to refill fertilizer. In the headlands, it is not recommended to stop. The fertilizer distributor is closed and opened through the spreader/sprayer controller as usual.



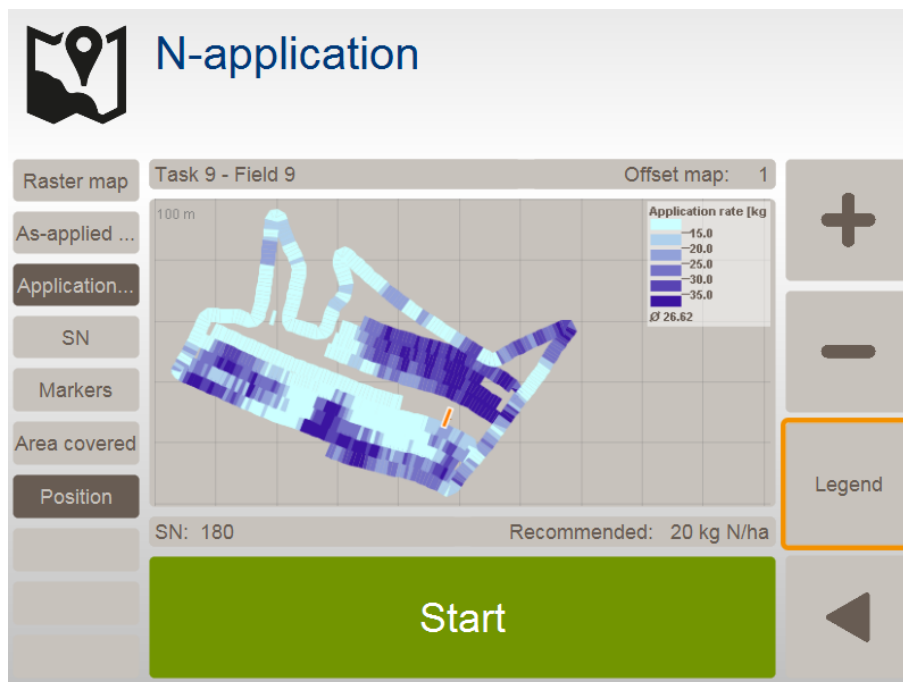
When the field is finally completed, press the *Stop* button to deactivate the system. You may now continue with another task on another field as described

in section 5 or remove the data stick and process the log-file(s).

7 Map display

The N-Sensor software allows to visualize N-Sensor maps as well as raster maps (prescription maps). Furthermore, the current position of the vehicle and the area covered can be shown in live-view during application. Use this feature to preview the data collected in a task and determine which part of the field has already been treated.

From the work screen, press the *Maps* button.



The map layers to be displayed can be selected through the buttons on the left hand side. Generally multiple layers can be selected; maps will be overlaid in this case.

In standby mode the following map layers are available:

Raster map: Prescription map that has been assigned to the task. For details see section 8.2.

As-applied rate: Application rate as returned by the spreader/sprayer controller. This layer is only visible if the controller is capable to send as-applied rates and if the *Unidirectional only* option has been disabled. This map can only be displayed with the N-Sensor stopped.

Application rate: Application rate as recommended by the N-Sensor and as sent to the spreader/sprayer controller. This map can only be displayed with the N-Sensor stopped.

SN: Sensor value SN as recorded by the N-Sensor. This map can only be displayed with the N-Sensor stopped.

Markers: Areas where one of the three available markers were enabled are shown as coloured points in the map. Marker 1 is shown in red, marker 2 in green and marker 3 in blue colour.

Calibration line: The area used for reference calibration is displayed in red. This layer is only visible in case a *Calibrate at reference plot* calibration (in operation mode N-application) has been carried out.

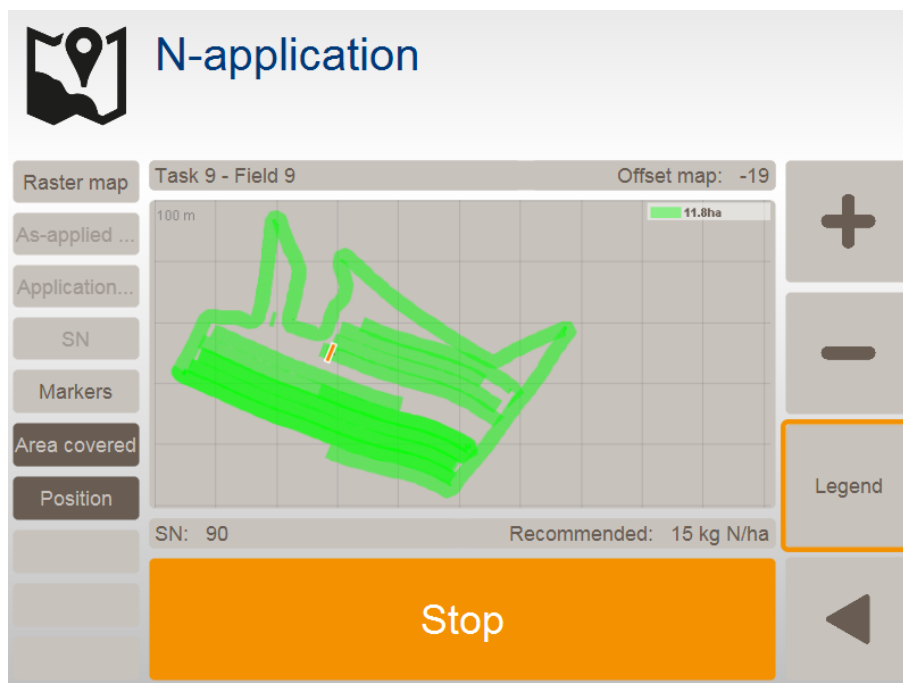
Area covered: The processed area is shown as a green line behind the symbolized vehicle. The width of the line corresponds to the *Working width* as set in the spreader/sprayer controller settings.

Field border: Shows the field boundary. This option is only available if raster-map in WTK ADIS format (*.rst) is linked to the current task.

Position: Displays the current position of the vehicle.

By default, the map is scaled automatically to fit the whole area to the screen. Use the + and – buttons to zoom the display in and out, respectively. Press the *Legend* button to enable and disable a legend in the upper right corner of the map display.

In active mode (i. e. with the N-Sensor running) only the area covered and the current position can be displayed:



Use the *Back* button to return to the standard work screen at any time.

8 Using raster maps (prescription maps)

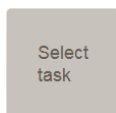
The N-Sensor software can handle so-called raster maps (prescription maps) to provide spatially variable application information. While for standard N-Sensor based applications these maps are not required, they can be used optionally to “overlay” N-Sensor recommendations with map information or to control the application rate solely from the map.

Raster maps are mandatory for the *Base application* operation mode and are optional for all other modes. They have to be prepared by third-party software in Surfer ASCII grid file format (*.grd), WTK ADIS format (*.rst) or ESRI-shape format (*.shp + *.dbf + *.shx). The total number of grid cells should not exceed 65000. For more detailed information on how to create raster maps contact your local service partner.



To use raster maps, the *Raster map handler* module needs to be installed and enabled in the *Setup - Select modules - Auxiliary services* menu.

8.1 Linking raster maps to tasks



From the work screen, first choose *Select task* and then either create an empty task by pressing the *New* button or press *Edit* to link the raster map to an existing task.

Task editor
Change the properties of task 13 1 / 1

◀	Field name	Hanninghof_Field_5	▶
	Raster map	Demo2_OffsetMap_05m.grd	
New	Application mode	Overlay map	▲
	Field size	16.5 ha	
Delete	Customer	Yara	▼
	Comment		
Delete all	▶		Select

Choose *Raster map* and select the desired raster map file (*.grd, *.rst, *.shp) from the list of available files. Note that only files which are present in the working directory (either the data stick or a fixed directory on the terminal computer) can be selected.

In *Application mode*, determine how the N-Sensor should handle the select map. Choose one of the following:

No map: Prescription maps are not used at all. The application rate is solely based on the N-Sensor reading. This is the default setting for standard N-Sensor operation.

Overlay map: The final application rate is determined solely by the prescription map.

Offset map: The final application rate is calculated as the sum of the N-Sensor recommendation and the rate from the offset map. Note that in this case the offset map may contain positive as well as negative rates.

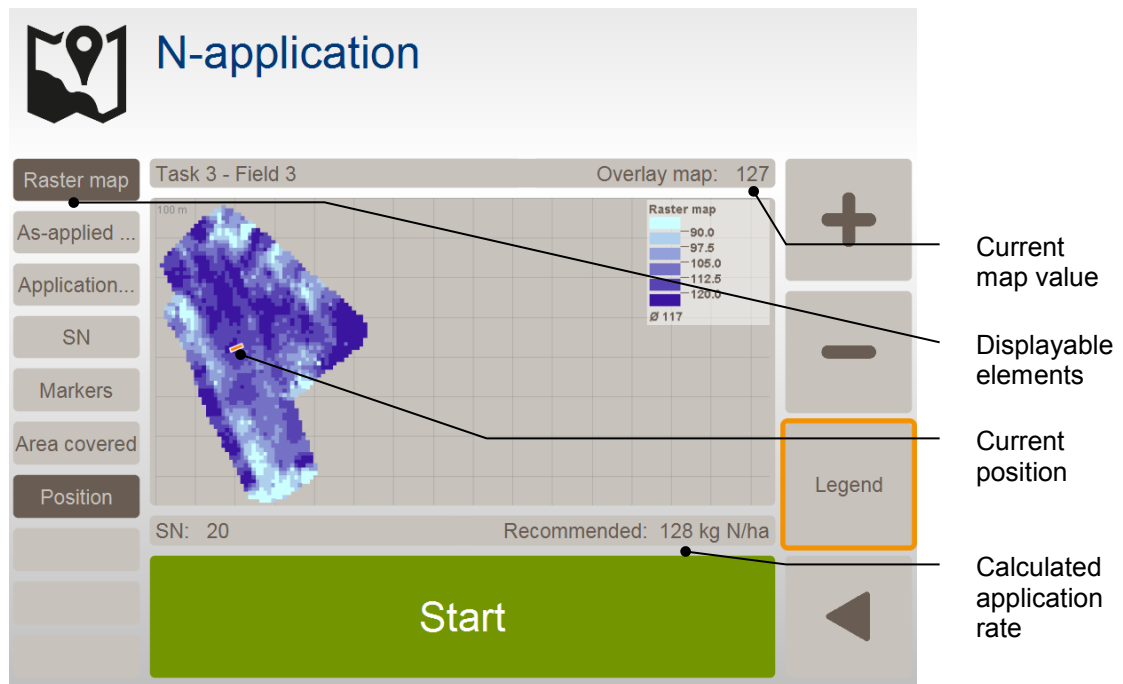
Factor map: The final application rate is the N-Sensor recommendation multiplied by the value from the prescription map.

In all cases if the map is not available or if the vehicle is outside the map area the application rate will be based on the N-Sensor only. (Except in *Base application* operation mode where the uniform rate as selected in the agronomic calibration menu will be applied.)

Subsequently press *Back* and *Ok* to return to the work screen.

8.2 Visualize raster maps

To visualize the raster map, on the main menu of the work screen press *Maps*. This will change the work screen to map display mode.



Choose *Raster map* and *Position* from the list of displayable elements to show the map itself and the current position of the vehicle, respectively. The current map value is displayed in the top right corner, while in the bottom right corner the resulting application rate is shown. Note that the map value can be negative if the map is used as an offset to the current N-Sensor recommendation.

A map legend can be shown by pressing the *Legend* button. The + and - buttons can be used to zoom in and out. Note that by default the map is scaled so that all elements fit to the screen. This may lead to large scales if i. e. the current position is far out from the raster map. In this case it might be useful to disable the *Position* element on the left hand side.



Press the *Back* button to return to the normal work screen at any time.

8.3 Apply fertilizer (or other products) from the map

Finally, with the map linked to the task and the map mode properly set, the product can be applied on the field. From a practical point of view, there is no difference in N-Sensor operation with and without raster maps. The variable-rate application is started and stopped by pressing the *Start* and *Stop* buttons on the work screen, respectively.

Map rates can be followed on the work screen. The raster map and the current position within the map can be visualized at any time during N-Sensor operation by pressing the *Maps* button (see section 8.2).