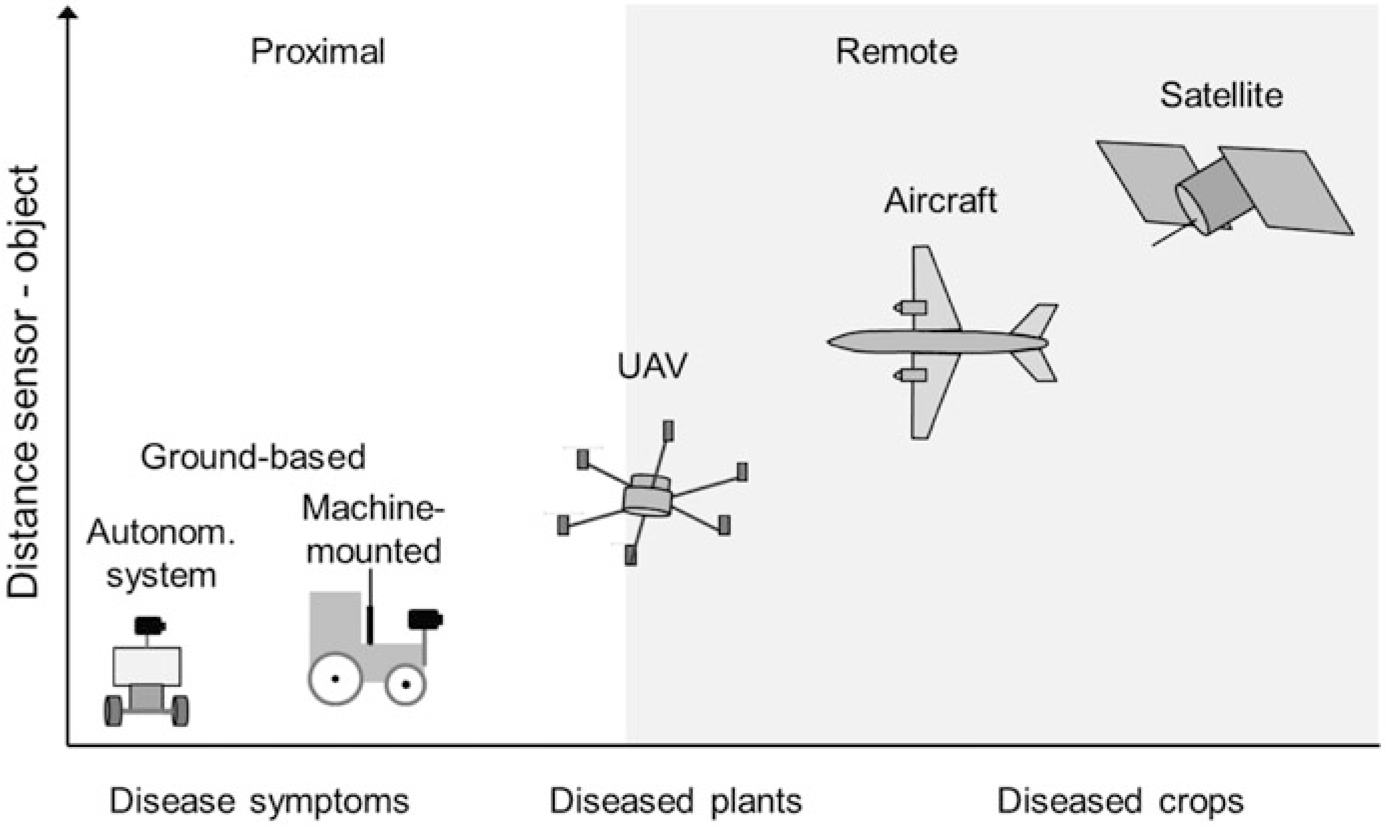
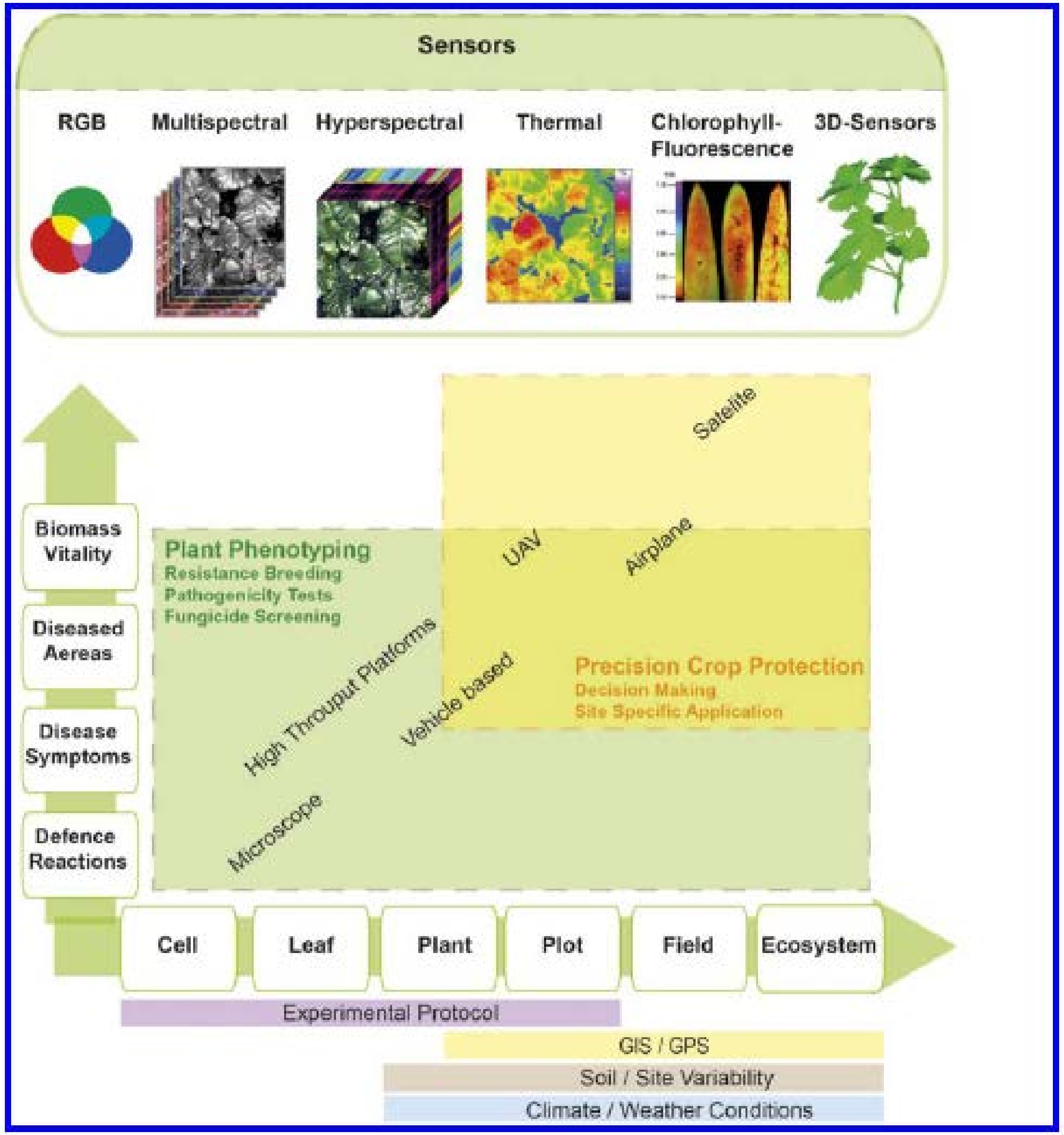
Proximal-sensing of plant diseases

- Common methods for diagnosis of plant diseases include visual estimation, microscopic evaluation, as well as molecular, serological, and microbiological techniques
- New sensor-based methods assess the optical properties of plants within different regions of the electromagnetic spectrum and are able to utilize information beyond the visible range.
- They enable the detection of early changes in plant physiology due to biotic stresses.

- Currently the most promising techniques are sensors that measure reflectance, temperature, or fluorescence
- Remote sensing is a method used to obtain information from plants or crops without direct contact or invasive manipulation. The concept has been recently enlarged by proximal, close-range or small-scale sensing of plant material.
- Proximal sensors may be hand-held, machine-mounted or attached to suitable unmanned aerial vehicles (UAVs).

Proximal Sensing vs. Remote Sensing

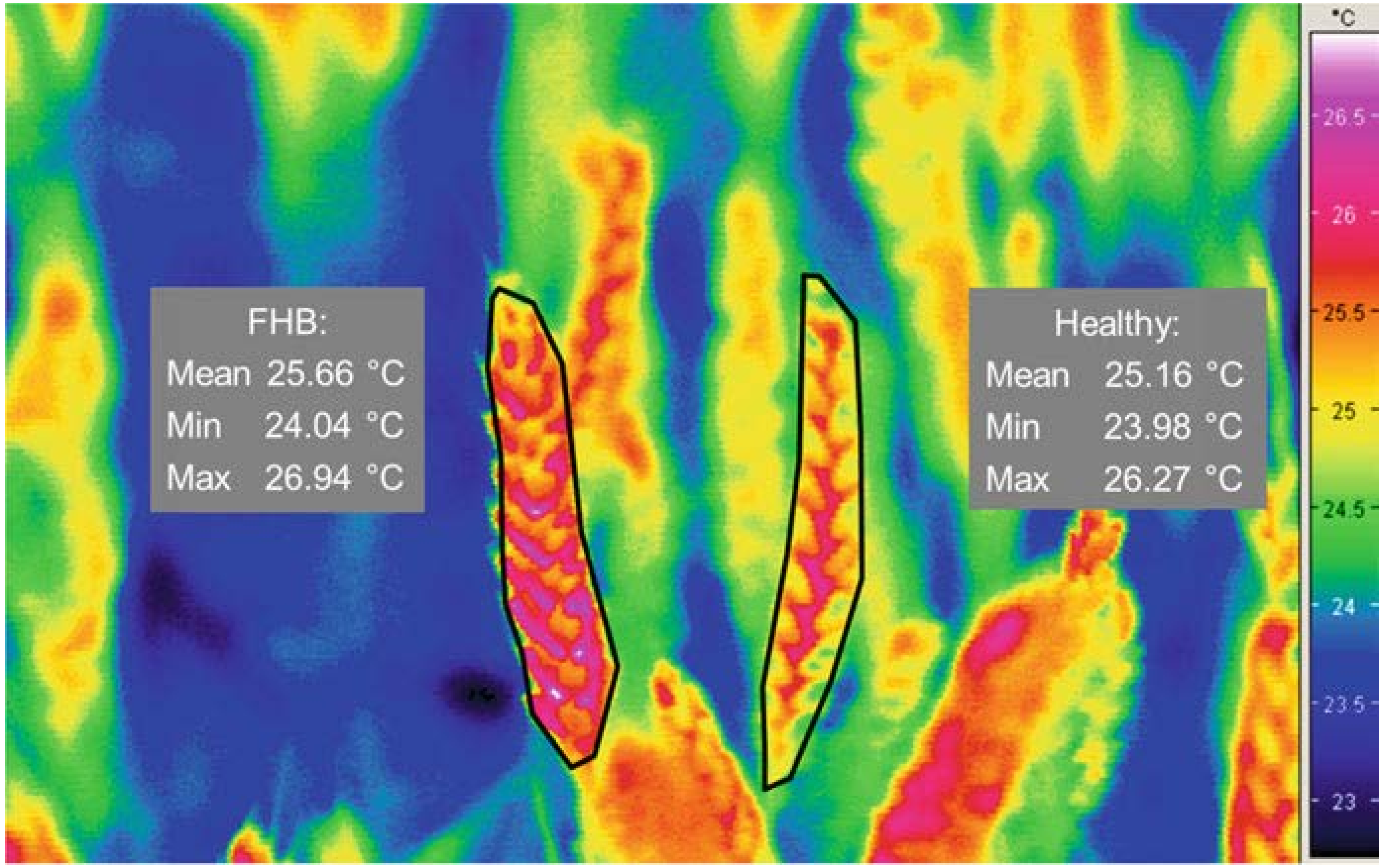




Current sensor technologies used for the automated detection and identification of host-pathogen interactions

Systems for Proximal Disease Sensing

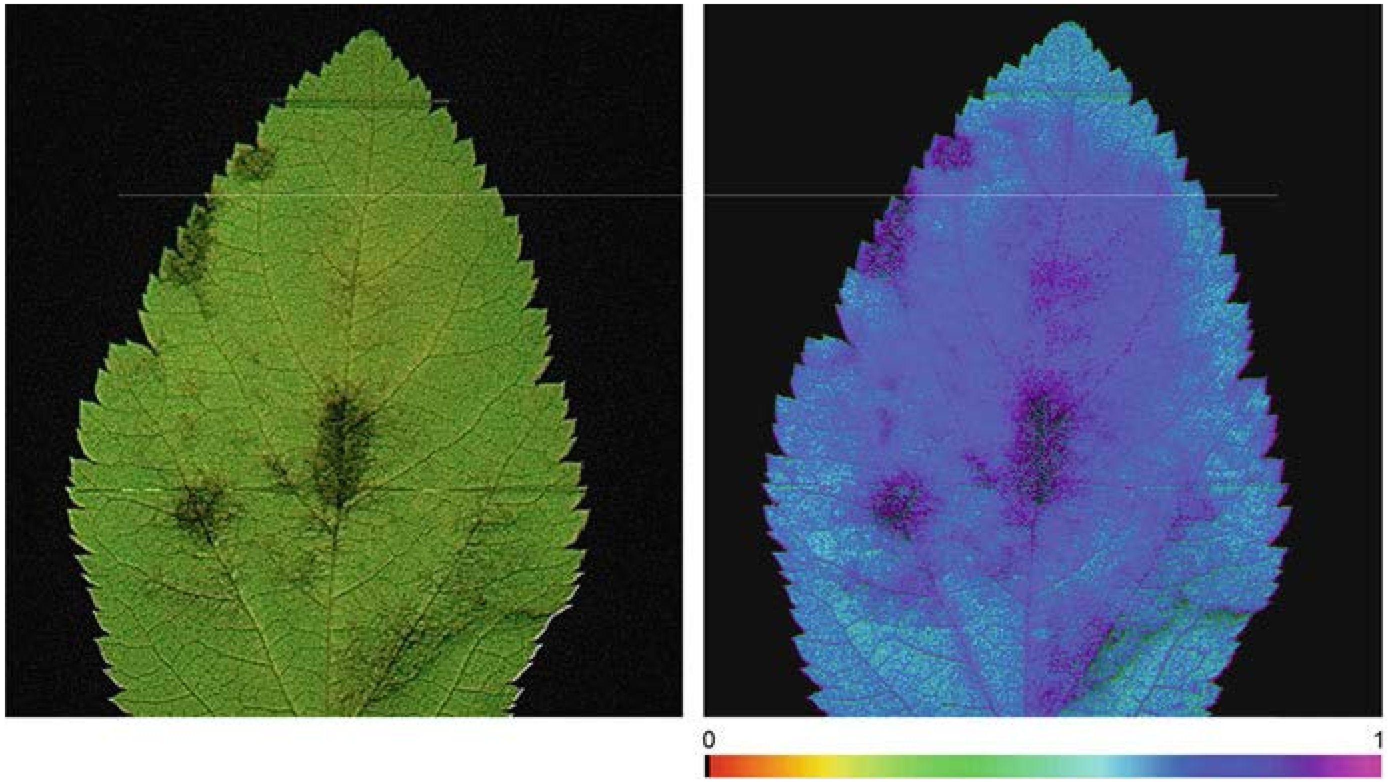
- **Thermography**
- Thermal imaging is a non-contact technique to determine the temperature distribution of any object in a short period of time. Infrared radiation emitted from plant surfaces may be recorded by detectors sensitive to radiation in the TIR from 8 to 12 μm. Each pixel of the images is related to a temperature value of the object's surface and may be illustrated in false color images.
- The technology can be used from microscope applications to ground-based equipment covering a range from (leaf) tissue to crop canopies.
- It is used to detect tobacco infected with tobacco mosaic virus, sugar beet infected by *Cercospora beticola*, downy mildew of cucumber caused by *Pseudoperonospora cubensis*, grapevine leaves infected with *Plasmopara viticola*, and for apple leaves infected by *Venturia inaequalis*.



Thermographic detection of Fusarium head blight-infected wheat ears at growth stage 75 in the field; comparison of temperature of infected and non-infected ears

Fluorescence Measurements

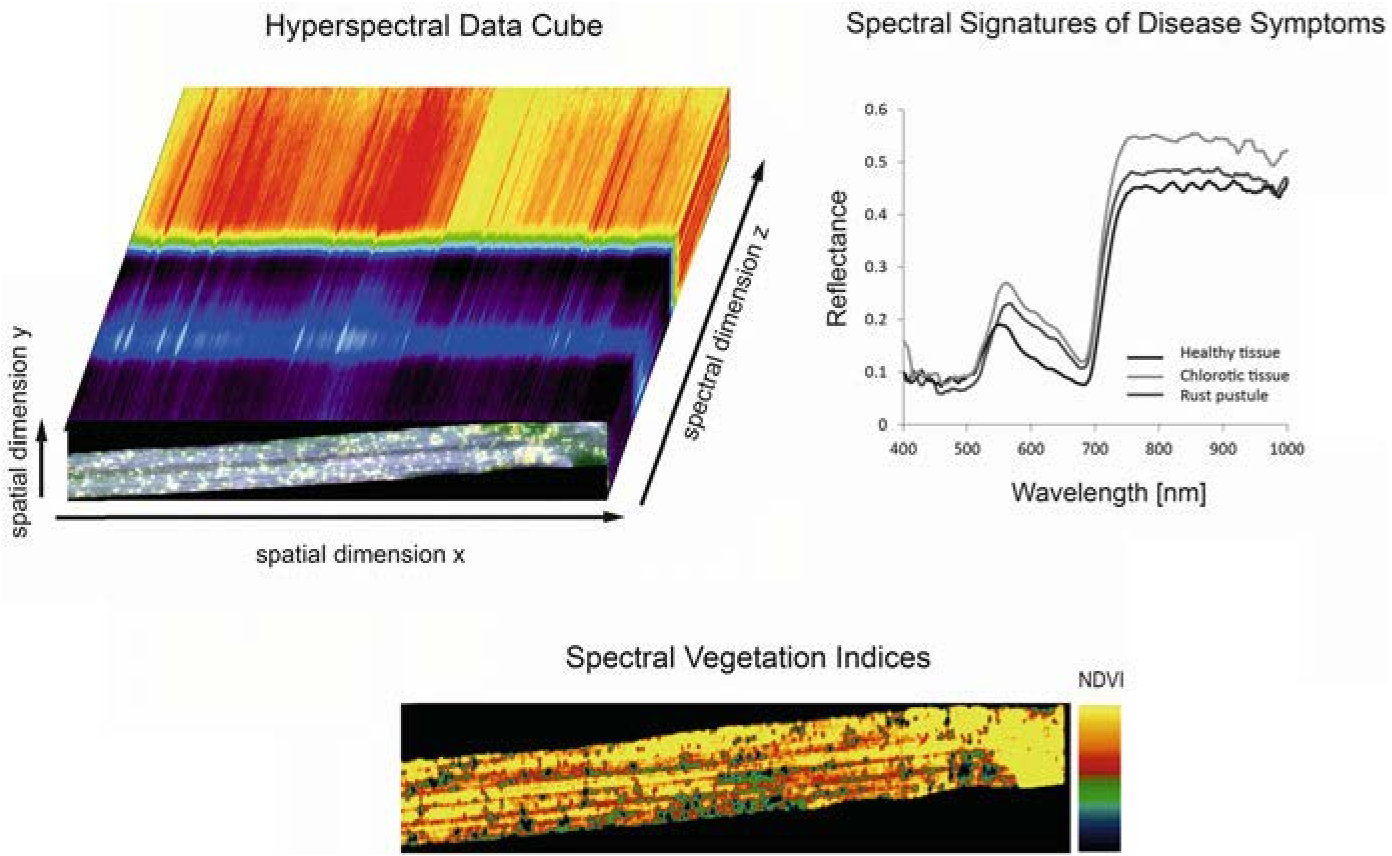
- Various fluorescence parameters of plants irradiated with ambient excitation light may be recorded for the assessment of photosynthetic activity and the content of chlorophyll and other plant metabolites, e.g. phenols. These methods are very sensitive to detect changes in photosynthesis.
- Since disease development also affects the crops photosynthetic apparatus – pigments, electron transport chain, enzymes of the CO_2 fixing Calvin cycle – the intensity as well as the spectrum of chlorophyll fluorescence are modified in diseased plants, sometimes even before visible symptoms appear.



Color image (left) and chlorophyll fluorescence parameter qN (right) of an apple leaf infected by *Venturia inaequalis*

Spectral Techniques

- Reflectance of incoming electromagnetic radiation in the visible, near infrared and short wave infrared depends on multiple interactions: back scattering at the leaf surface and internal cellular structures, radiant energy absorption induced by leaf chemistry, e.g. content of pigments, leaf water, proteins or carbon
- The detection of diseased plants, i.e. plants with a spectrum different from that of healthy ones, using spectroscopic techniques has been successful for *Magnaporthe grisea* on rice, *Phytophthora infestans* on tomato, *Venturia inaequalis* on apple trees, canker lesions on citrus fruits, *Blumeria graminis* on barley, and Rhizoctonia root and crown rot of sugar beet. Infections of sugar beet by various leaf pathogens could be detected even pre-symptomatically



Hyperspectral imaging of barley leaf diseased with brown rust. Each pixel of the 3-dimensional data cube contains a continuous spectral signature from 400 to 1,000 nm. Based on this imaging data spectral vegetation indices maps may be calculated