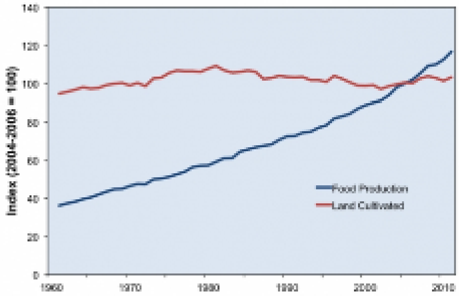
Hello, my name is Pieter Blok, and I work as a research manager at Wageningen University and Research. The presentation I'm about to give, will focus on smart farming technologies that are expected to revolutionize the agricultural domain.

Wageningen University and Research is based in the Netherlands. Wageningen University is being rated as the best agricultural university in the world and has about 10.000 students. Wageningen Research does contract-research for industry and government. In particular, Wageningen Research has extensive experience in robotics and sensor technologies that are applied in agriculture.

* Presented at the 14th Jeju Forum for Peace and Prosperity, Jeju, South Korea, May 29-31, 2019, http://www.jejuforum.or.kr/m21_program.php?year=2019

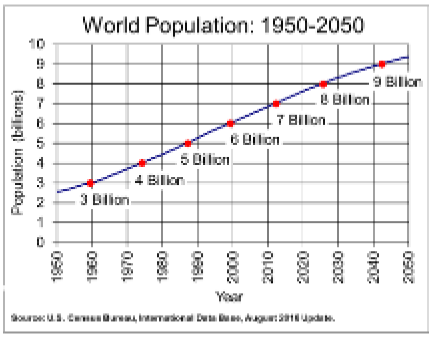
Global trends in agriculture

- Food production growth:
  - Plant breeding
  - Fertilizer
  - Mechanisation



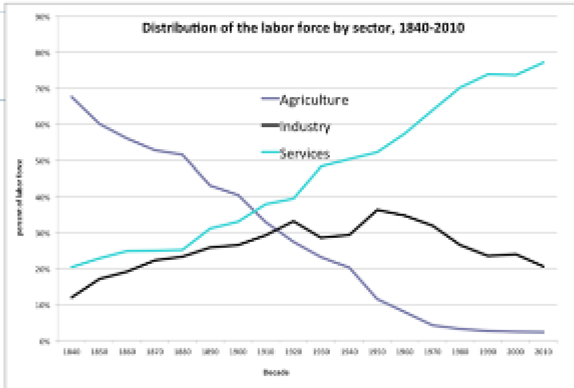
Global trend: 9 billion people in 2050

How to feed them all?



In the last century, there was a massive increase in food production due to plant breeding, enhanced fertilizers and mechanisation. However, the land available for agriculture will stagnate or decrease over the next years, mainly due to increased urbanization and drought and salinity stress. When the world population grows to 9 billion people in 2050, a logic question arises: how can we feed all these people with less available land?

Actual concerns



Resource scarcity

- Land
- Fertilizers
- Water
- Fossil fuels
- Human labour

Health and environmental issues

- Human, animal, plant diseases
- Food safety
- Animal welfare
- Greenhouse gas and ammonia emissions, dust
- Pollution by chemicals and waste nutrients

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Besides issues with land, agriculture faces other resource scarcities. The most important issues include phosphate depletion and shortage of human labor. This in times where consumers and lobbyists require the farmers to produce healthy food in an environmental friendly way.

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How can smart farming help?

SMART farming to achieve more outputs (food) with less inputs:

- **dedicated actions**: smaller machines to ease the soil
- **precision tasks**: seeding, fertilisation, disease control, harvesting
- **resource efficiency**: more in less time, less inputs and less labour
- **information**: big data farm management

  animal and crop monitoring, tracking & tracing

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Smart farming is becoming an important asset to produce more food with less inputs. Smart farming is the use of intelligent machinery, such robots, to enable a higher efficient food production. With smart farming, issues concerning labor and resources can be alleviated.

Examples of smart farming

- Autonomously guided robots
  - Alleviate the problems with human labour
  - Small robots and swarm robotics to ease the soil
- Sense and act
  - Autonomous detection and control of weeds
  - Autonomous crop harvesting
- Big data for improved farm management
  - Drones
  - Deep-learning

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My presentation will focus on several examples of smart farming, which are currently being researched and developed in Wageningen. I'll focus on autonomous robot navigation, weed control, crop harvesting and data management. With the use of several videos and photos, I'll explain how these systems work and how they are built. Most of the examples I'll show are currently being commercialized into a real working agricultural machines.

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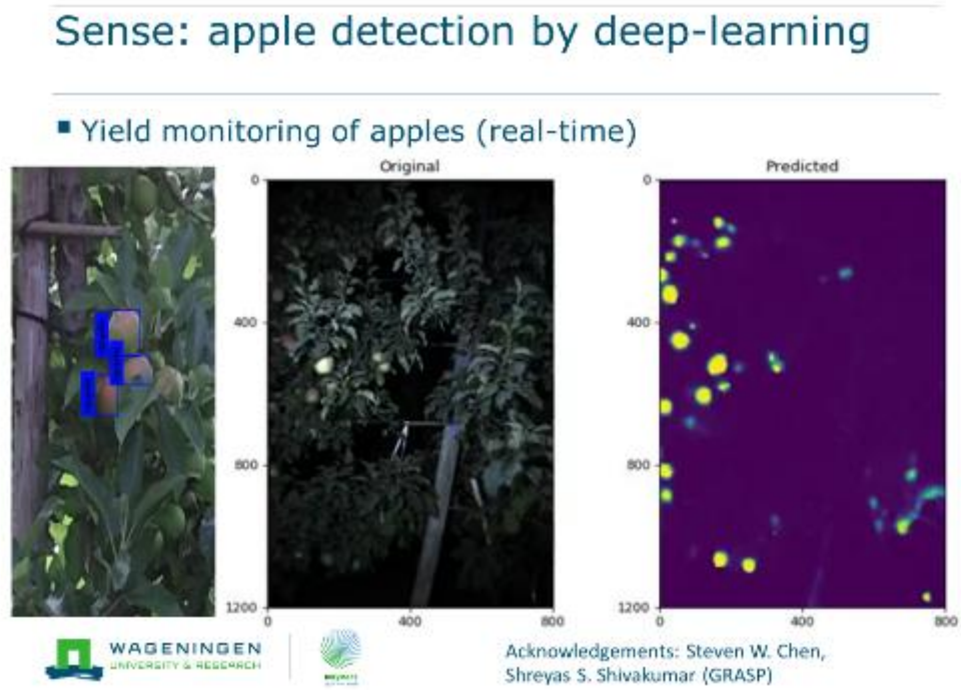
This video highlights the result of a 3-years collaboration between Wageningen and the Rural Development Administration, which is based on Jeonju, Korea. Together with RDA, we developed an autonomous orchard robot that can execute unmanned field work in South-Korean orchards (apple and pear). The robot was designed to travel mountainous orchards with slopes up to 10%. The robot is fully electronically powered and uses a state-of-the-art laser scanner (lidar) to perceive its environment. Obstacles are detected and evaded using a camera that is integrated with the most recent deep-learning algorithms.



Eventually, every robot requires sensors and intelligent processing algorithms to do autonomous work on the field. This is an example of an apple detection algorithm that can be used on an orchard robot. The

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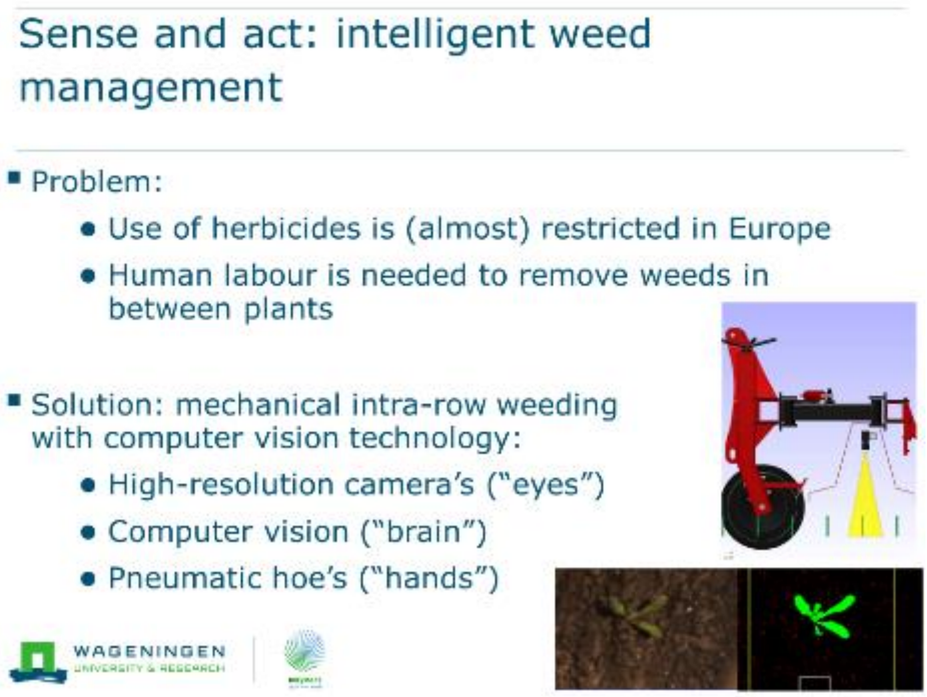
algorithm uses deep-learning to detect apples in real-time for yield monitoring. With the use of this information, a farmer can do site-specific application of plant protection productions which saves agricultural chemicals. In addition, these information can be used for selective harvest of apples with robots.



Another example of smart farming includes intelligent weed control. This machine can be used to control weeds that grow in between the plants. These weeds can normally not be controlled by a mechanical hoe, as the hoe might damage the crop. At Wageningen, we developed an intelligent weed control machine that uses a camera to differentiate between weeds and crops. When a weed is detected, a pneumatic hoe is being triggered to destroy the weed while keeping the plants unharmed.

The brain of the weed robot consists of deep-learning algorithms. These algorithms are robust and above-all very fast. This algorithm can process 30 frames per second to differentiate between the weed, which is volunteer potato, and the crop, sugar beets.

This video demonstrates the weed robot that is currently being commercialized. You can see that the pneumatic hoe’s are triggered by the visual information of the camera.

For grasslands, there is a need for a different robot. The soil of grasslands is usually less capable of bearing heavy machinery. This lighter robot is able to detect broad-leaved weeds in grassweeds using a color-camera. When a weed is detected there is a mechanical drill that destroys the weed from leaf to root. With this robot, farmers can control there weeds without the use of labor or chemicals.

A very interesting new robot is currently produced and sold by the Dutch company Cerescon. Cerescon develops a robot that can automatically harvest asparagus. The robot uses capacitive sensors to detect asparagus and uses a robotic arm to selectively harvest the asparagus. With this robot, the ever existing labor problems are alleviated.

This video shows the asparagus robot in action in the field.

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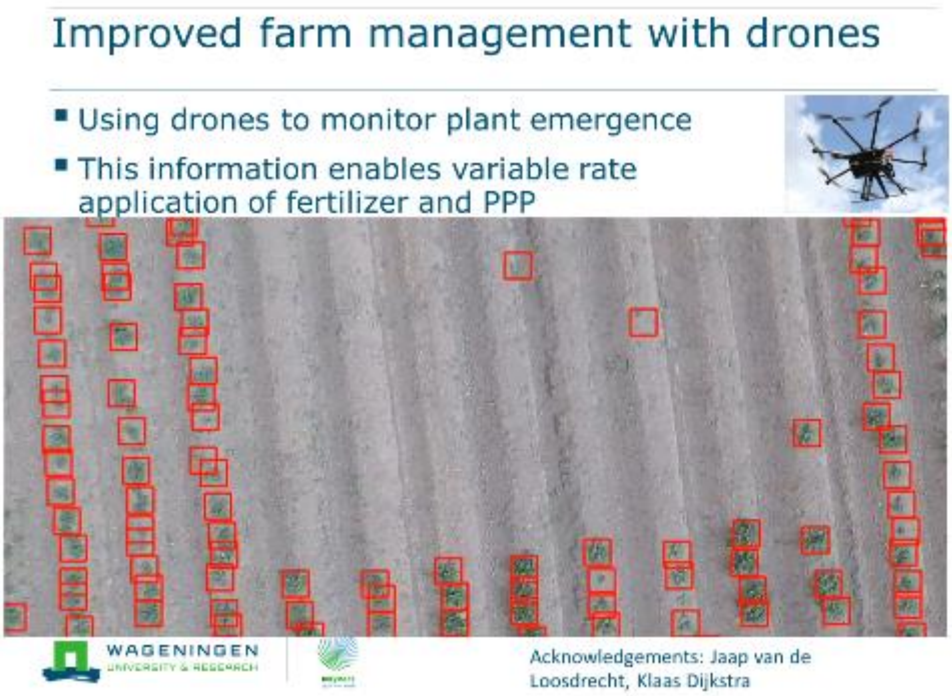
Similar to asparagus, there is currently a strawberry robot (Agrobot) available that can harvest strawberry autonomously with the use of sensors and small mechanical cutters.

Within Wageningen, there is a lot of research on greenhouse automation. Greenhouse production typically requires much human labor in conditions that are harsh for people. This robot is developed by our university to autonomously harvest sweet pepper. Although sweet pepper is a difficult crop to harvest, the robot showed enough potential to alleviate the labor problems. The robot uses state-of-the-art deep-learning with a smart mechanical actuator to harvest peppers.

Grafting is the process of connecting a root-stem of a different tomato cultivar with a different vegetative part of another tomato cultivar. Currently, this is a labor-intensive job. This automatic system enables the autonomous grafting of tomatoes using sensor-technology and precise robot actuation.



Similar to other domains, agriculture is a field where "big data" exists. With the use of drones, farmers can monitor their crops. With drones it is easy to reveal parts of the land that suffer crop growth problems. With this information, a farmer can do a site-specific application of fertilizer or plant protection products to enhance crop growth. As the application will be site-specific, there will be a massive reduction on inputs while simultaneously increasing the crop production.

The 4th industrial revolution in agriculture

- Internet-of-Things (IoT) and block-chain
  - Machine-to-machine connectivity
  - Improved traceability of food products (inspection, transparency)
- Artificial intelligence (deep-learning)
  - Improved decision-making
  - Robot autonomy
- Big-data
  - Improved yield forecasts
  - Year-to-year trends (weather, historical data)

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As previous machines showed, there is a huge potential to increase food production with smart farming technologies. These technologies enable the fourth industrial revolution in agriculture as well. With the using of Internet of Things and block-chain, we are able to connect machines and monitor our food production instantaneously. A key-changing technology in agriculture involves deep-learning, which is a form of artificial intelligence. Deep-learning is a technique that enables robot autonomy and improved visual perception. The majority of the presented machines included a form of deep-learning. Besides artificial intelligence, we believe that agriculture can profit from big-data and improved weather and yield forecasts. Drones are useful platforms to enable big-data.

How is smart farming stimulated in the Netherlands?

- Public-private collaborations in The Netherlands:
  - Cross-pollinate science (public) and innovative industries (private)
  - 50% of budget needs to come from industry and Dutch government doubles this budget to stimulate the public-private collaboration
- Consequence:
  - Science becomes more applied and market-oriented
  - Industries will collaborate more easily with universities

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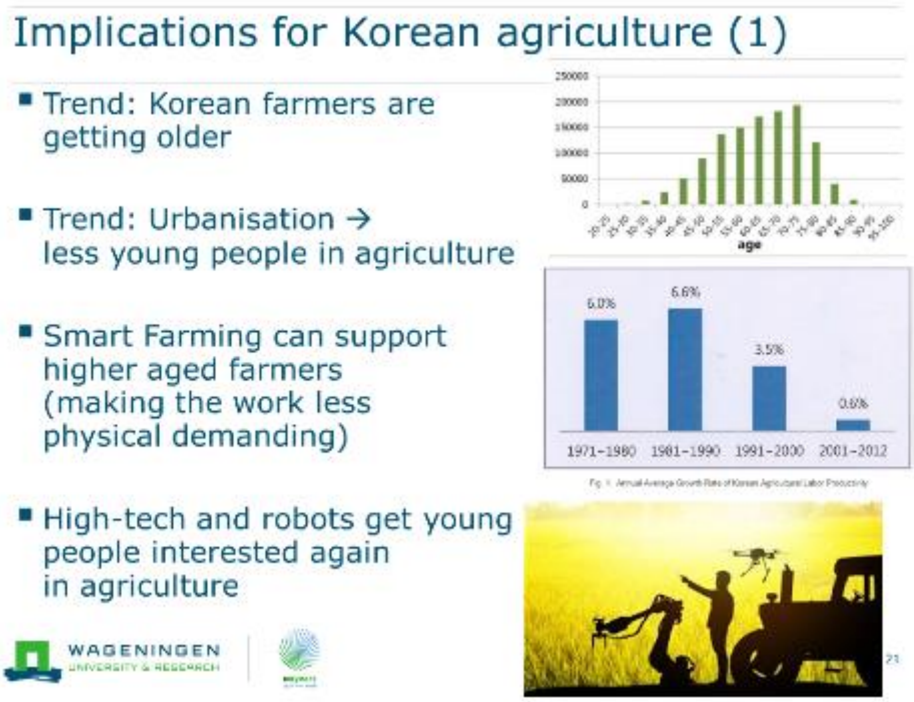
You might wonder how these technologies were initialized? In the Netherlands, smart farming is currently being stimulated in public-private collaborations. These collaborations are initialized by the Dutch government to enable knowledge transfer between universities and companies. The government subsidizes 50% of the total research budget when companies pay the other 50%. As a result, universities and companies need to collaborate to receive funding from the government. This yields more applied research and interesting prototypes for commercialization, as being showed in previous slides.



To conclude my presentation, I need to highlight the perspectives of smart farming for South-Korean agriculture. Smart farming enables a higher food production with less inputs. These reduced inputs also includes less human labor that allows higher-aged farmers to do the same work with less effort. Simultaneously, I believe that high-tech solutions can trigger the interest of young people to re-enter agriculture again.

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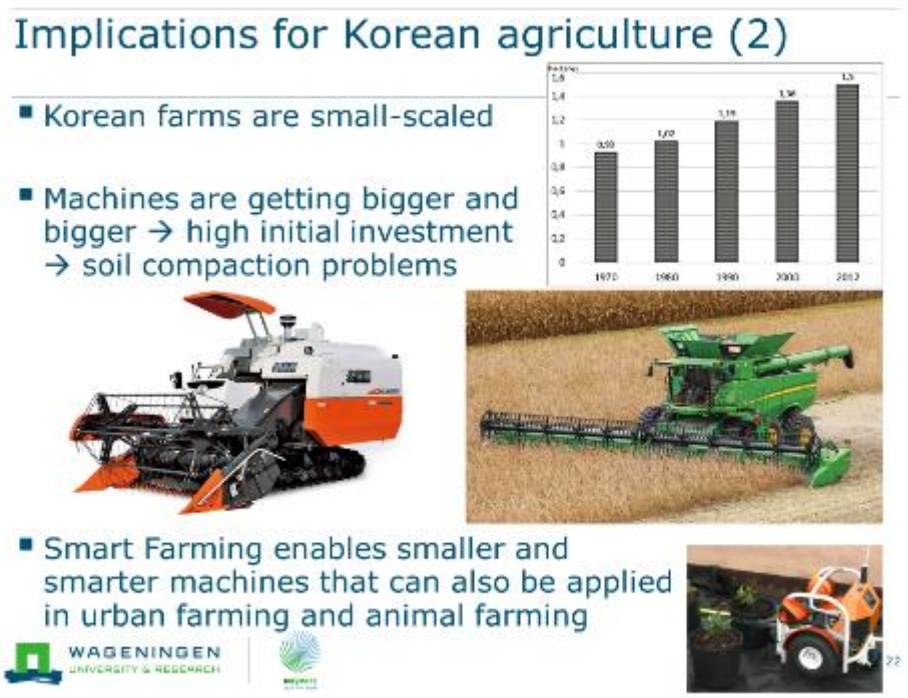
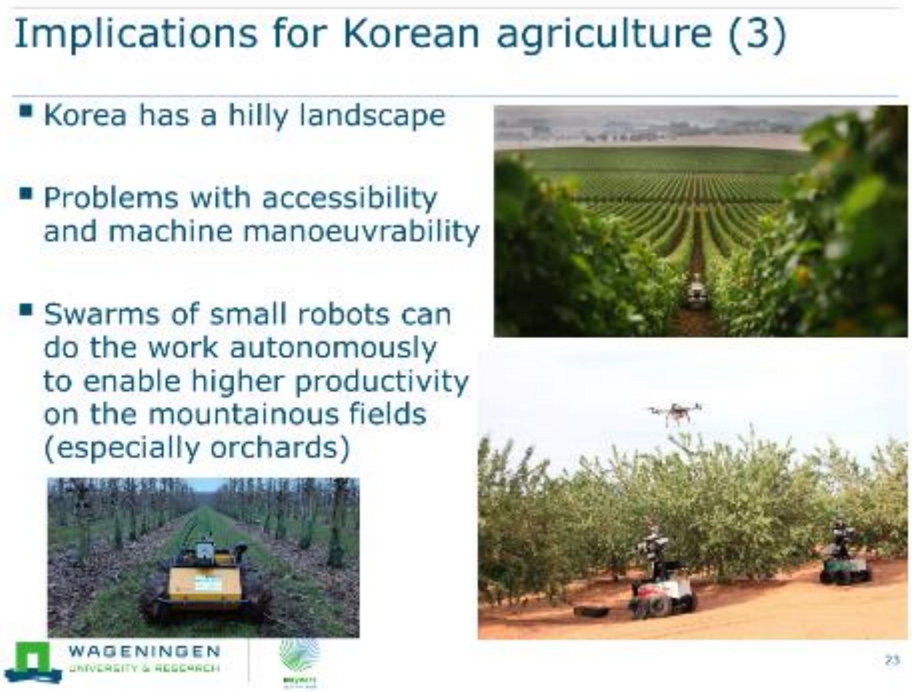


In addition, smaller-scaled robots also enable more mechanical actuation that are less dependent on agricultural chemicals. This is particularity promising for organic and animal farming.



As the RDA robot showed, small scaled robots are expected to increase food production on infeasible lands. That is especially interesting for mountainous countries, like South-Korea. If you ask me, smart farming will be a crucial technology to revolutionize agriculture.

Thank you for your attention. I'm open to answer several questions.