

OPERATION MANUAL

for the

Yara N-Sensor

Software release 3.728



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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 General issues

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 issues. 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:

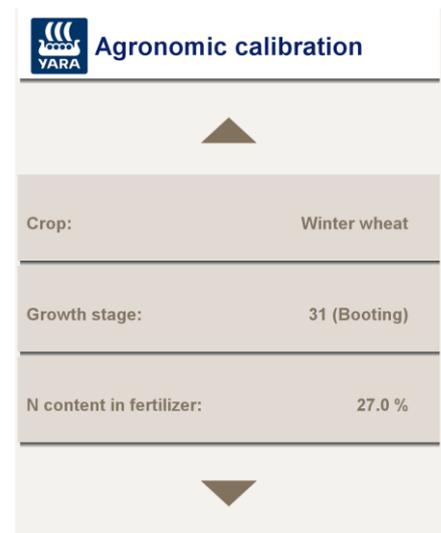
- N-Sensor mounted on the vehicle and connected to power supply
- GPS receiver mounted on the vehicle and connected to power supply
- Variable-rate controller mounted in the cabin, connected to power supply and fertilizer distributor
- Terminal computer (Panel PC) mounted in the cabin and connected to 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
- (optional) *CardWriter* software installed on the office PC
- (optional) Internet connection on the office PC
- (optional) Internet connection on the in-cab terminal computer

2 System operation

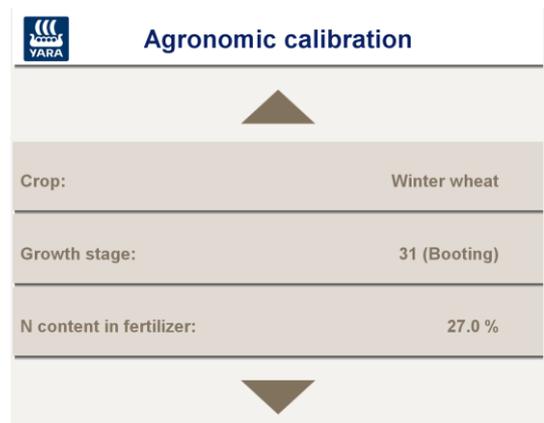
2.1 Screen layout

Depending on the screen layout (portrait or landscape) and resolution the layout of the menus and screens looks slightly different, but the functionality is all the same.

Work screen and agronomic calibration menu in portrait format:



The same work screen and agronomic calibration menu in landscape format:



For clarity, all screenshots in this manual are shown in landscape format.

2.2 Buttons and menus

Generally, the menu structure and the size of the buttons is designed to do the standard N-Sensor operation by touching the screen with bare fingertips, even on small dis-

plays. A pen is only required for more sophisticated settings that are usually made only once and left untouched afterwards.

In menus, list items can be selected by successively pressing the menu key several times until the desired setting appears on the menu button:



Numeric entries are edited by pressing the menu button. A numeric keypad will pop up to enter a number:

N content			
7	8	9	C
4	5	6	ESC
1	2	3	OK
	0	.	

27 %

Pressing *OK* replaces the old setting with the new number. *ESC* will dismiss the new value and keep the old setting. The *C* button clears the number that has been entered so far.

Text fields have to be filled by touching the text field first and then using the keyboard to enter the text.

Comment:

Penguins walking around

If no hardware keyboard is available and depending on the individual set-up, an alpha-numeric software keyboard pops up if the text field is touched:

Comment:



Pressing *OK* overwrites the old setting with the new text. *ESC* dismisses the new text and keeps the old setting. To clear the whole line, press *CLR*. The << button clears the last character that has been entered.

Capital letters can be accessed through the *ABC* button. Language-specific characters are entered through the *ÄÉÛ* button.

2.3 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 5), the work screen may look slightly different from what is shown below, but the general structure will be the same.



In particular, the work screen displays:

Operation mode title: The current operation mode is displayed as menu header. For standard N-Sensor operation, make sure *N-Application* is selected. Refer to section 3.2 to change between operation modes.

Operation mode icon: A logo is displayed dependent on the selected operation mode. Refer to section 3.2 to change between operation modes.

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.

Status icons: Status icons are arranged on the left side of the work screen. They provide information about GPS, N-Sensor connection, irradiance conditions, crop density and prescription maps. Generally, if no icon is displayed the system is running properly. For a more detailed description, see section 2.3.1.

Start/Stop button: By pressing the *Start* button on the main menu bar you can toggle between active and non-active mode. Only in active mode rates are transmitted to the fertilizer distributor and logged to the N-Sensor log-file. If a padlock is displayed, the system requires a proper software license code for unlocking. Contact your local service partner in this case. See section 2.3.2 for further information.

Task information: The task information line displays the current task number together with the name of the field associated to this task.

2.3.1 Status icons



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.

If the *Reconnect manually* option (see section 3.3) is checked, the connection needs to be re-established manually by touching the GPS icon. Otherwise the GPS will be reconnected automatically as soon as it is available.



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.



Tramline overlapping: The vehicle has returned to a location that has already been recorded to the current task application. This information may be useful to avoid double fertilizer application.



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 “No connection to N-Sensor” will be issued (see section 2.4) 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. If this icon appears for more than two seconds, contact your local service personnel. It is normal if it shows up for one second from time to time during operation.



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. However, no usable sensor readings are available. In addition, application rates from prescription maps (raster maps) are ignored. This mode is mainly intended for demonstration and testing purposes. *No real application must be done with this icon on the work screen!*

To disable the simulation mode and return to normal N-Sensor operation, contact your local service personnel.



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.

In any case the system will switch to the uniform rate predefined in the *Agronomic calibration* menu.



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

The system will switch to the uniform rate predefined 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 re-

duced and recommended rates may drift over time. It is strongly recommended to finish N-Sensor work as soon as possible.



Low crop density: The current N-Sensor reading is below the preset biomass cutoff value (see section 5.1). 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.



Uniform rate: 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 *Sensor* again on the work screen to return to sensor-controlled application.



No connection to spreader controller: The connection to the spreader or sprayer is lost. Either the spreader/sprayer 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 “No connection to spreader controller” (see section 2.4) 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.



Raster map: A raster map (prescription map) is available and the vehicle position is within the map borders. The selected application mode determines whether and how the rates are interpreted: not at all, as offset map, as overlay map or as application map (see section 3.2 for further details).

The symbol shows an excerpt of the map with the current GPS position marked with a red crosshair. As the vehicle is moving, the map moves beyond the crosshair and the rate changes accordingly.

Unless the selected application mode (see section 3.2) does not make use of map data, the map rate is displayed on top of the icon in addition.

This symbol is only displayed if a raster map has been assigned to the current task and the GPS position is within the map.



Sprayer warning: (Potato haulm killing 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.

2.3.2 Start/Stop button



Start: Press the *Start* button to start the variable-rate application. Application rates are continuously transmitted to the controller and data is logged. The green moving indicator (see below) appears.



Stop: Press *Stop* to stop the variable-rate application. The system stops sending rates to the controller and it stops logging data. The red indicator bar appears (see below).



Padlock: The padlock 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, touch the padlock or select *License* in the *N-Sensor* menu (see section 3.2). The 8-digit license code can be obtained from the local service partner.

2.3.3 Start/Stop symbols

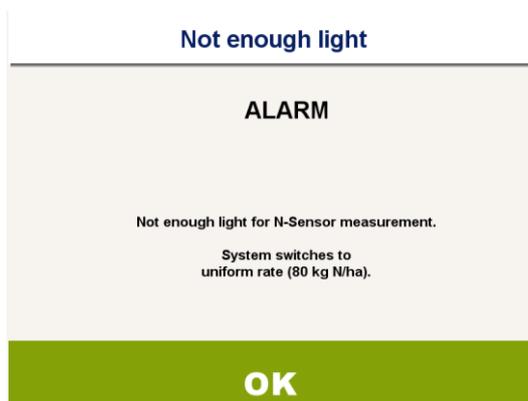


Red indicator bar: The system is currently not activated. In this mode, the N-Sensor does not communicate with the fertilizer distributor nor log any data. Depending on the type of N-Sensor, application rates may still be processed and displayed continuously.



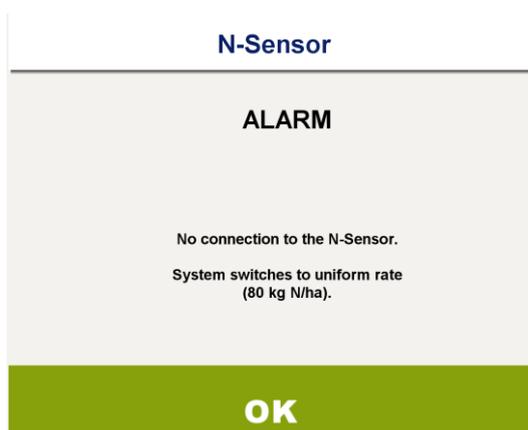
One green moving indicator: The system is currently active. In this mode, the N-Sensor continuously measures and displays the application rate, sends the rate to the fertilizer distributor and logs data to the selected task.

2.4 Alarms and warnings



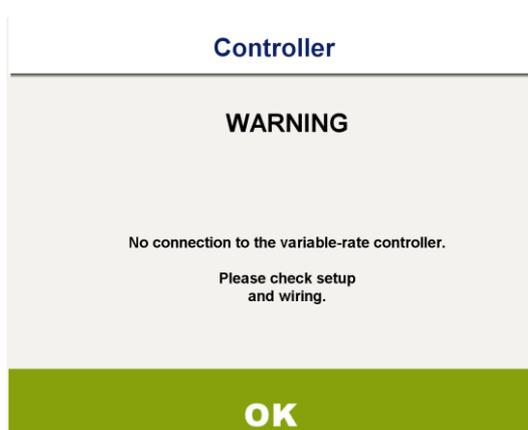
Not enough light: The current irradiance is too low to receive a suitable signal from the N-Sensor optics.

The system switches to the preset uniform application rate. After the alarm is acknowledged, the low light level symbol (see section 2.3.1) is displayed on the work screen until the irradiance conditions have improved. When this happens, the system continues to apply the uniform rate until it is switched back to sensor control manually.



No connection to N-Sensor: The connection to the N-Sensor is lost. Either the N-Sensor is not working properly or the connection itself is faulty. Eventually the N-Sensor is not powered properly.

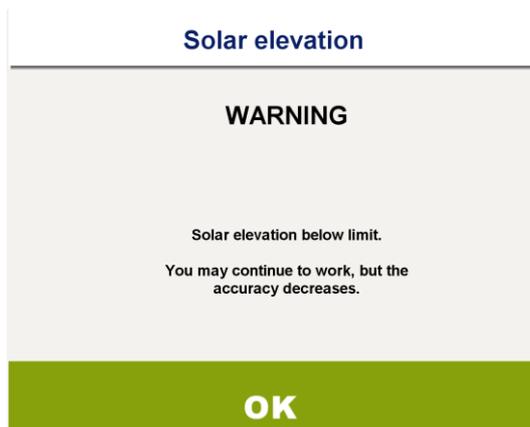
The system switches to the preset uniform application rate. After the alarm is acknowledged, the no-N-Sensor-symbol (see section 2.3.1) is displayed on the work screen until the connection has been re-established.



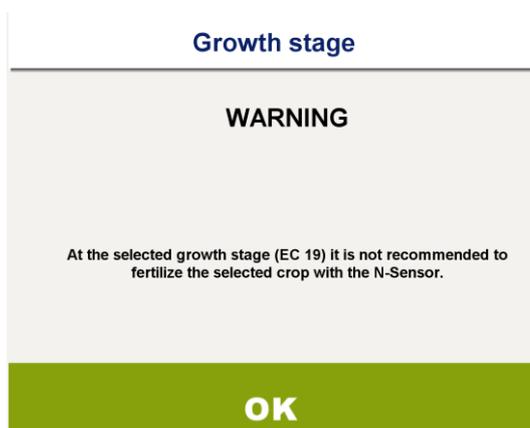
No connection to the variable-rate controller: The connection to the spreader or sprayer is lost. Probably the controller is not working properly or it is set up wrongly.

The system will be automatically deactivated and stop data logging and sending application rates.

To circumvent this warning, the *Unidirectional only* option may be checked in the *Controller* page of the *System* menu (see section 3.3). With this option checked, no warning will be generated at all, but as-applied rates will not be logged.

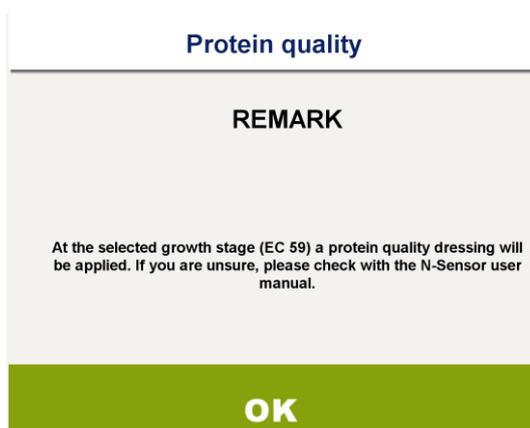


Solar elevation below limit: (passive N-Sensors only) The current solar elevation is below 25° above the horizon. As long as enough light is available, the system continues to work, but accuracy may be reduced and recommended rates may drift over time. It is strongly recommended to finish N-Sensor work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



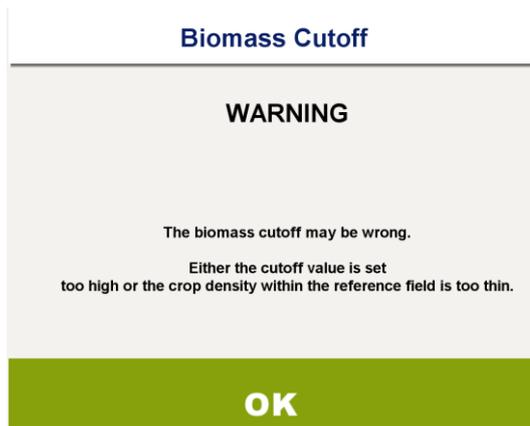
Wrong growth stage: An agronomic calibration function is not available for the selected combination of *Crop type* and *Growth stage*. This warning is displayed immediately after crop type and growth stage have been entered in the agronomic calibration menu.

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



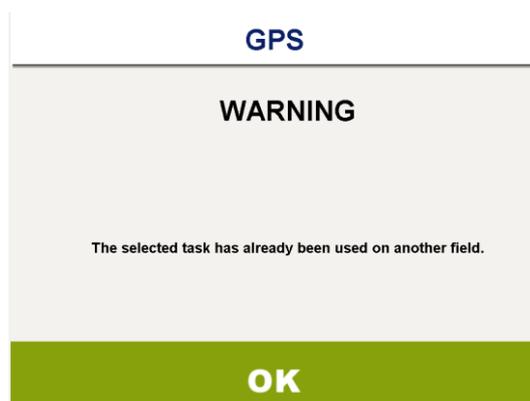
Protein quality dressing: In cereals, at growth stages between EC 59 and EC 69 a protein quality dressing will be applied. In general, the agronomic calibration function is opposite to the “normal” calibration functions at earlier growth stages. Application rates will increase with increasing N-Sensor 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.



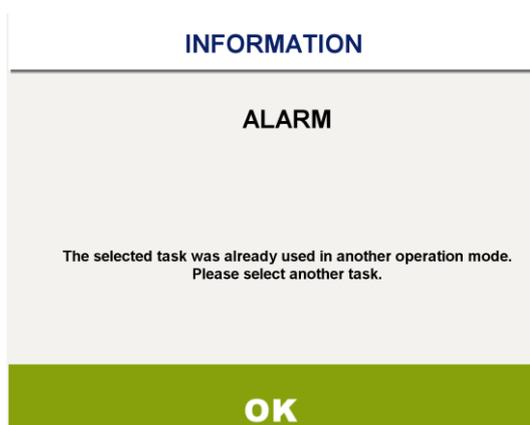
Biomass cutoff: (N-application only) The average sensor value on the reference area is close to or lower than the *Biomass cutoff* entered in the *Agronomic calibration* menu.

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



Wrong field: The current position of the vehicle is far away from the last position recorded in the selected task. Data from different fields should not be recorded in a single task.

Select a new task in order to start a new field.

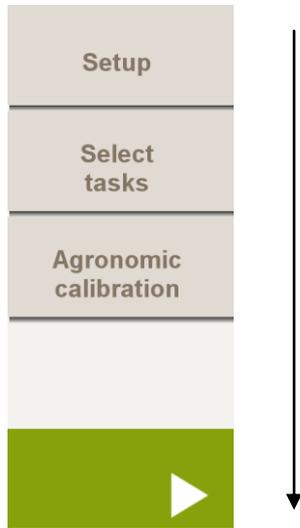


Wrong operation mode: The selected task already contains data which has been acquired using a different operation mode (see section 5). It is not possible to store data from different operation modes into a single task.

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

2.5 Main menu

Generally, to work with the N-Sensor, you only need to go through the main menu bar from top to bottom:

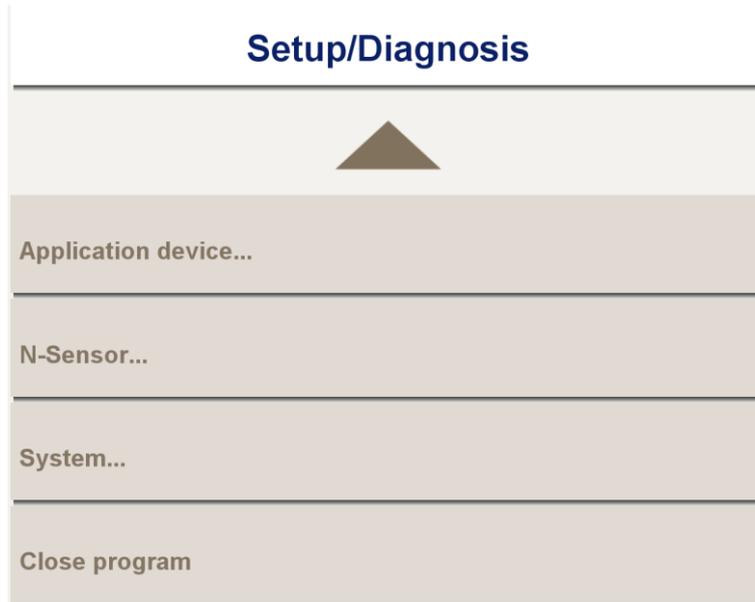


The *Setup* menu makes some general settings to the spreader or sprayer, the N-Sensor, the GPS receiver and the program itself (see section 3). Normally, you will rarely enter this menu after you have made your initial settings. In contrast, the *Select tasks* menu (see section 4) and the *Agronomic calibration* menu (see section 5) have to be entered once every time a new field is started. Finally, the *Start/Stop* button will be used several times within the field to activate and deactivate the N-Sensor.

The following sections will guide through the menus and the relevant settings. If the initial setting have already been made, you can skip the following section and continue with the *Task* menu in section 4.

3 Setting up the System

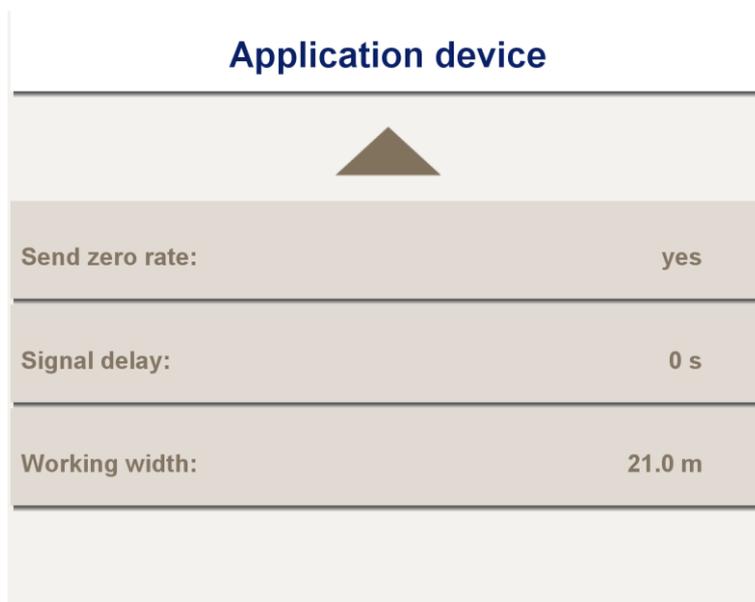
Prior to first use, the *Setup/Diagnosis* menu has to be entered for initial settings. To do so, press the *Setup* button in the main menu bar. The following menu appears:



The *Back* button will get you back to the main menu bar on the work screen. Pressing *Close program* will quit the N-Sensor program.

3.1 Application device submenu

Press the *Application device...* button in the *Setup/Diagnosis* menu to enter this submenu. It provides settings associated to the spreader or sprayer.



Send zero rate: Determines whether you want to send a zero rate command to the controller when you press the *Stop* key on the work screen. It is recommended to select “yes” unless your controller cannot handle zero rates properly. Some controllers, especially those connected to sprayers, might display an alarm message when they receive a zero rate.

Signal delay: The application rate calculated by the N-Sensor usually has to be delayed several seconds before it is sent to the controller in order to match the scanned and the treated area. As a rule of thumb, the signal delay can be calculated as follows:

$$\text{Signal delay} = d / v - t_s - 1 \text{ [s]}$$

d: distance sensor - centre of spreading pattern [m]

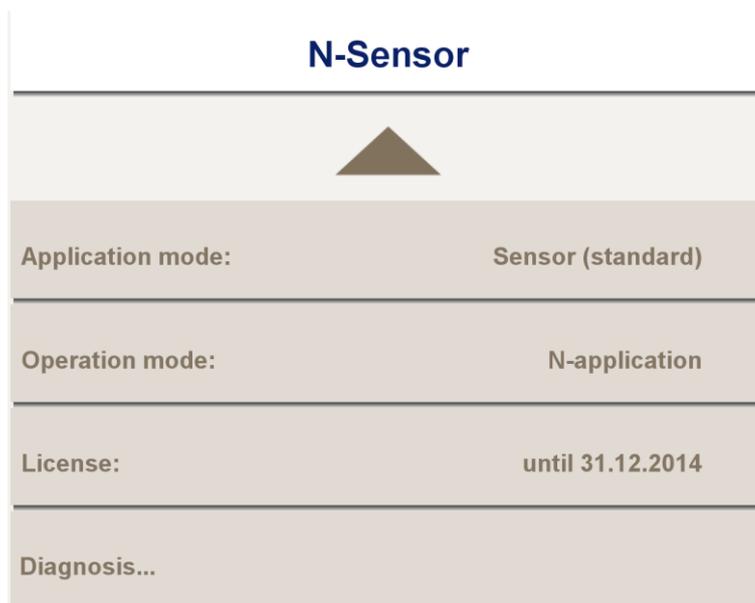
v: tractor speed [m/s]

t_s: response time [s] (usually 1...2 s for granular spreaders)

Working width: The distance between two tramlines. This information is not required for the N-Sensor operation itself, but will be used by the mapping software for processing the application map afterwards.

3.2 N-Sensor submenu

Press the *N-Sensor...* button to open the *N-Sensor* submenu. This menu provides settings and diagnosis for the N-Sensor itself.



Application mode: The *Application mode* setting determines how the N-Sensor handles prescription maps. Note that only the default *Sensor (standard)* setting works without prescription maps. For the other settings it is required to properly prepare the prescription map and to link it to the current task. Refer to section 6 for further reading.

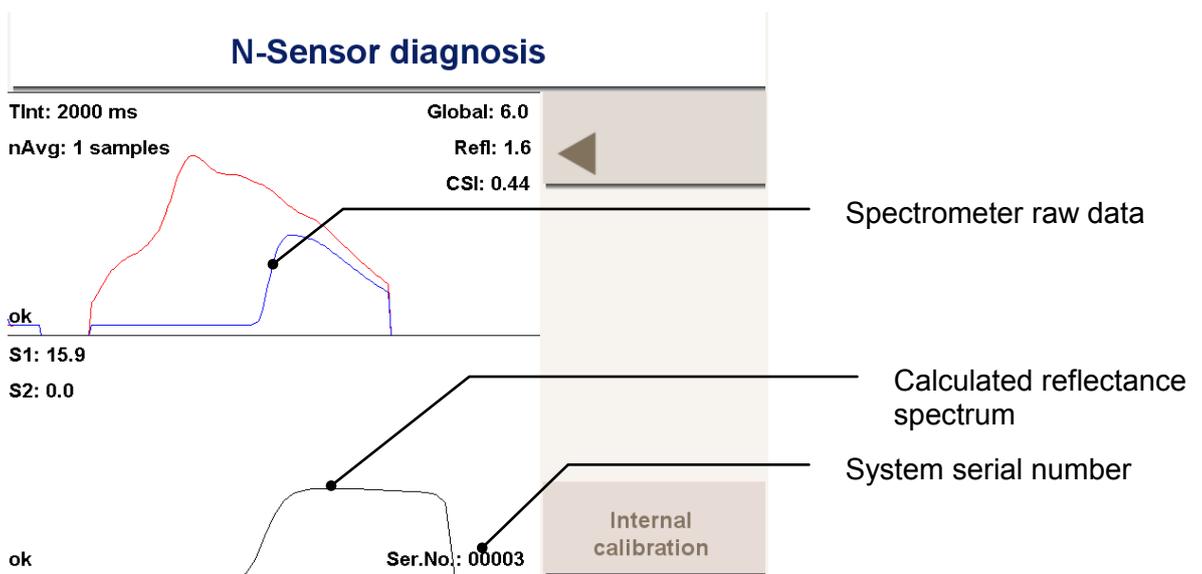
Operation mode: The operation mode setting determines how the N-Sensor works in general. Depending on the local configuration, various options may be available. Depending on the operation mode, the work screen and the agronomic calibration menu (section 5) will be different. For default operation, *N-application* must be selected.

License: To unlock the N-Sensor software, an 8-digit license code needs to be entered at this position. Usually, your local service personnel will provide and enter this code. If the software has not been unlocked, a padlock symbol appears on the work screen and it is impossible to activate the system.

Diagnosis: Display N-Sensor status information (see section 3.2.1).

3.2.1 N-Sensor Diagnosis submenu

The *N-Sensor Diagnosis* submenu displays current N-Sensor raw data readings together with status information and sensor values. Furthermore, some internal calibrations can be carried out. The layout and the displayed information depend on the type of N-Sensor connected. Below the diagnosis screen for passive N-Sensors is shown.



Internal calibration: Access to internal calibration procedures for service personnel only. This section is password-protected to prevent unwanted modification of calibration parameters.

3.3 System menu

Press the *System...* button in the *Setup/Diagnosis* menu to enter this submenu. It provides general settings for GPS, application device and the system in general. The *System* menu consists of 4 pages: *General settings*, *GPS*, *Controller* and *Sensor*. Select the desired page by clicking on the tab at the bottom of the page.

Once all settings have been entered properly, press the *Back* button to return to the *Setup/Diagnosis* menu.

3.3.1 General settings

System

Position longitude: 8.0

Position latitude: 52.0

Date (UTC): 30.11.2011

Time (UTC): 3:31:24

Time difference to UTC: 2

Solar elevation: -33.0

Task specific presets

Show tramline overlapping

Directory F:\

General GPS Controller Sensor

i

Position longitude and **Position latitude**: The approximate geographic longitude and latitude of the system. These numbers are required for calculation of the current solar elevation. Normally, values are automatically taken from the GPS receiver. They only need to be entered if no GPS receiver is connected.

Date (UTC) and **Time (UTC)**: The current time at 0° latitude (Greenwich time). Values are calculated from local time minus *Time difference to UTC* (see below). To adjust your local time, use the standard time setting procedure on your computer. *Make sure that both your local time and the Time difference to UTC are set correctly as this is a prerequisite for a good and stable N-Sensor reading!*

Time difference to UTC: Specify the difference (in hours) between your local time and Greenwich time. Positive values are time zones east of Greenwich; negative values are west. *Note that you need to change this when you change your clock to daylight saving time!*

Solar elevation: The solar elevation in degrees above the horizon calculated from date, time and position.

Task specific presets: If enabled, the operation mode and the agronomic calibration parameters can be pre-programmed for individual tasks. See section 8 for further information.

Show tramline overlapping: If enabled, the *Tramline overlapping* symbol (see section 2.3.1) appears on the work screen whenever the vehicle returns to a position that has been logged before. This feature can be useful to prevent double application in the field.

Directory: Specifies the drive letter and/or the path to the directory where the N-Sensor stores log-files and prescription maps. By clicking the button you can select from the existing drives and paths. It is recommended that a drive or a path is selected that belongs to an (external) flash card. This will allow to easily move files to and from the N-Sensor and will protect the data from unwanted loss if the computer crashes.

3.3.2 GPS data

System

Baudrate: 4800

Latitude: 0.000000

Longitude: 0.000000

Altitude: 0.0 m

Time (UTC):

Status

```
ACC: NOT_FUNCTIONAL
LAT: 0,0000
LON: 0,0000
ALT: 0,0000
SAT: 0
DOP: 0,0000
TIM: null
```

General GPS Controller Sensor

Baud rate: The baud rate of the GPS receiver signal. Often 4800 bit/s and 38400 bit/s are common. Check the manual of the GPS receiver for the right setting.

Latitude, Longitude, Altitude: Displays the current positioning data from the GPS receiver.

Time (UTC): Displays the current time reading from the GPS receiver. Do not mix up with the *Time (UTC)* reading on the *General settings* page. However, as the GPS clock signal is highly accurate, you may use this information for setting the clock on your N-Sensor computer properly.

Status: Displays GPS connection details.

3.3.3 Controller settings

System

Controller type: LH 5000

Show as-applied rate

Unidirectional only

Round to full 1.00 kg/ha

Response time: 1 s

Limit amount

Absolute minimum: 0.00 kg/ha

Absolute maximum: 1000.00 kg/ha

Factor rate: 1.000

General GPS Controller Sensor

Controller type: Select the type of variable-rate controller that the N-Sensor is connected with. Normally this setting must not be changed unless the N-Sensor is attached to another controller.

Show as-applied rate: When enabled, the as-applied rate from the application device will be displayed on the work screen. This may be especially helpful for testing the communication with the controller.

Unidirectional only: Normally, this option should remain unchecked for all variable-rate controllers. This will provide maximum information exchange between the N-Sensor and the controller. However, when enabled the N-Sensor will send rates to the controller regardless whether the controller receives them or not. The *No connection to the variable-rate controller* alarm is suppressed. This can be helpful for testing the connection.

Round to full: All application rates will be rounded to full multiples of this number. Note that this setting applies to the product rate, not the nitrogen rate. Normally the standard setting of 1 must not be changed.

Response time: Enter the typical response time of the variable-rate controller, i. e. the time the controller needs to adjust to a new prescription rate. Typically for granular spreaders the value is between 1 and 2 seconds; for sprayers much higher values might apply. The setting does not affect the result of the N-Sensor application itself; it is only used to correctly process as-applied maps. Do not mix up with *Signal delay* in the *Application device* menu (see section 3.1).

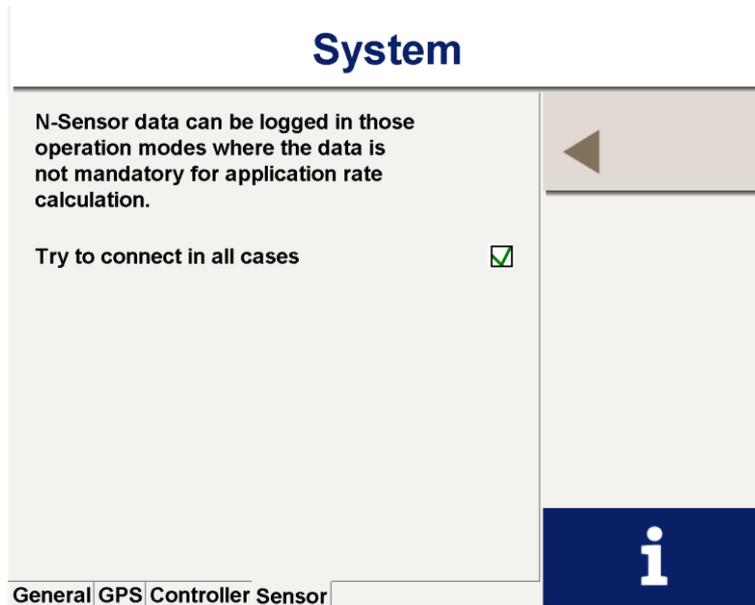
Limit amount: When enabled, all application rates sent to the controller will be limited to the *Absolute minimum* and the *Absolute maximum* rates given below.

Absolute minimum: If the *Limit amount* option is enabled, the rates sent to the controller will never be lower than this number, with the only exception of the zero rate that is optionally sent when the *Stop* button is pressed on the work screen. This setting might be particularly helpful if the spreader or sprayer is limited to a certain minimum rate. Note that the unit of measure is in product rates, not in active ingredient rates.

Absolute maximum: If the *Limit amount* option is enabled, the rates sent to the controller will never be higher than this number. This setting might be particularly helpful if the spreader or sprayer is limited to a certain maximum rate. Note that the unit of measure is in product rates, not in active ingredient rates.

Factor rate: All application rates are generally multiplied by this application factor before they are sent to the variable-rate controller. Normally this number should always be set to 1.00.

3.3.4 Sensor settings



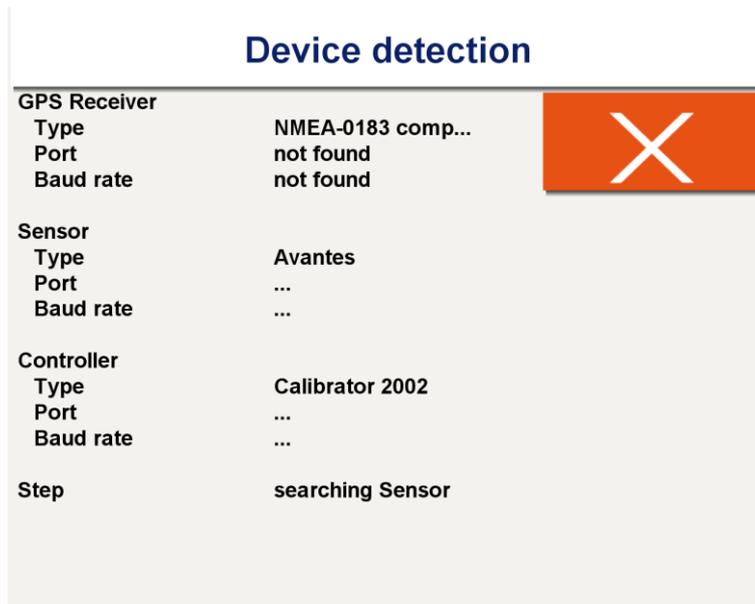
Try to connect in all cases: By default, the software continuously tries to connect to the N-Sensor even in those operating modes (i. e. Base application) where the N-Sensor is not required for application rate calculation. This enables the user to record N-Sensor data while applying a uniform rate or applying from a prescription map. However if no N-Sensor is physically present this option should be disabled

3.3.5 Device detection



To simplify the assignment of serial ports to the individual devices (GPS, N-Sensor and variable-rate controller), the *Device detection* option may be used. When this button is pressed, the system will automatically search the available serial ports for the selected devices. For this purpose, make sure that all devices are switched on and connected properly.

Device detection may take several seconds and the progress can be followed on the device detection screen.



 The detection process can be cancelled at any time pressing the *Cancel* button.

 When the detection has been completed, an *OK* button will be displayed to apply the new settings.

Note that depending on the local configuration the *Device detection* option may not be available on certain systems.

3.3.6 Information screen

 The information screen displays the current software version number together with the type and the serial number of the attached N-Sensor.

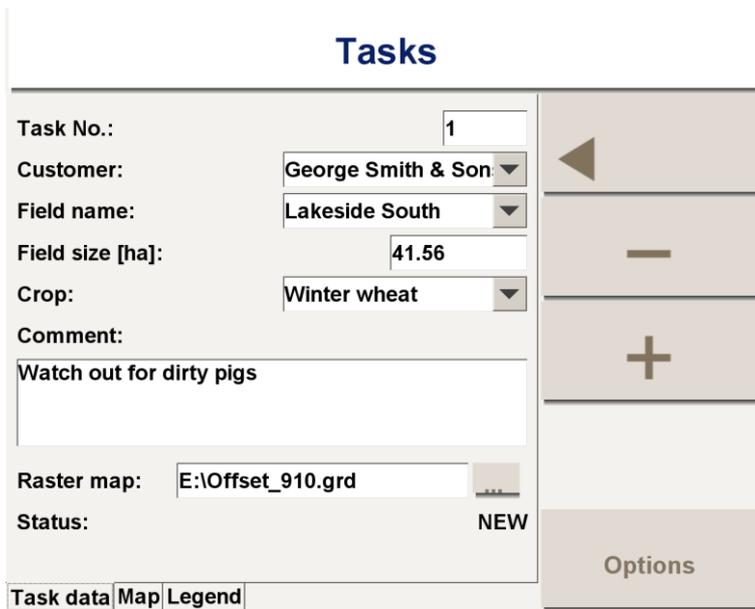
4 Task management

Generally, the N-Sensor handles up to 99 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 from 1 to 99 and contain general field information (i. e. field name, field size, comment) together with a link to the corresponding N-Sensor log-file where all recorded data is stored. In addition, prescription maps (sometimes referred to as “raster maps”) can be attached to a task optionally.

Tasks can be prepared either on a desktop PC using the separate *CardWriter* software or “on the fly” by filling in the menu entries in the *Task* 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* menu, press the *Select tasks* button in the main menu bar. Usually, this menu is entered once on each individual field before N-application is started.

 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 and other related information.



 **Task No.:** The number (1-99) of the selected task. Tasks can be flipped through using the *Minus* and *Plus* keys or they can be addressed directly by entering the task number into this data field.



Customer: A customer name entered here will be displayed on the map printout later. If *CardWriter* has been used for task preparation, customer names previously entered into the *CardWriter* database can be chosen from the drop-down menu.

Field name: The name of the field will appear on the work screen and in the file name of the corresponding log-file. If no field name is entered, only the task number and the date of operation will be used to name the log-file. If *CardWriter* has been used to prepare the tasks, field names previously entered into the *CardWriter* database can be chosen from the drop-down menu. Note that only those fields are displayed which are assigned to the selected customer.

Field size: The field size is not required for N-Sensor operation itself, but it will be stored with the log-file and can be displayed later when the application map is printed. If *CardWriter* has been used for task preparation, the field size is automatically determined from the *CardWriter* database.

Crop: The crop type entered here is not required for N-Sensor operation itself, but it will be stored with the log-file and can be displayed later when the application map is printed. If *CardWriter* has been used for task preparation, the crop type is automatically determined from the *CardWriter* database.

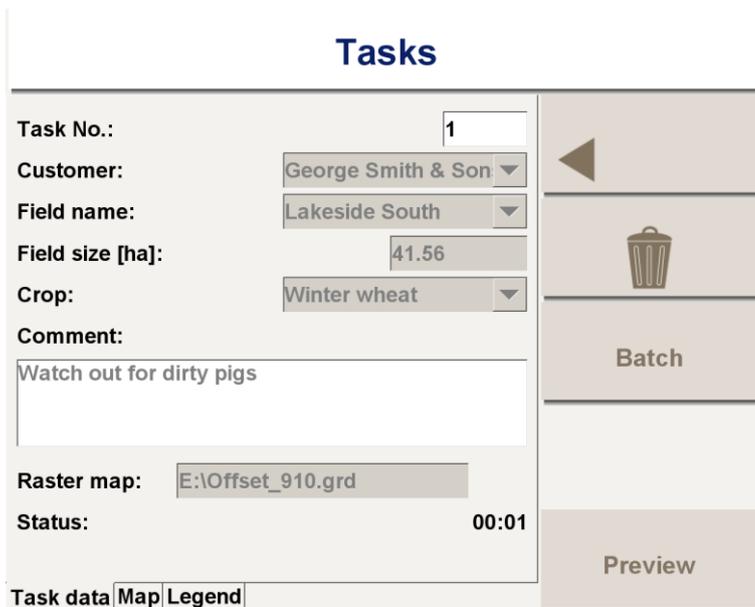
Comment: The comment field can contain any additional information. It can be used to notify to the N-Sensor operator. The comment will also be displayed later when the application map is printed from within *SensorOffice*.

Raster map: A raster map (prescription map) can be attached to the task by entering the full path and the name of the file. It can be displayed by clicking the *Map* tab at the bottom of the page. If no raster map is attached, the *Map* and the *Legend* tab are not available. For further reading refer to section 6.

Status: The status line displays the hours and minutes spent on the task so far. If the task has not been used for data logging yet, the status is displayed as *NEW*. It is only possible to enter the field name, field size and comment as long as the task is new. Once it has been used, the data field are greyed out and cannot be changed anymore.

 **Back:** Return to the work screen and the main menu bar with the last selected task ready for data logging.

Options: Pressing the *Options* button changes the buttons to allow for additional task operations as listed below:



The screenshot shows a 'Tasks' form with the following fields and values:

- Task No.: 1
- Customer: George Smith & Son
- Field name: Lakeside South
- Field size [ha]: 41.56
- Crop: Winter wheat
- Comment: Watch out for dirty pigs
- Raster map: E:\Offset_910.grd
- Status: 00:01

On the right side of the form, there are three buttons: a back button (triangle), a delete button (trash can), and a 'Batch' button. At the bottom, there are tabs for 'Task data', 'Map', and 'Legend', and a 'Preview' button.

 Delete the selected task. All data related to the selected task are deleted, including the log file.

Batch: Switch to the batch processing menu, see section 4.1.

Preview: A map of the recorded data is displayed. This option becomes available as soon as data have been recorded to the selected task. You can choose between previews of the N-Sensor recommendation map, the as-applied map and the bio-mass map. A crosshair marks the current vehicle position on the maps. This can be helpful for field scouting or for finding the point in the field where the application has been paused. Note that creating the preview may take some time depending on processing power, map size and grid size.

4.1 Batch processing

The *Batch processing* menu allows to transmit or to delete multiple files at a single key-press. Provided that the terminal computer has access to the Internet (usually through a GSM, GPRS, UMTS or WLAN connection), data files can be easily transmitted to the central *SensorOffice* server to automatically produce documentation maps out of the recorded data within minutes. The server will then immediately send an e-mail with the raw data and the processed maps to a user-selectable e-mail address.

Since all relevant files are sent through the Internet, there is no need to move a data card or a USB stick from the terminal to an office PC.

The Batch processing menu contains three individual pages: *Tasks*, *Login* and *Options*. For normal operation only the *Tasks* page is required. The settings on the *Login* page and the *Options* page are usually made once only and then left untouched.

4.1.1 Setting up

To initially set up the Internet data transfer, switch to the *Login* page:

The screenshot shows the 'Batch processing' interface. It features a form with the following fields and values:

- Login:** yara
- Password:** abcdef
- E-mail:** mickey.mouse@yara.com
- Files per e-mail:** 8
- Company:** Yara GmbH & Co. KG
- Logo:** C:\Temp\Yara_300.gif

Navigation and action buttons on the right side include a back arrow, a trash can icon, a 'Select all' button, and a 'Send' button with a globe icon. At the bottom left, there are tabs for 'Tasks', 'Login', and 'Options'.

Enter the login and password from the *SensorOffice* registration. Enter the return address for the map products and the maximum number of files per e-mail. Optionally, a company name and a company logo may be added. Both will be displayed on the printout later.

Switch to the *Options* page and enter the batch options:

Batch processing

Map products <input checked="" type="checkbox"/> N-Recommendation <input type="checkbox"/> Google Earth <input type="checkbox"/> As-applied <input checked="" type="checkbox"/> Biomass	  Select all 
Additional information <input type="checkbox"/> Isolines <input checked="" type="checkbox"/> Markers <input type="checkbox"/> Tramlines <input type="checkbox"/> Calibration area <input checked="" type="checkbox"/> Contour lines	
Additional options <input type="checkbox"/> Get field size from file header	
Tasks Login Options	

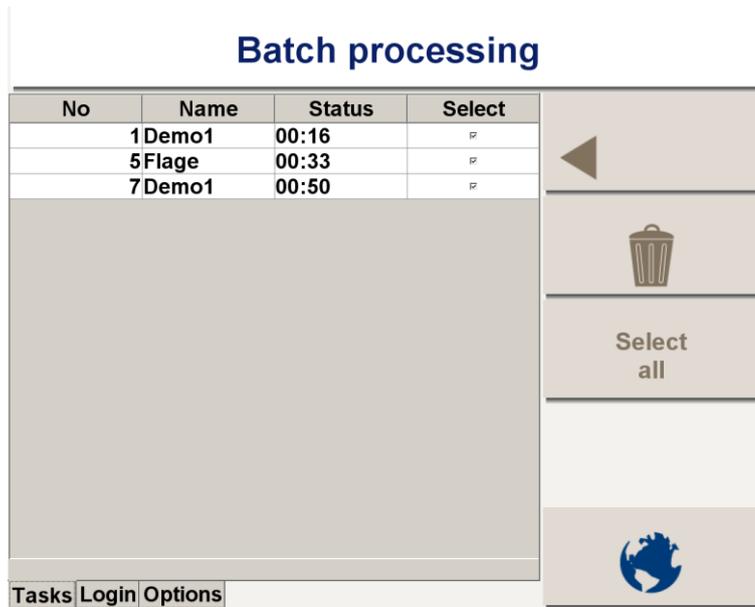
Map products: Checkmark the products that you want to get processed out of the log files. The *N-Recommendation*, *As-applied* and *Biomass* options will create printable document files (*.pdf) which contain the respective maps. If the *Google Earth* option is checked, a file that can be viewed in Google Earth will be created. This file contains all three map products in one.

Additional information: Check the desired options for the layout of the printouts.

Additional options: Check this option if you want the field size to be taken from the file header instead of being processed from the GPS data.

4.1.2 Using batch processing

The *Tasks* page displays a list of all tasks which have been used and where data files are available. For each task the task number, the field name and the task status (i. e. the recording time) are displayed:



Individual tasks can be selected and deselected by touching the check box in the *Select* column. By default, all tasks are selected. Use the *Select all* button to select or deselect all tasks at once.

-  Delete all selected tasks. Note that once the command is confirmed, all task data will be lost and there is no way to retrieve the data files later!
-  Touch the *Send* button to send the selected task data to the *SensorOffice* batch processing server. Depending on the amount of files, the file size and the internet connection data transfer can take several minutes. A progress bar is displayed to show the transfer status.

5 Operation Modes

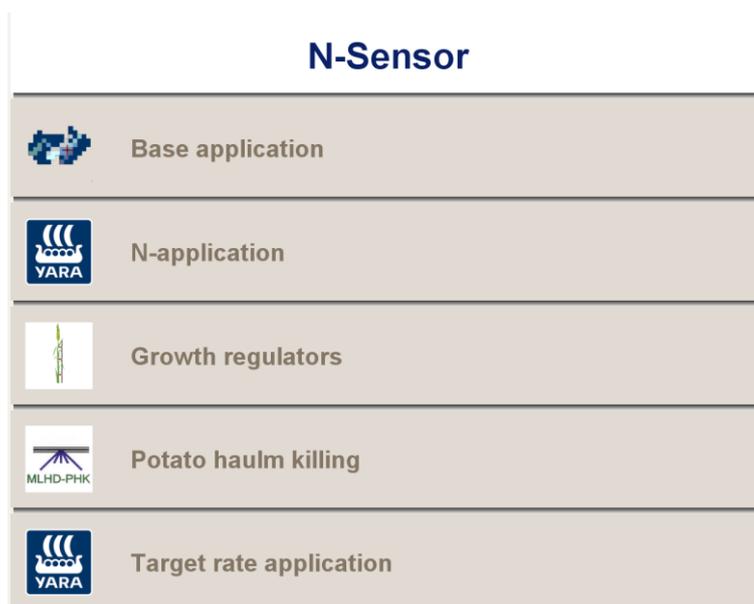
The N-Sensor can be operated in different so-called *operation modes*. These modes determine how the work screen and the agronomic calibration menu look like and what parameters are to be entered and displayed.

Currently the following operation modes are implemented:

- Base application (section 5.1)
- N-application (section 5.2)
- Target rate application (section 5.3)
- Potato haulm killing (section 5.4)
- Absolute N-application
- Free calibration
- Herbicide zone application
- Spraying
- Growth regulator application
- Malting barley N-application

Dependent on the local settings, only a subset of the above operation modes is visible and operational on a specific N-Sensor. At minimum, the *Base application* mode (section 5.1) is available to all systems.

To select an operation mode, from the main menu enter *Setup | N-Sensor* and then press the *Operation mode* button subsequently until the desired operation mode appears (see section 3.2). Alternatively, dependent on the local settings, it is also possible to select the operation mode immediately after start-up by pressing the respective button on the start-up screen:



If the *Task specific presets* option has been enabled (see section 3.3.1) and if the operation mode has been set for the selected task through *CardWriter*, any manual setting (through the start-up screen or through the *Operation mode* button) will be ignored.

Further note that a valid license must be present for the selected mode. Refer to section 3.2 for entering license codes.

5.1 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.

5.1.1 Agronomic calibration

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

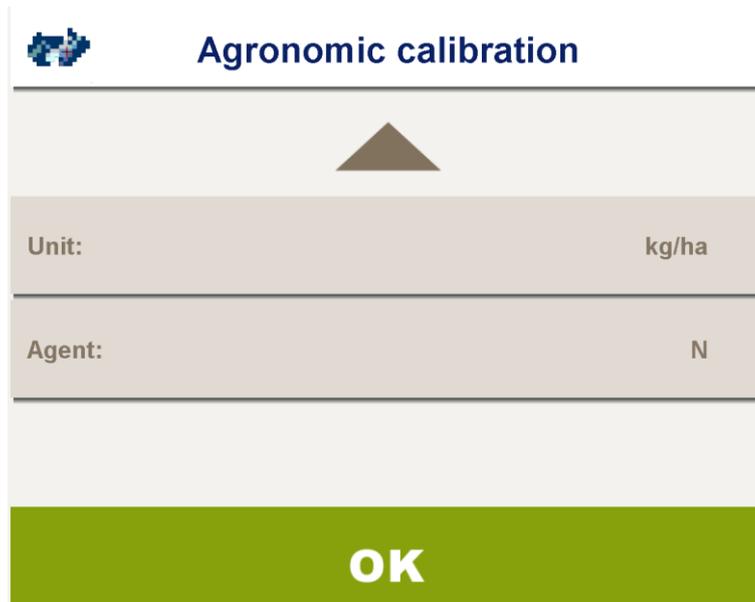
The screenshot shows a mobile application interface for 'Agronomic calibration'. At the top left is a small icon of a globe with a plus sign. The title 'Agronomic calibration' is centered at the top. Below the title is a large upward-pointing triangle. The main content area consists of three rows, each with a label on the left and a value on the right, separated by a horizontal line. The first row shows 'Uniform rate:' followed by '60 kg/ha'. The second row shows 'Agent content:' followed by '27.0 %'. The third row shows 'Map factor:' followed by '100.0 %'. At the bottom of the screen is a large downward-pointing triangle.

Parameter	Value
Uniform rate:	60 kg/ha
Agent content:	27.0 %
Map factor:	100.0 %

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. 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.



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.

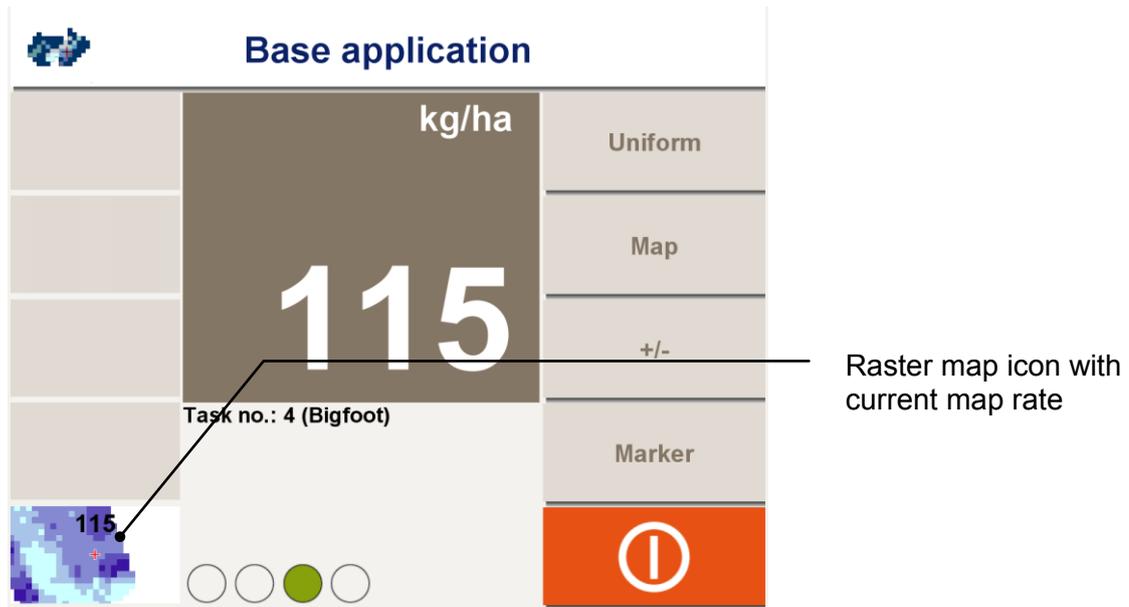
Agent: The type of active ingredient to be dispensed. This setting is stored with the log file for documentation purposes, but does not affect the behaviour of the system at all.

 Press the *OK* button to close the *Agronomic calibration* menu and to return to the work screen.

5.1.2 Base application 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 a moving green indicator 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.



If the position of the vehicle is inside the area covered by the map, the map icon is displayed together with the current map application rate on the bottom left of the work screen. If the position of the vehicle is outside the map or if the GPS signal is missing, the icon disappears and the predefined uniform rate is applied.

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 application rate is flashing and the “uniform” icon is displayed to remind that the rates are not based on the prescription map.

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

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.

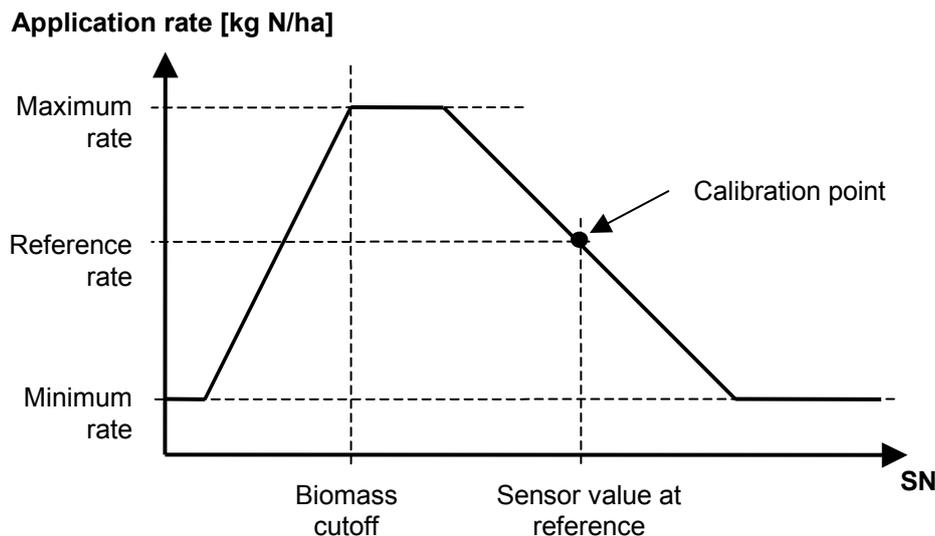
Usually, the system should be activated at the beginning of the field and should continue to operate throughout the whole field. The *Stop* button is only pressed to pause operation within the field, i. e. in order to refill fertilizer. In the headlands, the N-Sensor keeps running. The fertilizer distributor 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 and stop data logging. You may now continue with another task on another field as described in section 4 or remove the data card and process the log-file(s).

5.2 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:



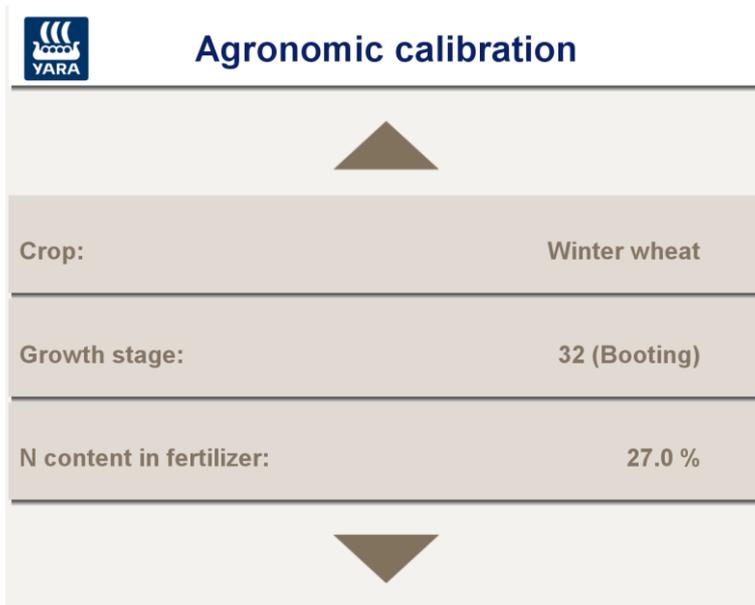
Generally, application rates decrease with increasing sensor values SN, i. e. the better the crop is developed and the more nitrogen has already been taken up by the plants, the lower the application rate will be. However, the rate is clipped to a user-selectable minimum and maximum rate. If the crop 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 that 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 (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.

5.2.1 Agronomic calibration

To enter the agronomic calibration menu, press the *Agronomic Calibration* button on the main menu bar. Usually, this menu is entered at the beginning of the field after a task has been selected (section 4).

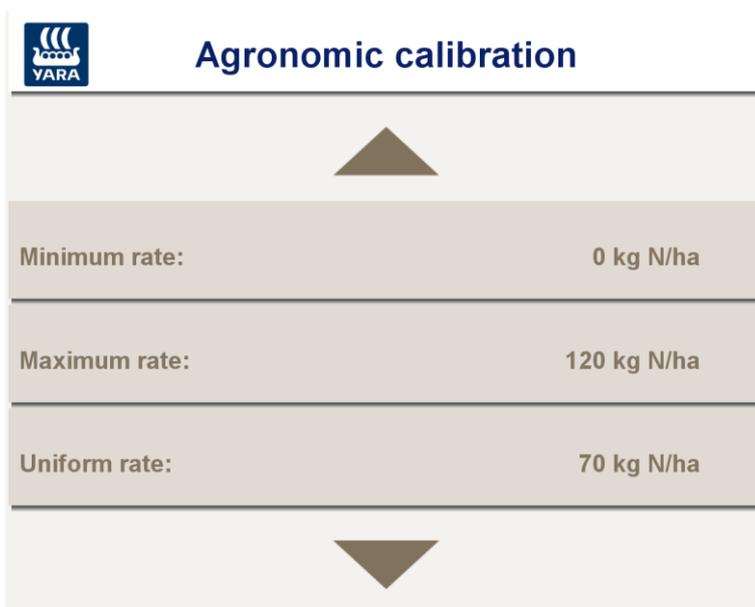
The menu itself consist of three pages that can be navigated using the *Up* and *Down* buttons:



Crop: Select the crop type to be fertilized by successively pressing the *Crop* button until the desired crop type is displayed.

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.

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.



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.

Agronomic calibration	
Reference rate:	45 kg N/ha
Sensor value at reference:	33.9
Biomass cutoff:	25.0
Calibrate at reference plot..	

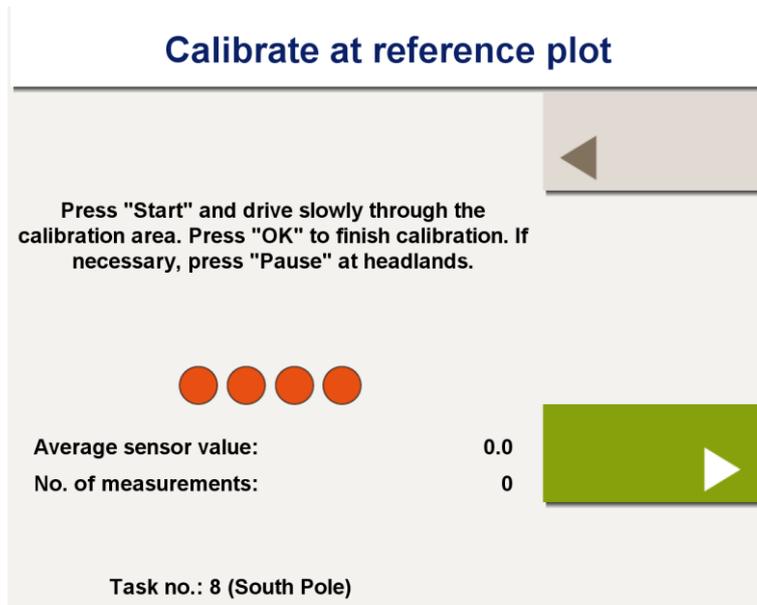
Reference rate: The application rate assigned to the reference area. Normally, it is not required to explicitly enter this value, as it will be automatically set during the *Calibrate at reference plot...* procedure.

Sensor value at reference: 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.

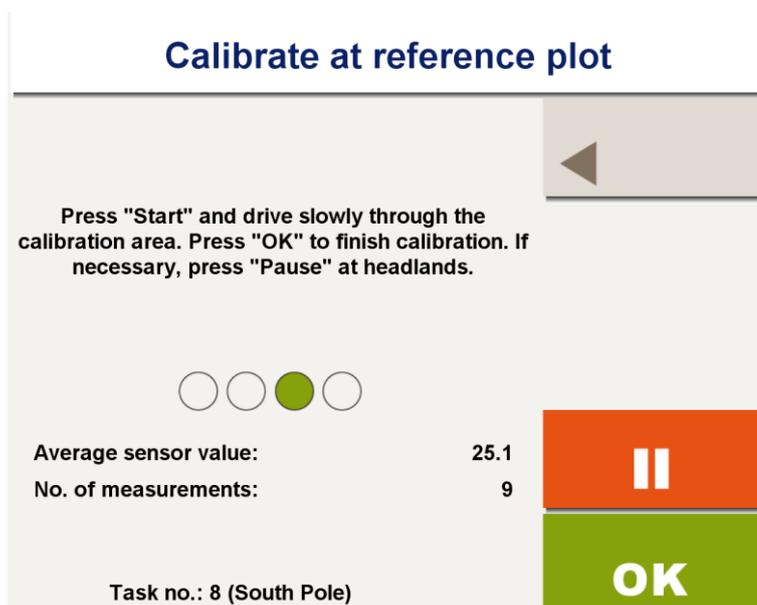
Biomass cutoff: If the sensor value is lower than the biomass cutoff, the crop density is regarded as too low to apply the full nitrogen rate. Instead, the rate will be reduced with decreasing sensor value. On the work screen, the “low crop density” icon is displayed. Depending on crop type and growth 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:



 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.

 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.

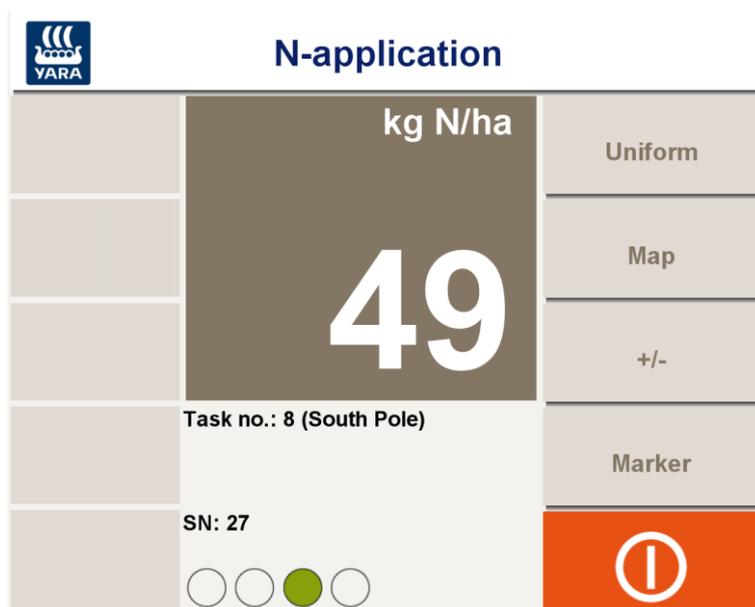


The system now asks for the application rate to be assigned to the reference area. Preferably, use the N-Tester[®] to determine this rate. Alternatively, any other method that provides a good recommendation for the reference area can be used. Note that this rate always refers to the reference area only; *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.

5.2.2 N-Application operation

 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 data logging.



The main menu bar changes and a moving green indicator 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:

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

Map: This button is only available if a prescription map is attached to the task. If pressed, the map is displayed with the current position of the vehicle and the current application rate at that point in the map. The application is continued as before.

+/-: 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 below the indicator bar.

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 activated 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 4 or remove the data card and process the log-file(s).

5.3 Target rate application

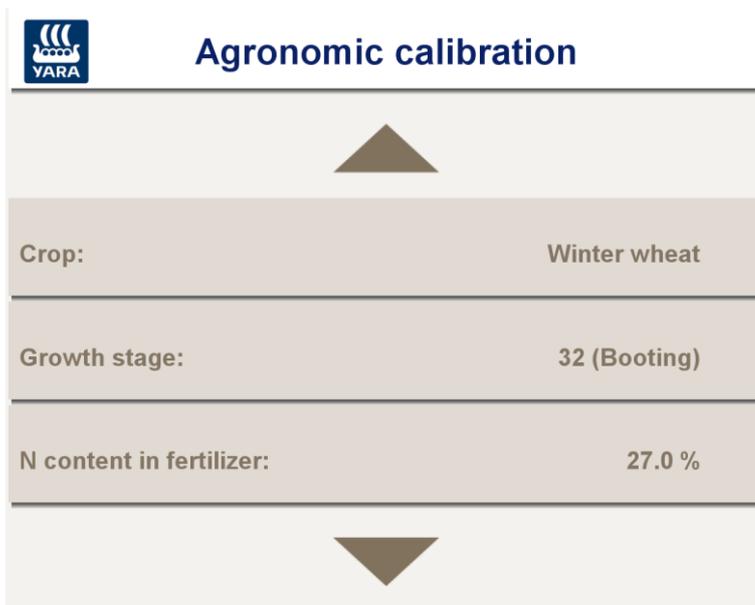
The *Target rate application* operation mode is very similar to the *N-application* operation mode (see section 5.2). The mode has been designed to apply a predefined target rate on the field, i. e. to locally redistribute a predefined rate according to the N-Sensor readings. If used properly, the average 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.

5.3.1 Agronomic calibration

To enter the agronomic calibration menu, press the *Agronomic Calibration* button on the main menu bar. Usually, this menu is entered at the beginning of the field after a task has been selected (section 4).

The menu itself consist of three pages that can be navigated using the *Up* and *Down* button:



The screenshot shows the 'Agronomic calibration' menu with the YARA logo in the top left. The menu is titled 'Agronomic calibration' and features a central upward-pointing triangle. Below the title, there are three rows of data, each with a label on the left and a value on the right:

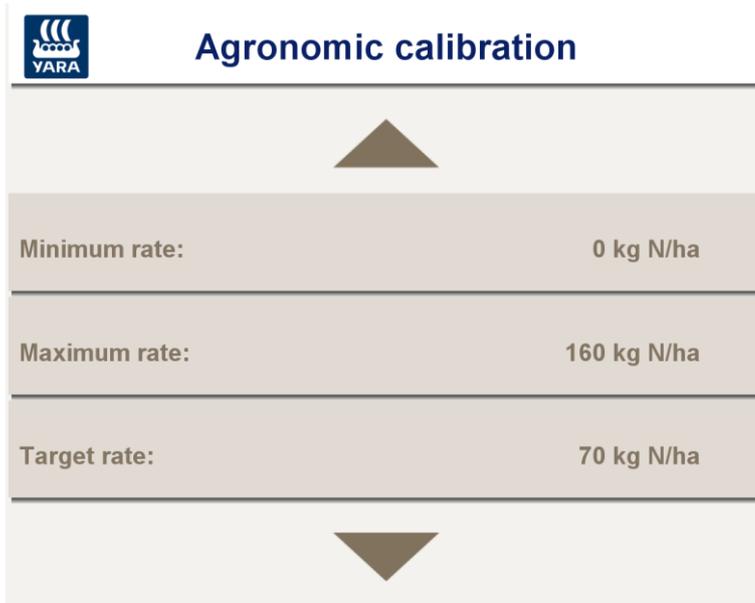
Crop:	Winter wheat
Growth stage:	32 (Booting)
N content in fertilizer:	27.0 %

At the bottom of the menu, there is a downward-pointing triangle.

Crop: Select the crop type to be fertilized by successively pressing the *Crop* button until the desired crop type is displayed.

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.

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.

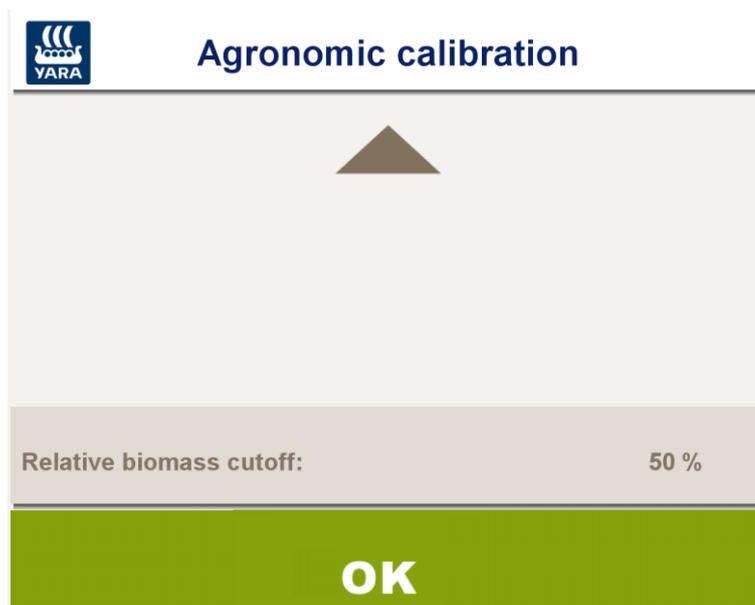


Agronomic calibration	
Minimum rate:	0 kg N/ha
Maximum rate:	160 kg N/ha
Target rate:	70 kg N/ha

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.



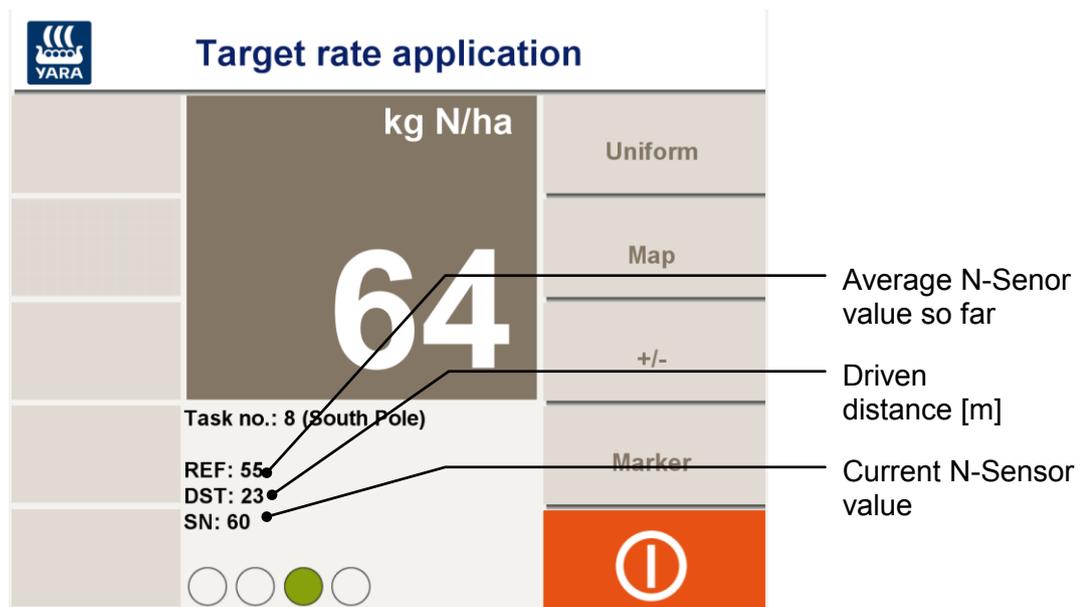
Relative biomass cutoff: If the current sensor value is lower than the given percentage of the average sensor value, the crop density is regarded as too low to apply the full nitrogen rate. Instead, the rate will be reduced with decreasing sensor value. On the work screen, the “low crop density” icon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

OK Press *OK* 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 *Up* buttons are used to return to the main menu, the calibration is not reset and the target rate will not apply.

5.3.2 Target rate operation

▶ 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 (DST) 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.



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:

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

Map: This button is only available if a prescription map is attached to the task. If pressed, the map is displayed with the current position of the vehicle and the current application rate at that point in the map.

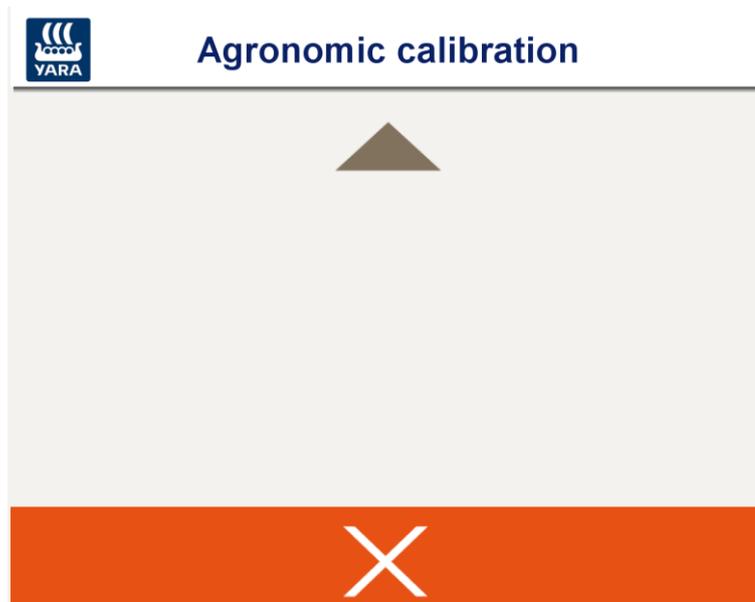
+/-: This button changes the menu to allow for manual application rate changes in steps of +10% and –10%. If rates are manually changed, the change factor is displayed below the indicator bar.

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 activated 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.

 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 *Agronomic Calibration* and *Cancel*. (see below).





After that, the reference N-Sensor value will remain unchanged until the agronomic calibration menu is entered again and until *OK* 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 4 or remove the data stick and process the log-file(s).

5.4 Potato haulm killing

This operation mode provides algorithms for site specific dosing of potato haulm killing herbicides. The *Potato haulm killing* module (*MLHD PHK* module) can be used to apply Reglone® (diquat dibromide 200 G/L), Finale® 14 SL (glufosinate ammonium (150 G/L) and Spotlight Plus (carfentrazone-ethyl 60 G/L) in a site specific manner. The module also contains dosing algorithms for two other products (Purivel® and Spotlight® 24 EC), but their use is phased out in most EU countries today.

In the next two sections, agronomic calibration and operation of the potato haulm killing herbicide is explained. More detailed background information and tips & tricks on MLHD PHK are given in the subsequent sections 5.4.3 and 5.4.4.

5.4.1 Agronomic calibration

To enter the agronomic calibration menu, press the *Agronomic calibration* button on the main menu bar of the Potato haulm killing work screen (see section 2.3 for general explanation of this work screen). Usually, this menu is entered at the beginning of the field after a task has been selected.

The agronomic calibration menu itself consists of three pages that can be navigated using the *Up* and *Down* buttons.

Agronomic calibration	
Agent:	Reglone
Risk level:	normal
No. of applications:	2

Agent: Select the agent type to be applied by successively pressing the *Agent* button until the desired agent is displayed.

Risk level: Select the risk level (Normal or High) by successively pressing the *Risk level* button until the desired risk level is displayed. High risk situations are situations when there are many weeds or there is *Phytophthora infestans* in the crop, or when the crop plants have very long stems and a lot of them are laying compacted on the soil (lodging of the canopy). In these situations, a higher dose can be applied by selecting a high risk level to set a dosing algorithm which doses a little higher than the one to be used for normal risk or standard situations (see also + 10 % button options on next page)

No. of applications: Select the number of applications (1 or 2, only valid if Reglone is selected) by successively pressing the *No. of applications* button until the desired number of applications is displayed.

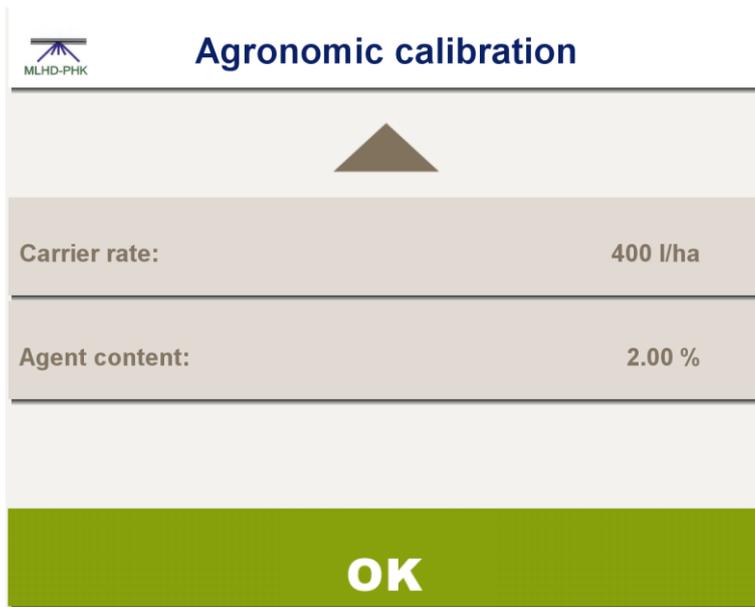
Agronomic calibration	
Minimum rate:	0.36 l/ha
Maximum rate:	2.00 l/ha
Sprayer type:	injection

Minimum rate: The minimum rate that is recommended by the N-sensor MLHD PHK module. Note that the final application rate may be less if the -10% button is pressed on the work screen during operation. The minimum rate can be changed (if desired) by pressing the *Minimum rate* button. The lowest possible rate depends on the selected agent.

Maximum rate: The maximum rate that is recommended by the N-sensor MLHD PHK module. Note that the final application rate may be higher if the $+10\%$ button is pressed on the work screen during operation. The maximum rate can be changed (if desired) by pressing the *Maximum rate* button. The highest possible rate depends on the selected agent.

Sprayer type: Select the sprayer type (conventional or injection) by successively pressing the *Sprayer type* button until the desired Sprayer type is displayed.

Injection Sprayer calibration



Agronomic calibration

Carrier rate: 400 l/ha

Agent content: 2.00 %

OK

Carrier rate: The carrier rate can be changed by pressing the *Carrier rate* button. The carrier rate is the rate of the carrier fluid (normally water).

Agent content: The agent content can be changed by pressing the *Agent content* button. The agent content is the concentration of agent in the injection tank, normally 100%. If very low application rates are to be expected for highly concentrated - low dose agents (e.g. Spotlight Plus), diluting may be required. Agent content should be set accordingly (e.g. a dilution of 25% and *Agent content* set accordingly).

OK

Press *OK* to complete the agronomic calibration and return to the work screen.

Conventional sprayer calibration



Warning level: For conventional sprayers the application rate is varied by changing the liquid pressure. The N-Sensor communicates with the sprayer computer to set the desired application rate and to read the actual (realised) application rate. A warning will be given if the measured application rate differs more than *Warning Level* % from the desired (calculated) application rate. On the work screen, the “rate warning” icon is displayed. To avoid too high or low pressures during operation, consider to increase or decrease driving speed when the actual pressure gets into a sub-optimal range. Sub-optimal ranges are sprayer and nozzle specific.

Agent content: The agent content can be changed by pressing the *Agent content* button. The agent content is the concentration of agent in the sprayer’s tank mix.

 Press *OK* to complete the agronomic calibration and return to the work screen.

5.4.2 Potato haulm killing operation

 With the N-Sensor properly set up and calibrated, potato haulm killing can be started on the field. On the work screen press the *Start* button to begin spraying and data logging.



The main menu bar changes and a moving green indicator appears. Calculated application rates are continuously sent to the sprayer 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:

Uniform: Pressing the *Uniform* button changes the application rate to the maximum rate that was set in the *Agronomic calibration* menu. In this case, the application rate is flashing and 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%. If rates are manually changed, the change factor is displayed below the indicator bar.

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 potato haulm killing.

Usually, the system should be activated 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 the sprayer. In the headlands, the N-Sensor keeps running. The sprayer is operated as without the N-Sensor connected, i. e. it is turned on and off in the headlands as usual.

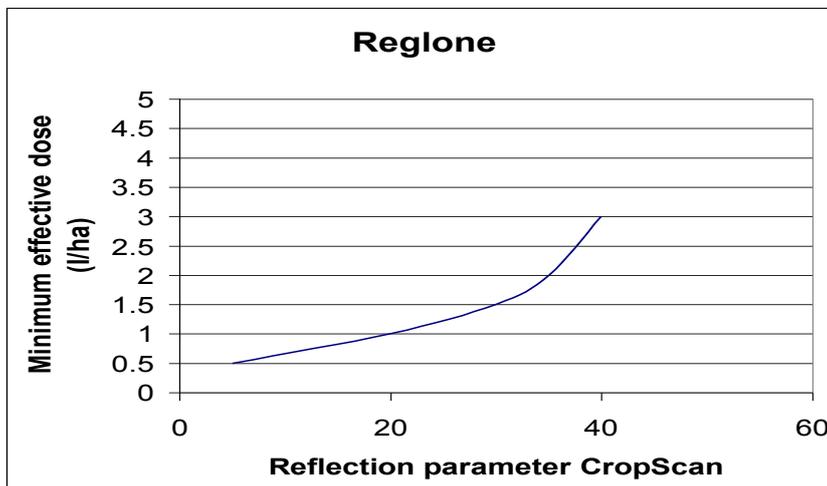
 When the field is completed, press the *Stop* button to deactivate the system. You may now continue with another task on another field as described in section 4 or remove the data card and process the log-file(s).

5.4.3 Background

The dosing algorithms in the *MLHD PHK* module were developed and tested by Plant Research International, part of Wageningen University and Research Centre, in the period between 1999 and 2004 (see 'An innovative dosing system for potato haulm killing herbicides' in XII International conference on weed biology, Dijon, 31-8 - 2-9 2004 : conference, AFPP, p. 511 – 518 by publication of Kempenaar, C., Groeneveld, R.M.W., Uenk, D.,).

The dosing algorithms relate crop reflection data at a scale of 1 – 10 m² to a minimum effective dose of potato haulm killing herbicides (e.g. Reglone®, Finale® 14 SL, Spotlight Plus (carfentrazone-ethyl 60 G/L) or Purivel®) for the respective area. Use of Purivel is phased out in the EU in 2008 in most countries. Potato haulm killing herbicides are sometimes called/classified as leaf desiccants.

The figure below shows a dosing algorithm for Reglone. The higher the crop reflection parameter, the higher the dose. A minimum and maximum dose is defined for each herbicide.



The integration of the MLHD PHK dosing algorithms in the Yara N-sensor was finalised in 2007. The system is tested in practice for both injection and conventional sprayers. In potato crops on arable farms in the Netherlands, MLHD PHK module showed an average reduction of 40 % compared to standard practice while efficacy remained good. Reports are available in Dutch on <http://www.geo-logisch.nl> and <http://www.mlhd.nl>.

5.4.4 Tips & tricks for agronomic calibration and operation

Read the instructions in the N-Sensor manual before MLHD PHK is used. (see section 5.4.1 and 5.4.2). Hereafter some tips & tricks for optimal use are given.

General: Usually, the system should be activated 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 the sprayer. In the headlands, the N-Sensor keeps running. The sprayer is operated as without the N-Sensor connected, i. e. it is turned on and off 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 or remove the data card and process the log-file(s).

Potato Haulm killing strategy: The user has to decide which potato haulm killing agent (herbicide) he wants to apply and the number of applications. In some situations two applications per crop are needed to get a good result. This is generally the case when the potato crop is still very dense and green at the time of potato haulm killing. Combinations of different herbicides are then possible, for instance to start with a spray of Reglone followed by a spray of Spotlight one week later. The user selects in the Agronomic calibration module menu per spray which agent he wants to use. For Reglone there is an option to select 2 applications when the first application is done. In this mode, the maximum dose of Reglone during the first application is 2 L/ha in stead of 3 or 3.75 L/ha when 1 application is selected.

How to deal with unfavourable conditions / Risk management: At the time of potato haulm killing, conditions may prevail that ask for higher doses than the default dosing algorithms. These conditions are for example (site specific) weed development through the potato canopy or foci of *Phytophthora infestans*. Another example is a very dense canopy with long thick stems and some lodging. In these situations, the user can select from the start the *High Risk* level and dosing algorithms, which generally give a 20 - 25 % higher dose than the default algorithms, or use the *+10 %* button locally to increase the dose on sites with unfavourable situations (weeds, diseases, lodging).

Of course, the user can also reduce the dose locally by using the *-10 %* button when conditions are highly favourable.

Agent content in containers for injection sprayers: Normally, the container with the agent can be connected to the injection sprayer without diluting. However, if a dry powder or a highly concentrated – low dose agent is used, the operator has to decide on what the optimal concentration in the container should be. In the case of Spotlight Plus, a dilution of 25 % v/v. Agent content in the Agronomic calibration menu should then be set accordingly.

Determining tank mix concentration for conventional sprayers: Before spraying, the operator has to decide about the maximum dose he wants to apply and what the optimal spray volume and concentration of the agent (herbicide) in the spray tank should be. There are three ways to get an estimate of the **maximum dose**:

1. to scan the crop canopy before spraying and read the maximum dose from the working screen,
2. to use scanning data and calculated dose obtained some days before potato haulm killing (for instance scanning data obtained during the last fungicide application against *Phytophthora infestans*),
3. to apply expert judgement.

Optimal spray volume, use label information and expert judgement.

Calculation of optimal tank mix concentration: Take 80 % of the recommended maximum dose and divide this dose by the optimal spray volume. For example, if the recommended maximum dose is 2 L agent per ha, and the optimal spray volume is 400 L per ha, the tank concentration is 80 % of 2 L/ha (equals 1.6 L per ha) divided by 400 L water per ha. This equals 0.4 % (1.6 divided by 400). Under these conditions, you can spray doses that vary from 1.2 – 2 L agent per ha.

For conventional sprayers the application rate is varied by changing the liquid pressure. The N-Sensor communicates with the sprayer computer to set the desired application rate and to read the actual (realised) application rate. A warning will be given if the measured application rate differs more than *Warning Level %* from the desired (calculated) application rate. On the work screen, the “rate warning” icon is displayed. To avoid too high or too low pressures during operation, consider to increase or decrease driving speed when the actual pressure gets into a sub-optimal range. Sub-optimal ranges are sprayer and nozzle specific. In general, this means when spraying is done on more green parts of the field, the driving speed could be reduced, and the driving speed could be increased on the less green parts of the field.

For further information, first contact your national N-Sensor distributor or contact Plant Research International in Wageningen (<http://www.plant.wur.nl>). Contact person: Corné Kempenaar, tel + 31 317 475701 or corne.kempenaar@wur.nl

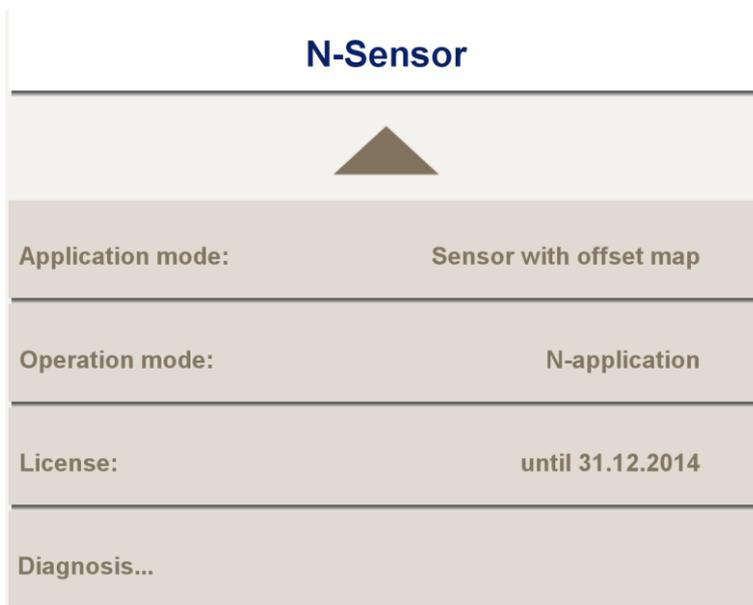
6 Using raster maps (prescription maps)

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) or WTK ADIS format (*.rst). 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.

6.1 Select the application mode

To make use of raster maps, you first need to determine how the N-Sensor should interpret the maps. This can be done through the *Application mode* setting the *Setup/Diagnosis – N-Sensor* menu:



The *Application mode* determines how the N-Sensor handles prescription maps. Depending on the selected operation mode, up to 4 different settings are available:

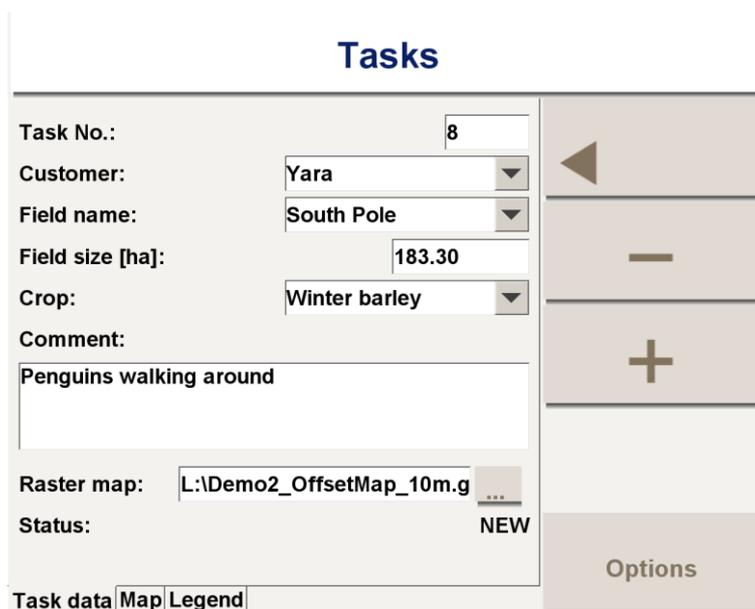
1. *Sensor (standard)*: Prescription maps are not used at all. The application rate is solely based on the N-Sensor reading. This is the default setting for standard N-Sensor operation.
2. *Sensor with offset map*: The final application rate is calculated as the sum of the N-Sensor recommendation and the rate from the offset map. The offset map may contain positive as well as negative rates. If the map is not available or the vehicle is outside the map area, the application rate will be based on the N-Sensor only. In this case, there is no difference to the Sensor (standard) setting.

3. *Sensor with overlay map*: The final application rate is the rate from the prescription map, if the map is available and the vehicle is inside the map area. Otherwise, the N-Sensor recommendation is used. In this case, there is no difference to the Sensor (standard) setting.
4. *Application map*: The final application rate is the rate from the prescription map, if the map is available and the vehicle is inside the map area. Otherwise, the uniform rate (entered in the agronomic calibration menu) will be applied.

One of the last three options has to be selected to make use of raster maps.

6.2 Linking raster maps to tasks

As a next step, the raster maps need to be linked to the task by clicking the  button next to the *Raster map* entry in the *Tasks* menu. Note that the *Raster map* option is only available if the *Application mode* has been properly set (see section 6.1).



Tasks

Task No.: 8

Customer: Yara

Field name: South Pole

Field size [ha]: 183.30

Crop: Winter barley

Comment: Penguins walking around

Raster map: L:\Demo2_OffsetMap_10m.g 

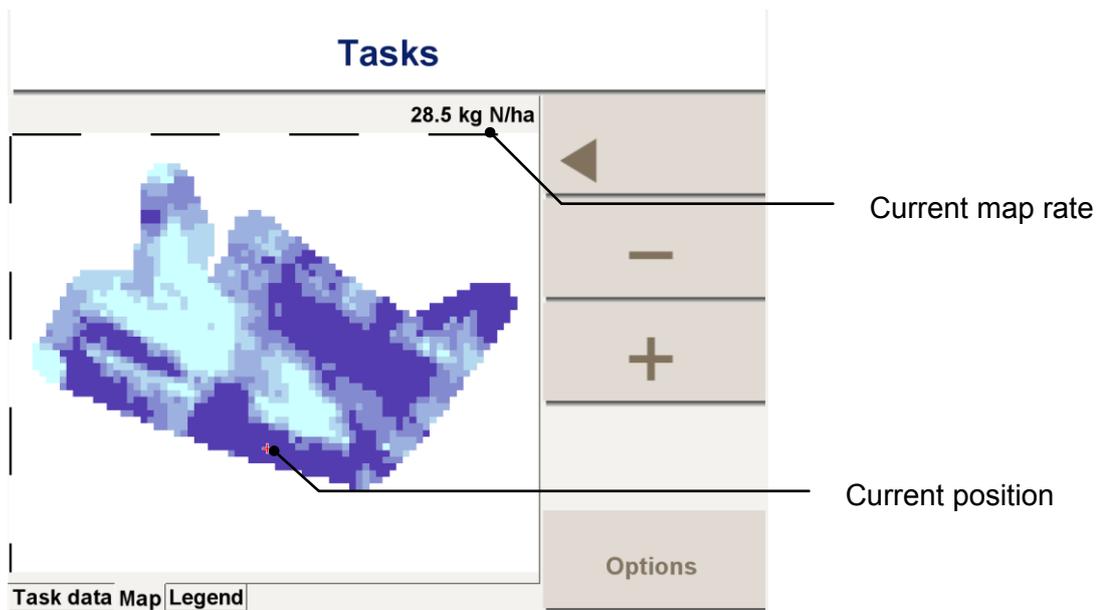
Status: NEW

Task data | Map | Legend

Options

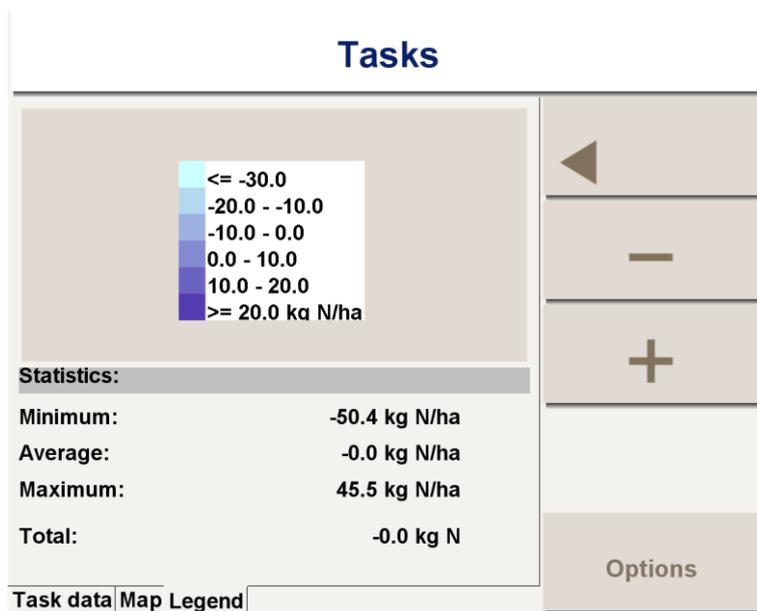
The full path and the name of the file can then be selected. Alternatively, raster maps can be linked to the task when preparing N-Sensor operations through the *CardWriter* software.

The selected map can then be displayed by clicking the *Map* tab at the bottom of the page:



A red crosshair displays the current position of the vehicle. Above the map, the current map application rate is displayed. Note that these rates can be negative if the map is used as an offset to the current N-Sensor recommendation (see section 6.1).

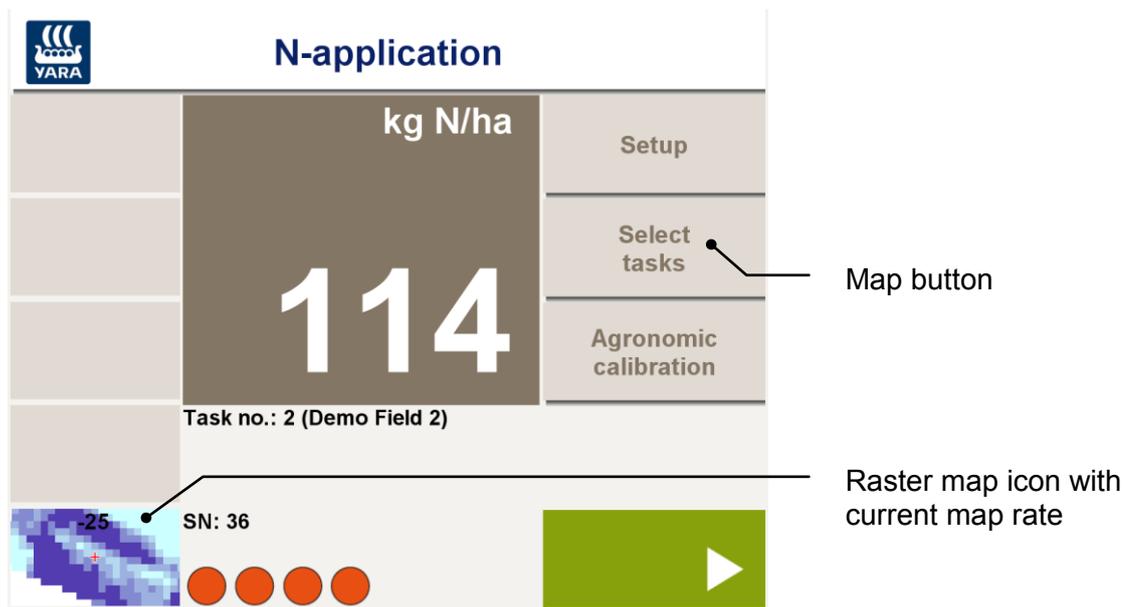
A map legend can be displayed together with some basic statistics by clicking the *Legend* tab:



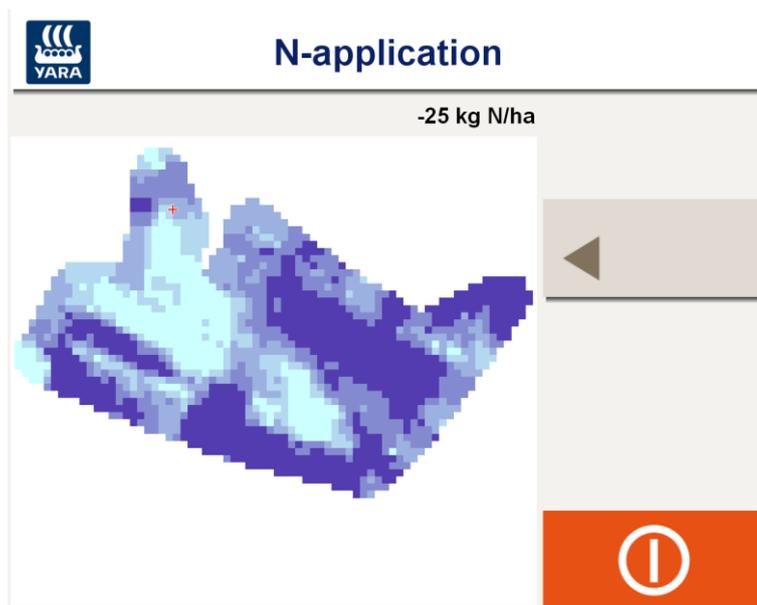
6.3 Apply fertilizer (or other products) from the map

Finally, with the map(s) linked to the tasks and the application 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.

If the position of the vehicle is inside the area covered by the map, the map icon is displayed together with the current map application rate on the bottom left of the work screen:



The raster map icon displays an extract of the map in the vicinity of the current position. Press the *Map* button to display the whole map:



7 Task management on the office PC

Data can be retrieved and processed in different ways and the techniques may be subject to your local set-up. Your service partner will advise the most suitable way of data processing according to your individual requirements.

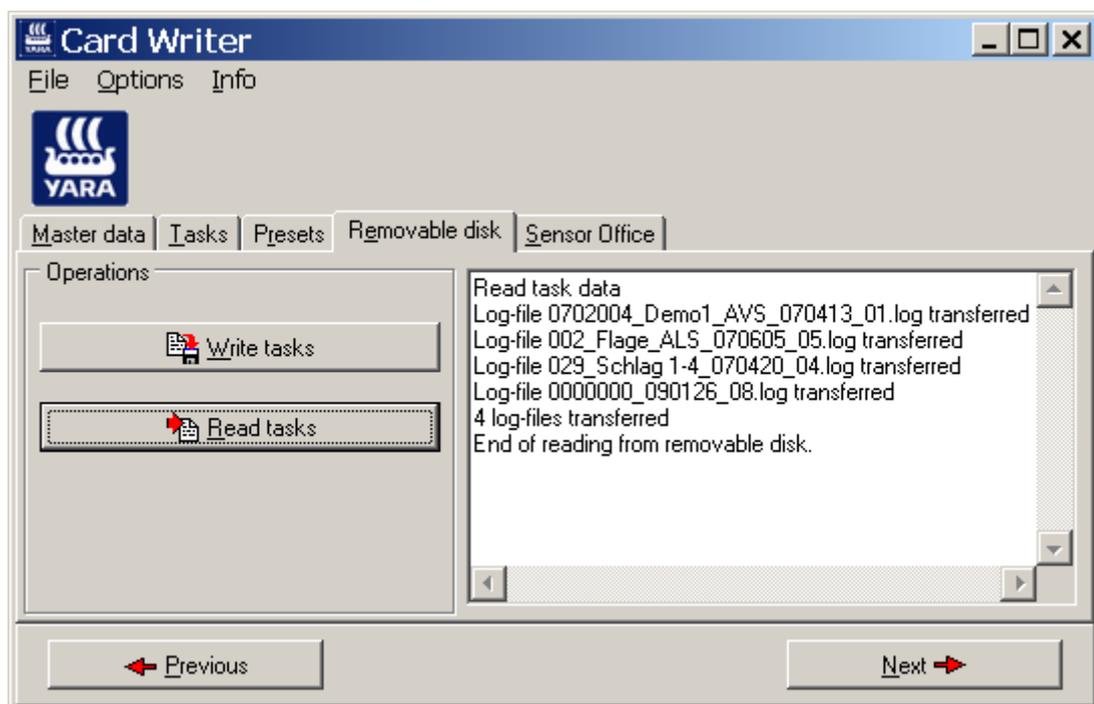
In the simplest case, no additional software is required for data management on the office PC side. Once the tasks have been completed on the N-Sensor terminal, the removable disk (usually a USB stick) just needs to be removed from the terminal and plugged into the office PC. Then the N-Sensor log files (*.log) can be copied to any location for archiving. Files can be uploaded to the *SensorOffice* mapping tool at <http://www.sensoroffice.com> for further processing and mapping.

However, for more sophisticated task management, it is recommended to make use of the *CardWriter* software. This program is available for installation on the office PC free of charge. Download the latest release from <http://www.sensoroffice.com> or contact your local N-Sensor service partner for installation.

7.1 Data retrieval and batch processing

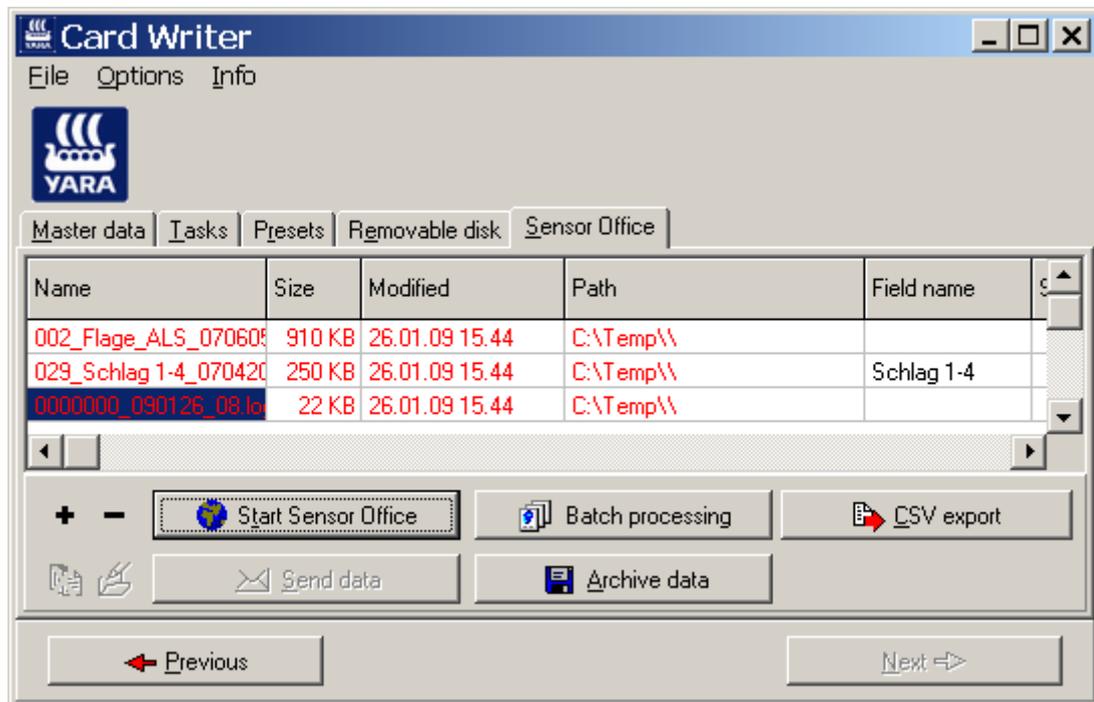
This section describes the standard way of processing using the server-based *SensorOffice* batch processing platform. This service is offered by Yara to allow for a quick and easy-to-use way to generate printable maps out of the N-Sensor data. A free-of-charge registration on the *SensorOffice* homepage (<http://www.sensoroffice.com>) is required to use this service. This will provide the login name and password required for the batch server.

To retrieve the data, attach the removable disk (usually a USB stick) with the N-Sensor log files to your office PC and launch the *CardWriter* program. On the *Removable disk* page press the *Read tasks* button and select a directory to store the log-files.



All previously recorded files are now transferred from the removable disk to the office PC for archiving.

Select the *Sensor Office* page or press the *Next* button. The log-files that have just been read are displayed in the list of files ready for processing. Individual files can be removed from the list or additional, previously recorded files can be added using the **-** and **+** buttons, respectively. Note that removing a file does not delete the file neither from the removable disk nor from the local PC. It just removes it from the list of files to process. The file can be processed later by adding it to the list again at any time.



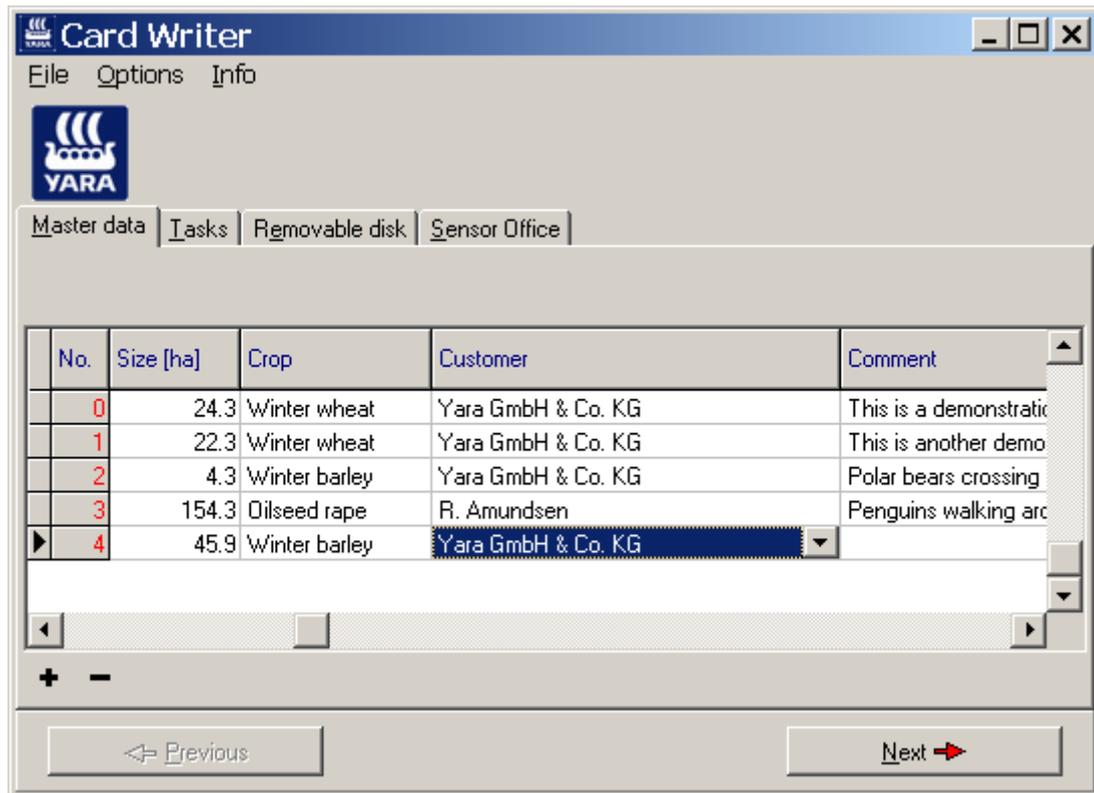
Once the list of files is completed, press the *Batch processing* button, make the desired settings for map products and press the *Send now* button. If the batch processing is used the first time, the *Login name* and the *Password* (both provided automatically after registering on the Sensor Office homepage) have to be entered first. The batch job is now created and sent to the Sensor Office server. A few minutes later the printable maps are returned in Adobe Acrobat format (*.pdf) to the e-mail address specified in the *General settings for Sensor Office* section.

7.2 Task preparation

With the help of *CardWriter*, it is possible to prepare individual tasks already beforehand, i. e. before N-Sensor operation is started on the field. This is specifically useful if the N-Sensor tasks are known in advance and may help the operator to be guided through his individual daily operations.

7.2.1 Master data

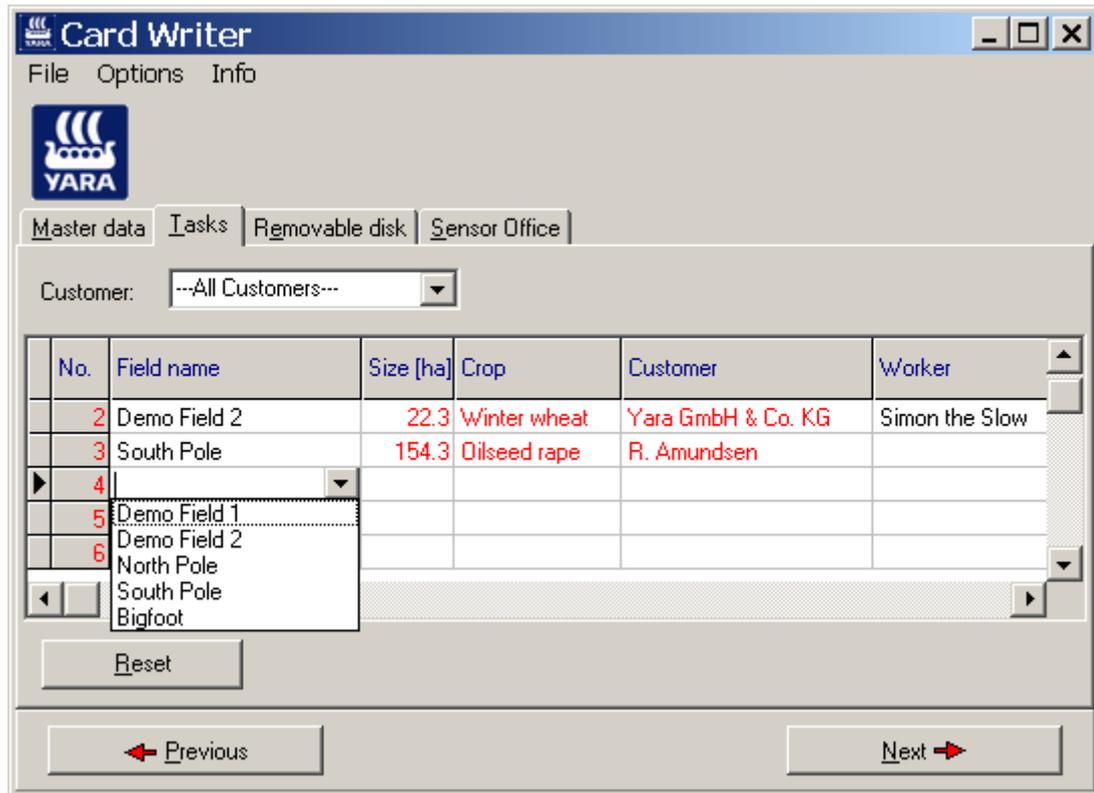
First, an individual list of master data needs to be entered into *CardWriter's* database. For this purpose, select the *Master data* tab first and enter the master data for each field to be treated by the N-Sensor. For each field, at least a *Field name* needs to be entered, further columns are optional but should be filled as far as possible. All information entered here will be displayed for the N-Sensor operator on the terminal later.



New records (i. e. fields) can be created through the **+** button. To erase records, select the record and press **-**. The total number of records that can be entered is unlimited.

7.2.2 Tasks

Once a set of master data has been entered, switch to the *Tasks* tab to prepare the individual tasks. Up to 99 fields can be selected from the master data entered before and assigned to the 99 available tasks. To assign a field to a task, simply select that field out of the drop-down list in the *Field name* column. Use the *Customer* drop down box to filter the list for individual customers.

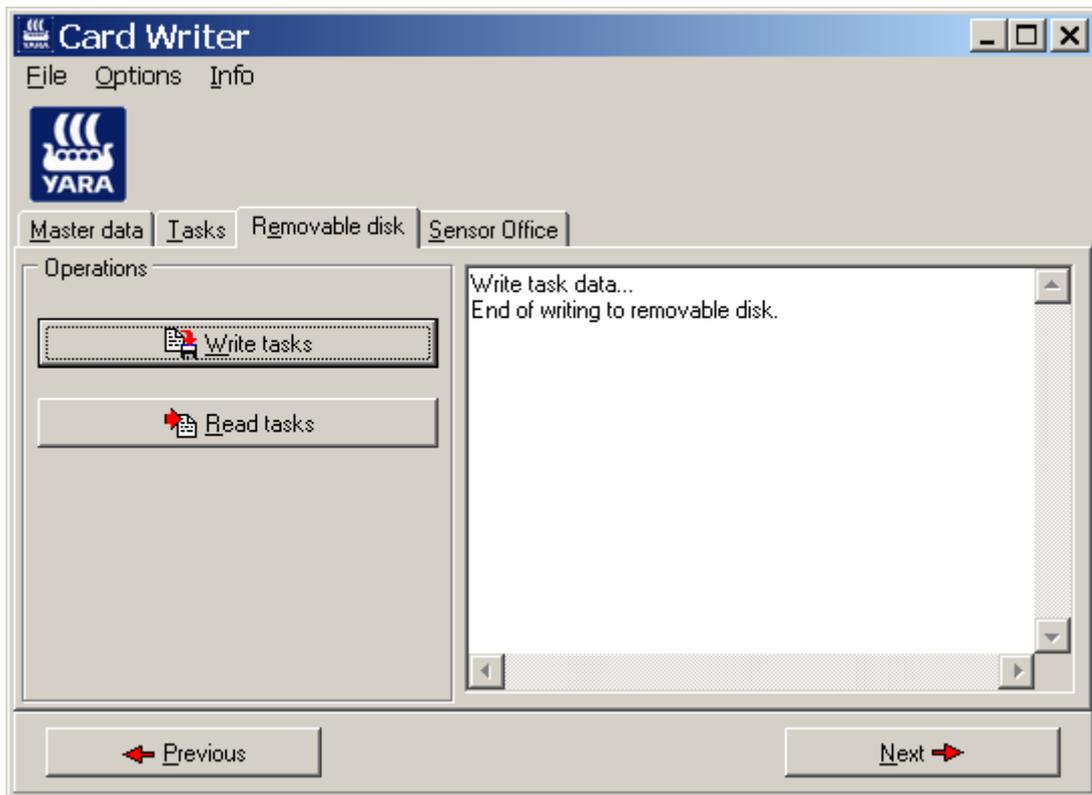


Related *Crop*, *Customer* and *Comment* columns are filled automatically according to the data entered in the *Master data* tab and are read-only on this page. The *Worker* column may be filled separately. Use the *Raster map* column to attach a prescription map to a task. The raster map must be available in Surfer ASCII grid file format (*.grd) or in WTK ADIS format (*.rst) and may be used to override and/or modify N-Sensor readings. For further reading about raster maps refer to section 6.

7.2.3 Removable disk

To finally write the prepared task information to the removable disk, select the *Removable disk* tab and press *Write tasks*. Note that all data on the root directory of the removable disk will be deleted.

The removable disk can now be taken to the N-Sensor terminal. The prepared data will be visible through the *Tasks* menu of the N-Sensor application (see section 4).

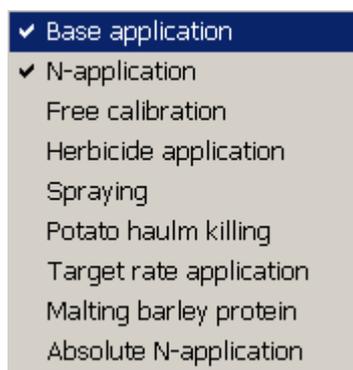


8 Using task specific presets

In conjunction with *CardWriter* version 4.00 (or above) it is possible not only to assign general field information to individual tasks, but also to preset the operation mode (see section 5) and most of the agronomic calibration parameters that are normally entered through the agronomic calibration menu. This is specifically useful if the N-Sensor operation needs to be planned beforehand. With the task specific presets, many agronomic decisions can be moved from the N-Sensor operator to the farm manager.

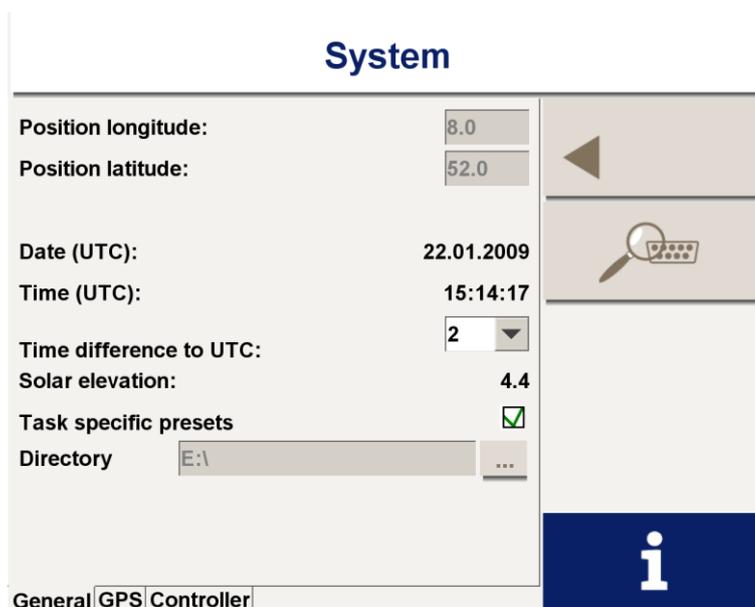
8.1 Enabling the task specific presets feature

To make use this feature, in *CardWriter* select *Options | Operation modes* and check at least one available operation mode:



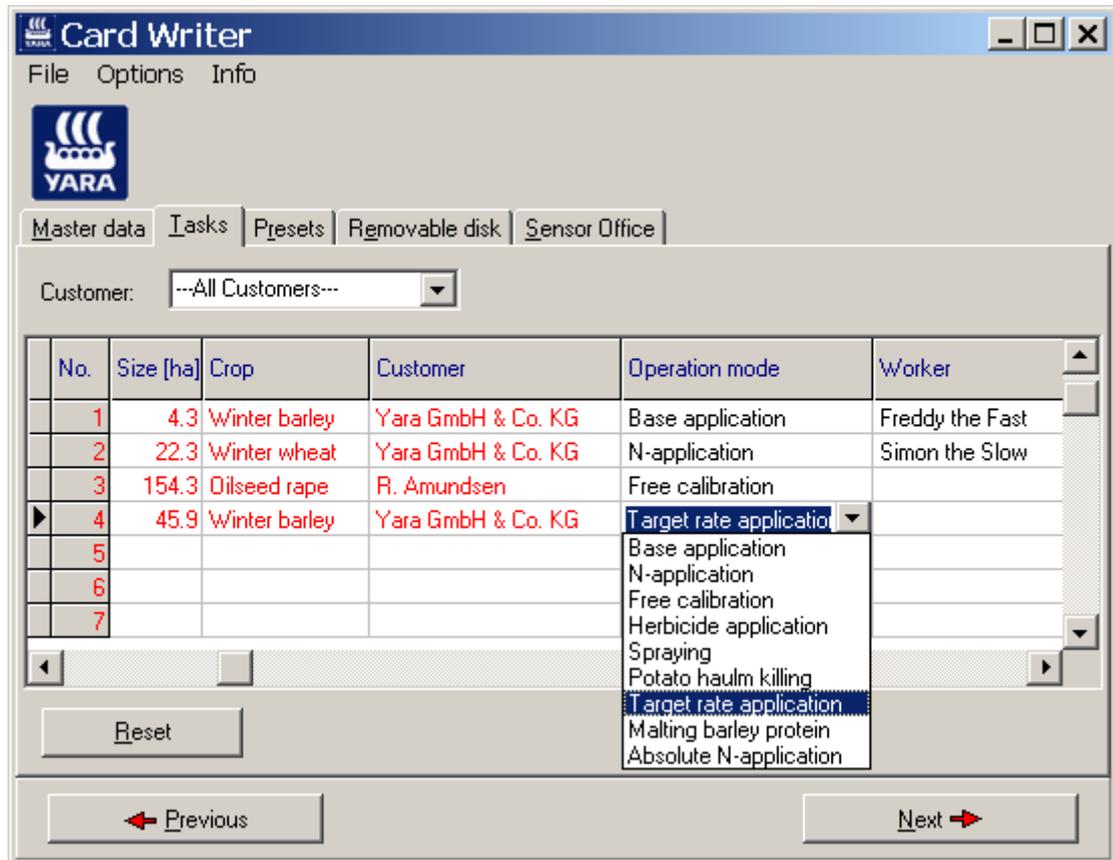
Availability of operation modes on individual systems depends on the local setup of your N-Sensor. Therefore it is recommended to only check those modes, which are really available on that specific device.

In the N-Sensor software, select *Setup | System...* and make sure that the *Task specific presets* option is checked:



8.2 Task preparation

If CardWriter has been setup as described in section 8.1, an additional *Operation mode* column is available on the *Tasks* page:



Select the operation mode that you want to assign to that individual task. If no operation mode is selected, that task will be operated conventionally, i. e. using the default operation mode and the agronomic parameters entered by the N-Sensor operator.

To enter the agronomic calibration parameters, switch to the *Presets* page. On the left side the general task information is listed as available in the table on the *Tasks* page. Tasks can be flipped through using the navigation bar on the bottom. On the right side the agronomic calibration parameters can be entered. The parameters entered here will be used for the agronomic calibration in the specified task only.

The screenshot shows the 'Card Writer' application window with the 'Sensor Office' tab selected. The interface is divided into several sections:

- Header:** 'Card Writer' title bar with 'File', 'Options', and 'Info' menus. The YARA logo is visible.
- Navigation:** Tabs for 'Master data', 'Tasks', 'Presets', 'Removable disk', and 'Sensor Office'.
- Main Content:**
 - Task Information:** 'No.: 4', 'Field name: Biofoot', 'Size [ha]: 45.9', 'Crop: Winter barley', 'Customer: Yara GmbH & Co. KG', 'Comment' (empty), 'Worker' (empty), 'Operation mode: Target rate applicatic'.
 - Calibration data:** 'Crop: Winter wheat', 'Growth stage: 31', 'N content in fertilizer: 27 %', 'Minimum rate: 10 kg N/ha', 'Maximum rate: 120 kg N/ha', 'Target rate: 60 kg N/ha', 'Relative biomass cutoff: 50 %'.
- Footer:** 'Previous' and 'Next' navigation buttons.

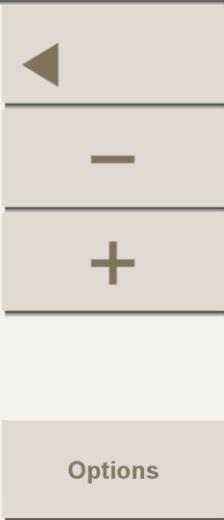
Once all settings have been made, switch to the *Removable disk* page and write the task data to the removable disk. Unplug the removable disk and plug it into the N-Sensor terminal.

8.3 Operating the N-Sensor with task presets

To operate the N-Sensor with task presets, on the N-Sensor terminal simply select the desired task using the *Plus* and *Minus* buttons in the *Tasks* menu, as described in section 4. Return to the work screen and either start application immediately or flip through the *Agronomic calibration* menu to modify agronomic parameters and/or to carry out a reference plot calibration. Note that all changes you make within this menu will be stored together with that specific task.

To display the current calibration parameters, enter the *Tasks* menu and switch to the *Presets* page:

Tasks

Operation mode:	N-application	
Crop:	Winter wheat	
Growth stage:	37	
N-content in fertilizer:	27.0 %	
Minimum rate:	10 kg N/ha	
Maximum rate:	120 kg N/ha	
Uniform rate:	60 kg N/ha	
Reference rate:	60 kg N/ha	
Sensor value reference:	52.0	

Task data | Map | Legend | Presets

Options

Note that this page is only available if an operation mode has been assigned to the selected task through *CardWriter* before. If this page is not visible, no task specific presets are available for that task.