LIGHT BUDGET AND LAND EFFICIENCY

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MOTIVATION
FROM SINGLE TO DUAL USE SOLAR PARKS

Societal acceptance?

- Government/politics/local communities:
  - Less and less societal support for single use solar parks
- Free market?
  - PV is more profitable than (most) agriculture
  - Land lease income vs uncertain crop yield and value
- The alternative: dual land use
  - Agrivoltaic solar farm
  - Farmed land, in appearance and function
  - Additional PV function

Offers range **from 900 to 1,200 euros** per year for the lease of an irrigated hectare and barely 300 for a rainfed one. In the best locations, they can go up to **2,000 euros**. The proliferation

This benefits you as the landowner because you earn a regular income stream (up to $2,000 per acre annually).

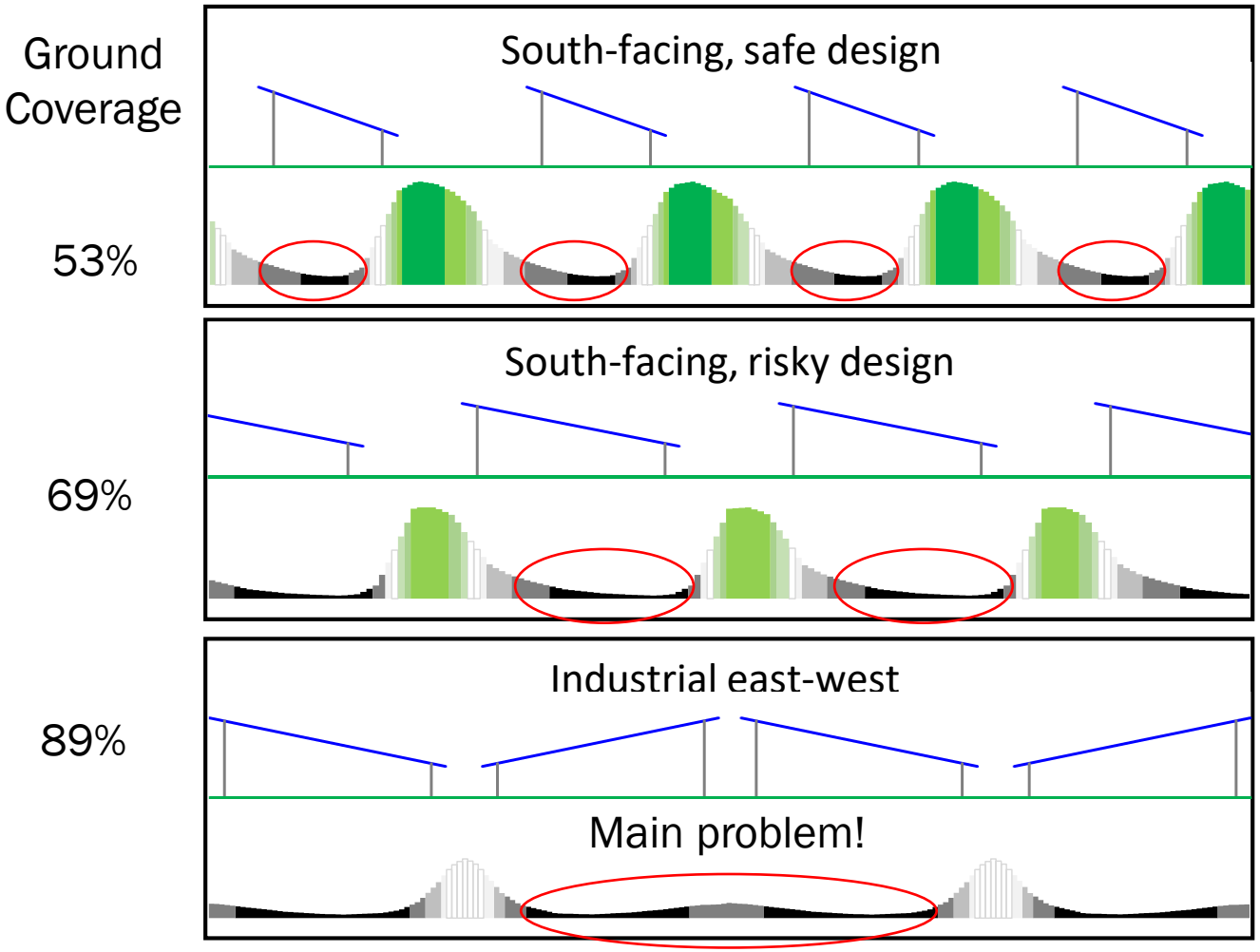

Dual land use

SIGNIFICANT AGRICULTURAL COMPONENT IN AGRI-PV
TO PREVENT FIELDS WITH LIMITED AGRICULTURAL FUNCTION

- How to determine the amount of agriculture in an agrivoltaic solar park
  - Yield in tonnes/ha
  - Quality and value of produce
- But
  - Crops come after the permit and construction
  - Agricultural yield likely to decrease
  - Year-on-year variations
- Agriculture requires
  - Water
  - Nutrients
  - Access for vehicles
  - Light
- Irradiance most affected by PV installation
  - Light budget to determine agri-PV?

LIGHT BUDGET FOR REGULAR SOLAR PARKS

CLEAR EFFECT ON RESULTING ECOLOGY AND CARBON CONTENT

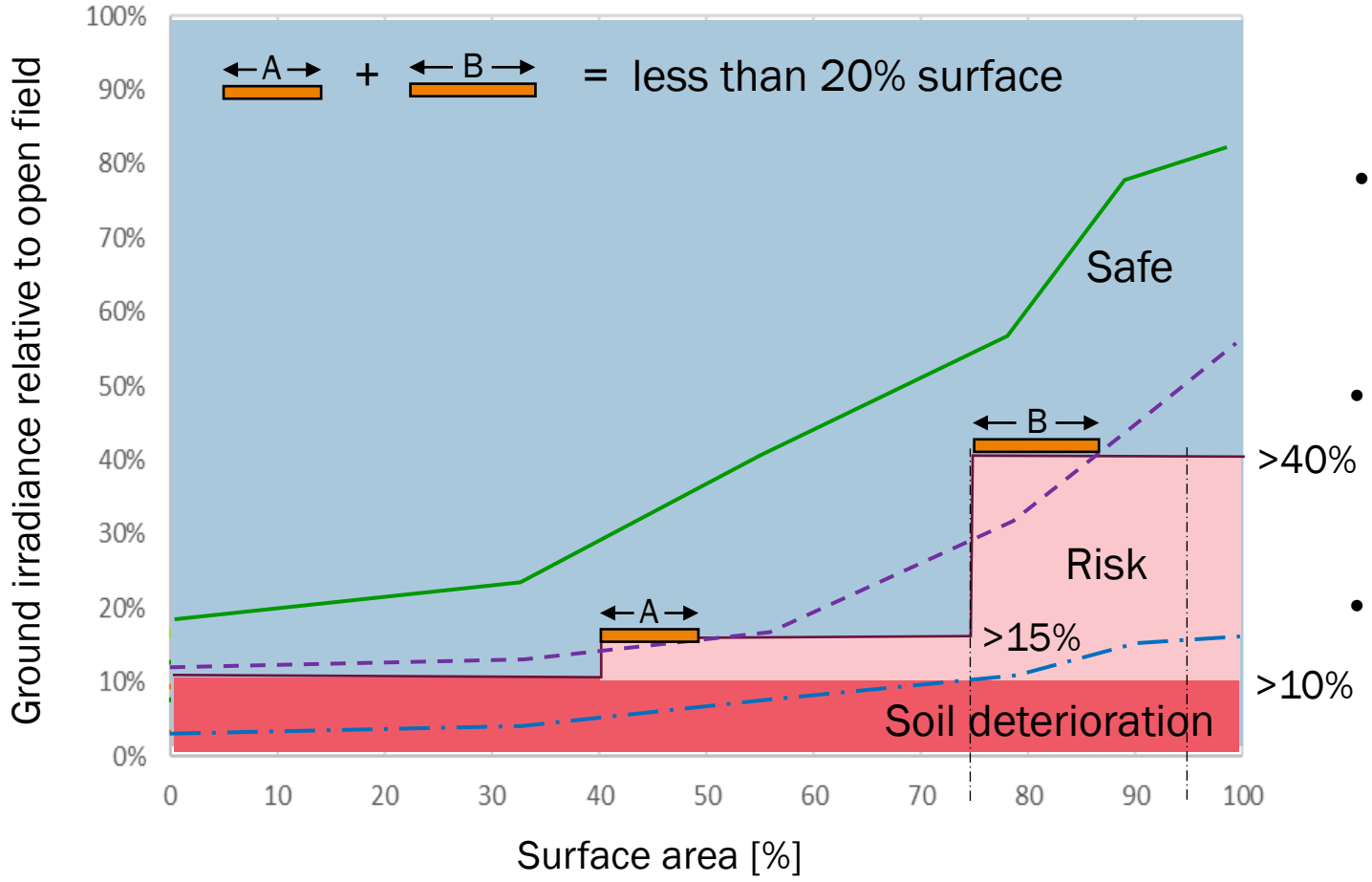


South safe

Industrial east-west

DESIGN RULES FOR MINIMUM SOIL QUALITY

LIKEWISE WE CAN DETERMINE MINIMUM LIGHT AVAILABLE FOR



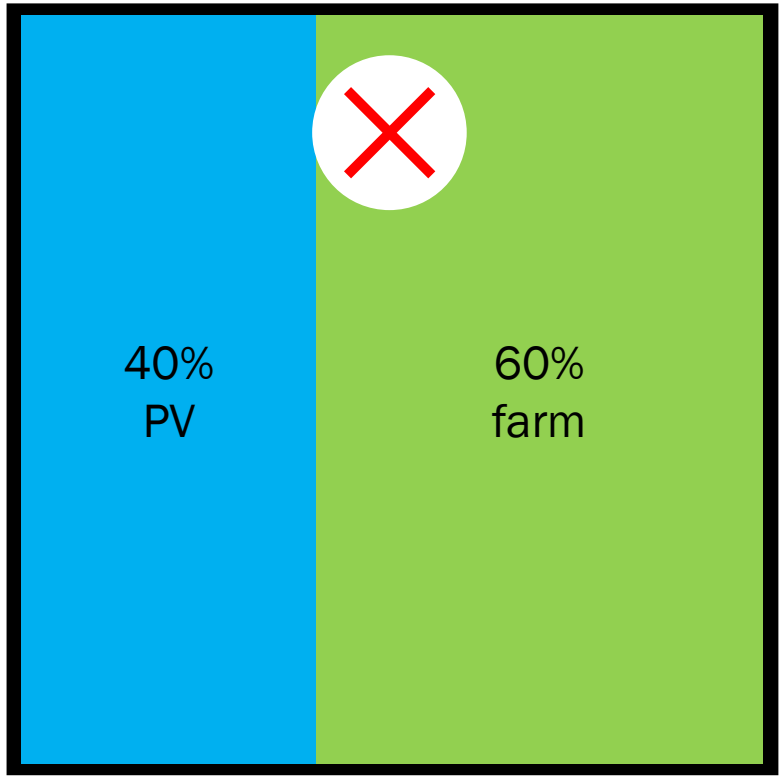
Qualifications

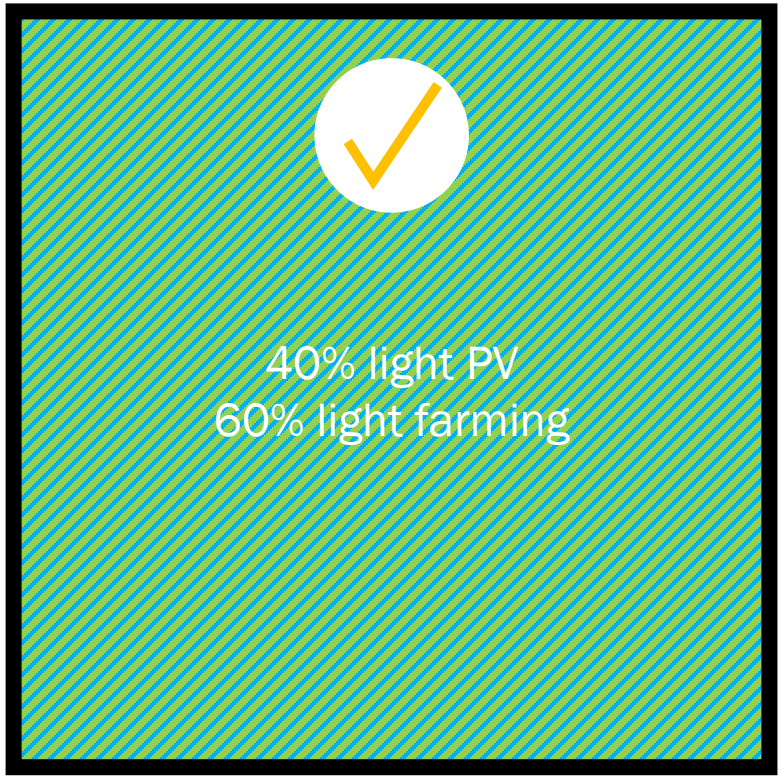
- **Safe**
- **Permissible with risk to soil quality**
- **Impermissible**

Work on ecology and design rules is supported by Dutch ministry of Economic Affairs and Climate in the EcoCertified project

AGRIVOLTAICS = COMBINED CROP AND ENERGY FARM

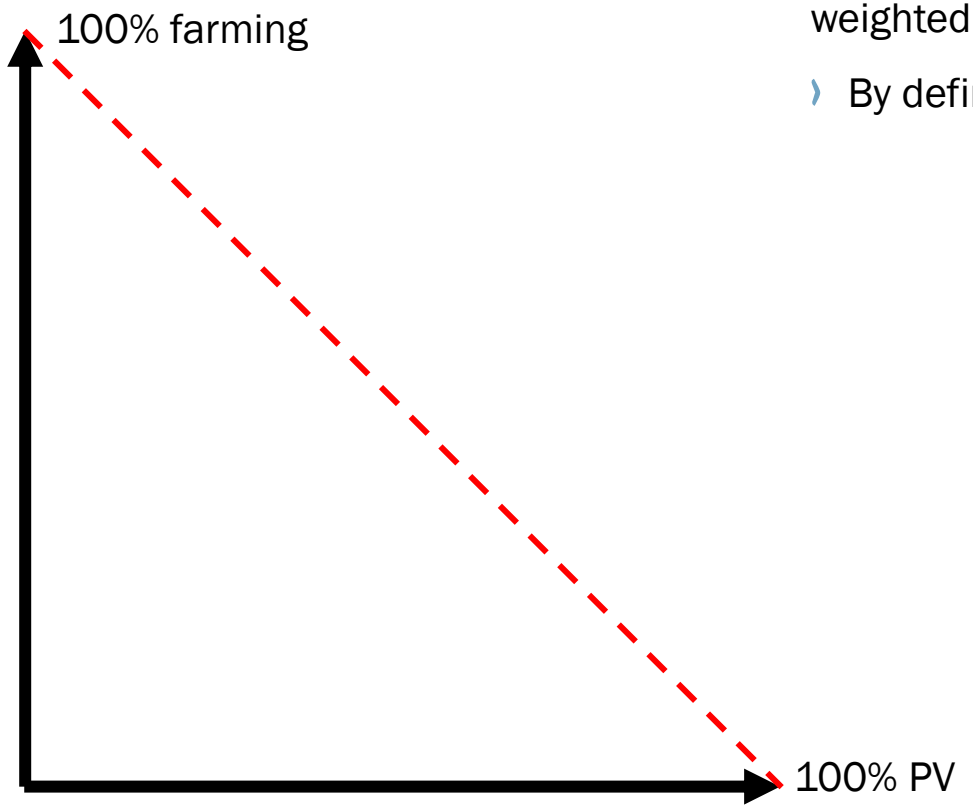
NOT A COMBINATION OF A CROP FARM WITH A SOLAR FARM



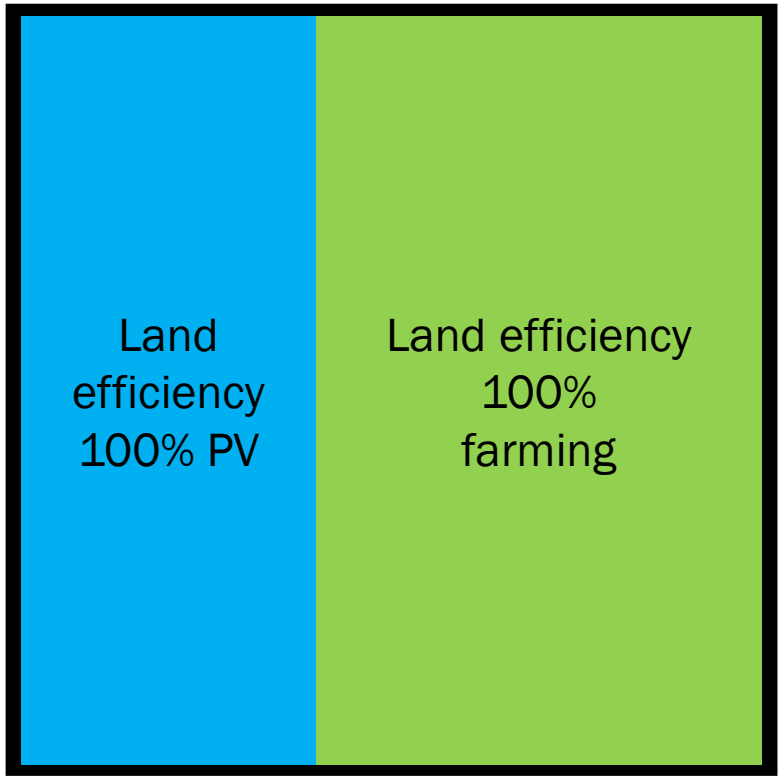


LAND EFFICIENCY RATIO

SEPARATE FUNCTIONS GIVE LAND EFFICIENCY OF 100%



- No interaction between functions
- Effective land efficiency is sum of two weighted efficiencies
  - By definition 100%

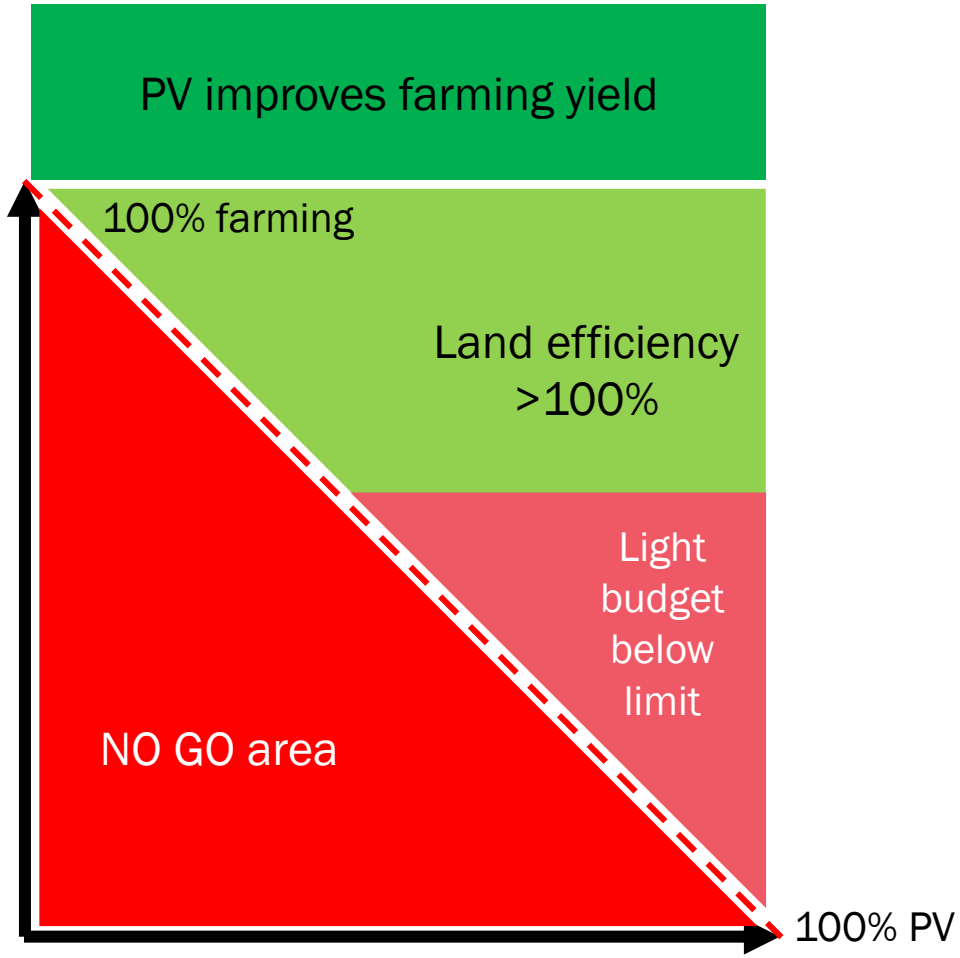


LAND EFFICIENCY RATIO FOR COMBINED FUNCTIONS

1) The simple choice
   positive effect of PV panels on crop yield
2) No go
   PV decreases farm yield more than PV improves energy yield
3) Farm and energy yield, in terms of land equivalent, larger than 100%
4) And sufficient light budget for farming

To predict crop and energy yield, we need combined crop and energy model

- Inhomogeneous irradiance on crop
- Non-standard PV systems
  Non-standard PV modules



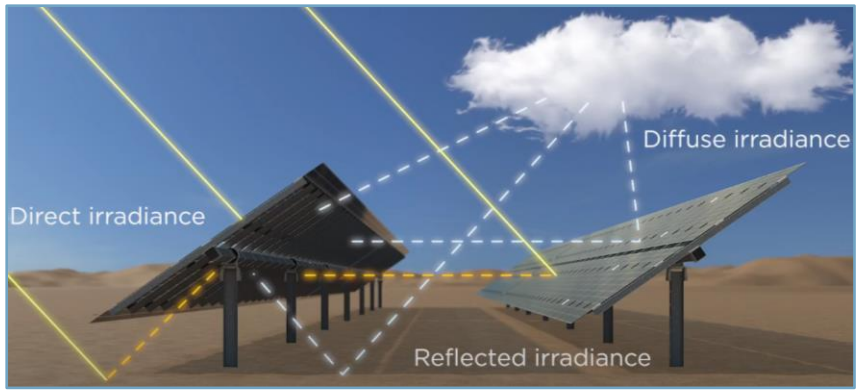
The Symbizon project is financially supported by the Top Sector Energy from the Dutch Ministry of Economic Affairs

STRIP FARMING INTERSPERSED WITH PV TRACKERS

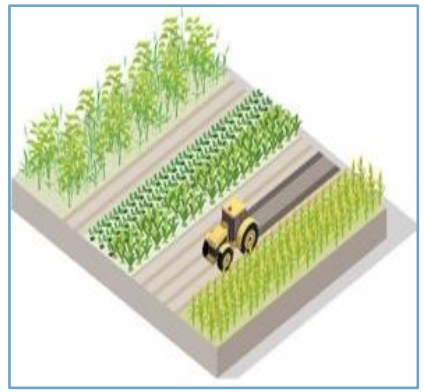
PV SYSTEM IS INSTALLED NOW

- Three state-of-the-art developments combined in one 700 kW agrivoltaics demonstrator
  - Single-axis tracking
  - Bifacial, semitransparent panels
  - Ecological strip farming
- Project partners
  - Vattenfall
  - Aeres – university of applied agricultural sciences
  - ERF & Hemus – ecological farmland managing
  - RVB – (state) landowner
  - TNO – R&D institute

Solar tracker with smart algorithm
Source: Schletter



Bifacial solar panels
Source: Soltec



Strip farming
Source: WUR

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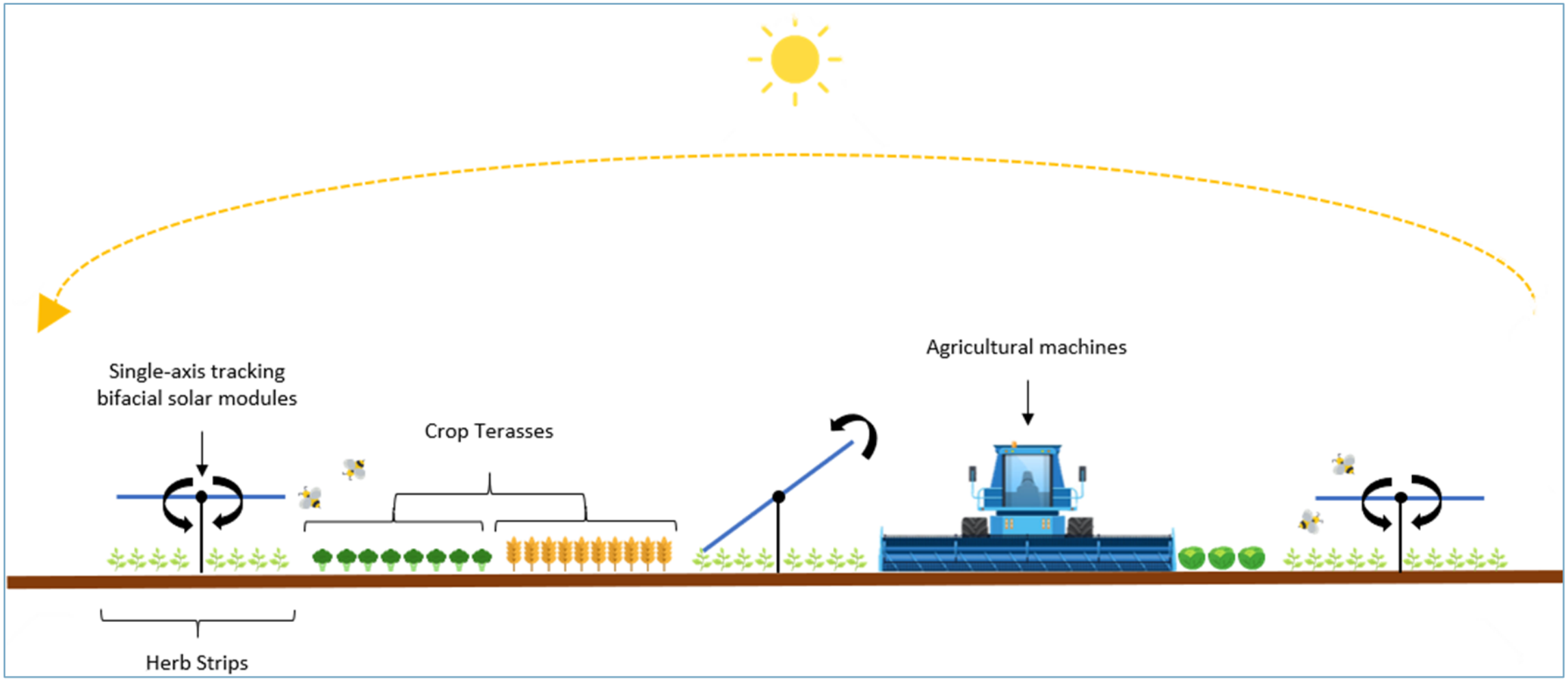
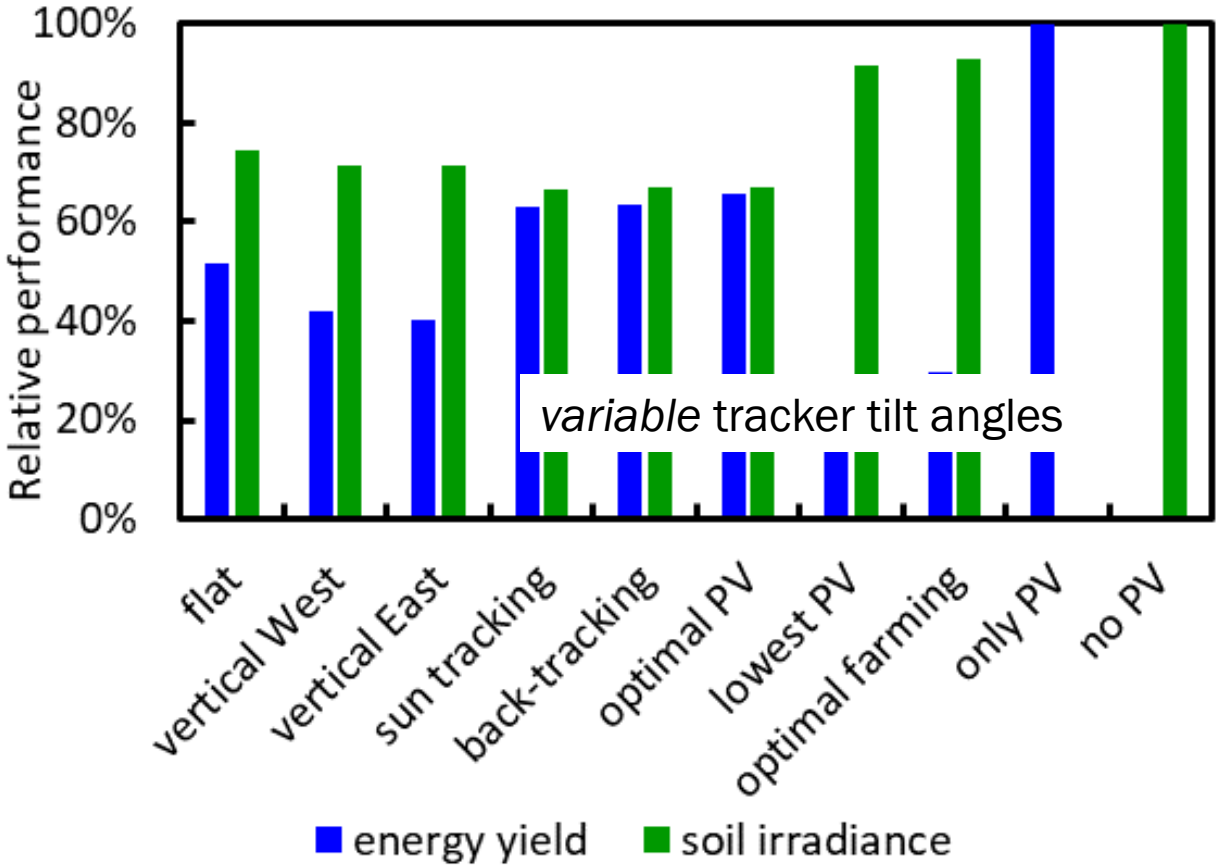
STRIP FARMING INTERSPERSED WITH PV TRACKERS

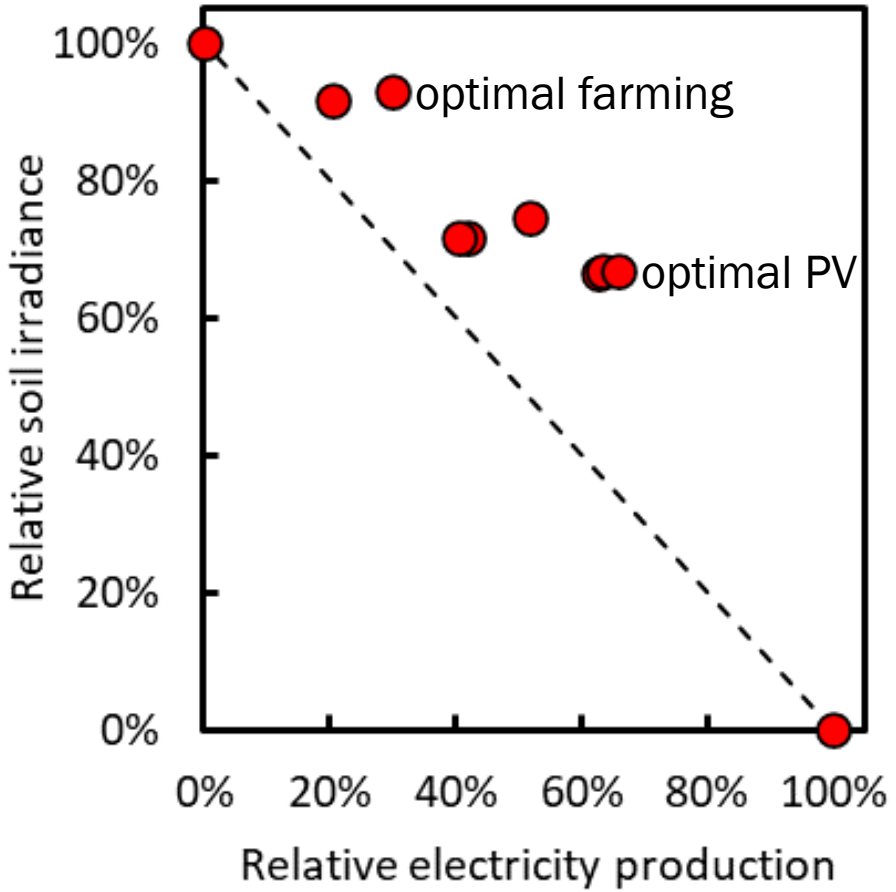
SECOND TITLE OF THE SLIDE



TRACKER ALGORITHM CAN BE TUNED FOR CROP OR KWH

SOIL IRRADIANCE ON STRIPS AS PROXY FOR CROP YIELD



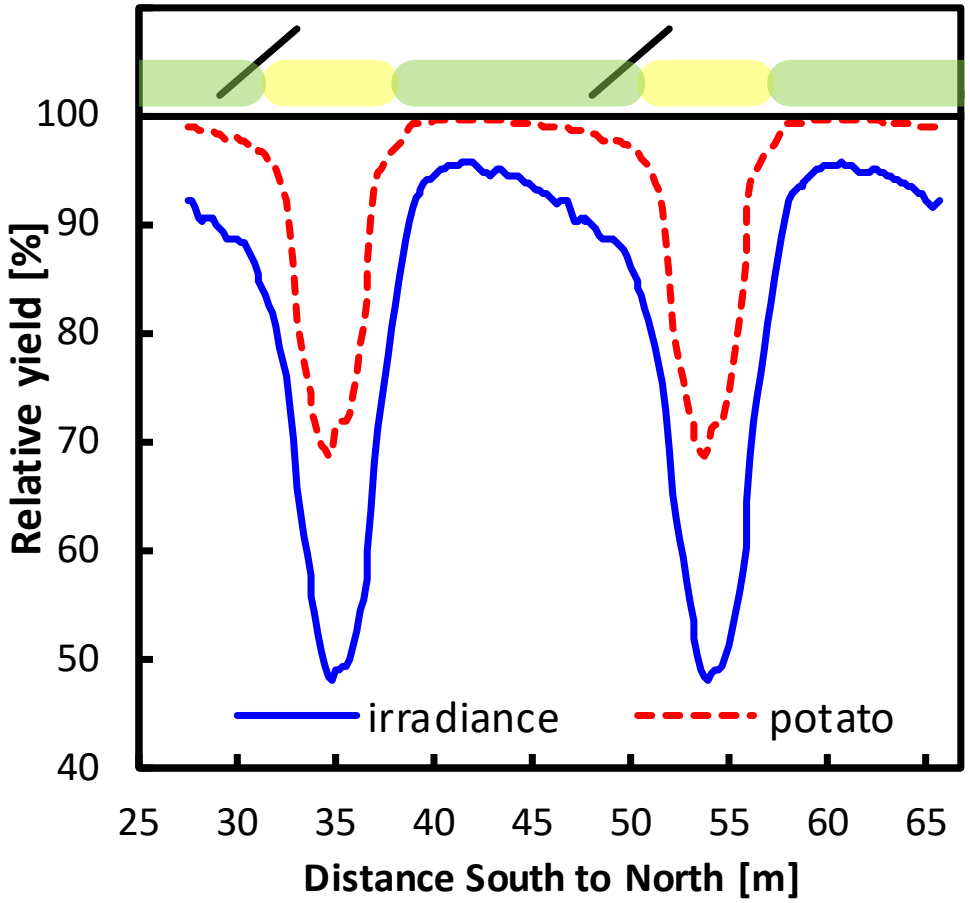


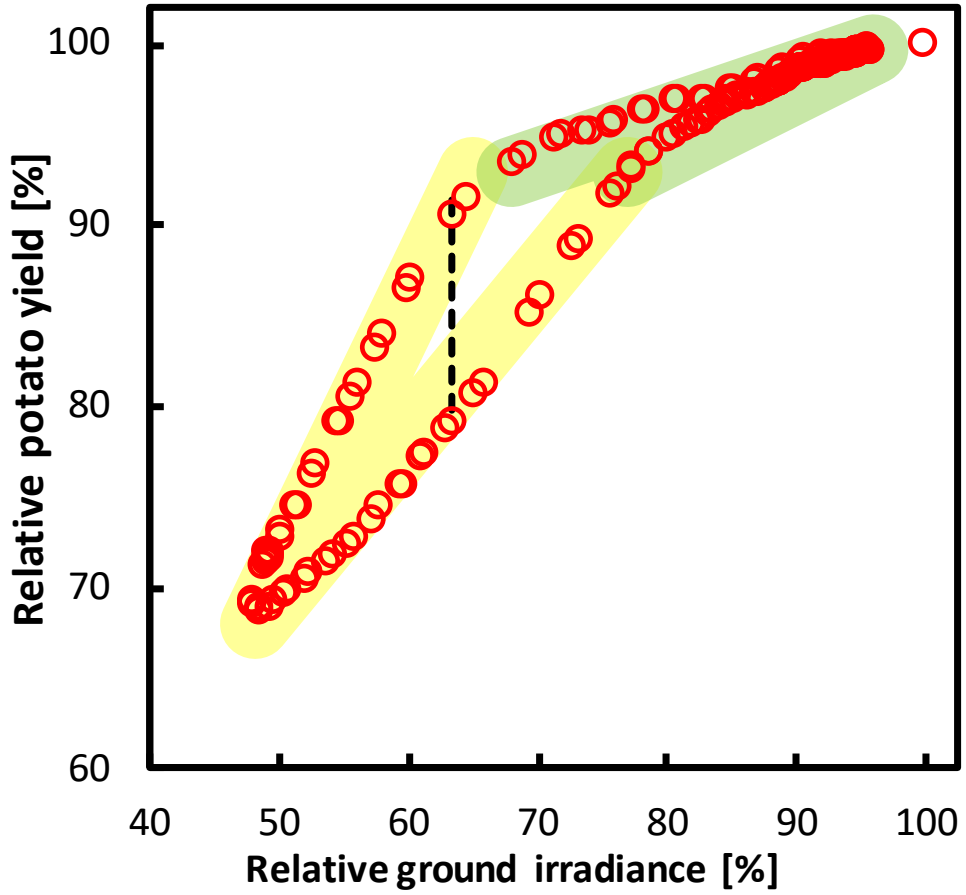
Note: Reduced irradiance can also reduce heat and water stress and prevent photo-saturation

Work on combined PV and crop modelling in the Sunbiose project is financially supported by the Top Sector Energy from the Dutch Ministry of Economic Affairs

TOWARDS AN INTEGRATED CROP-ENERGY OPTIMISATION

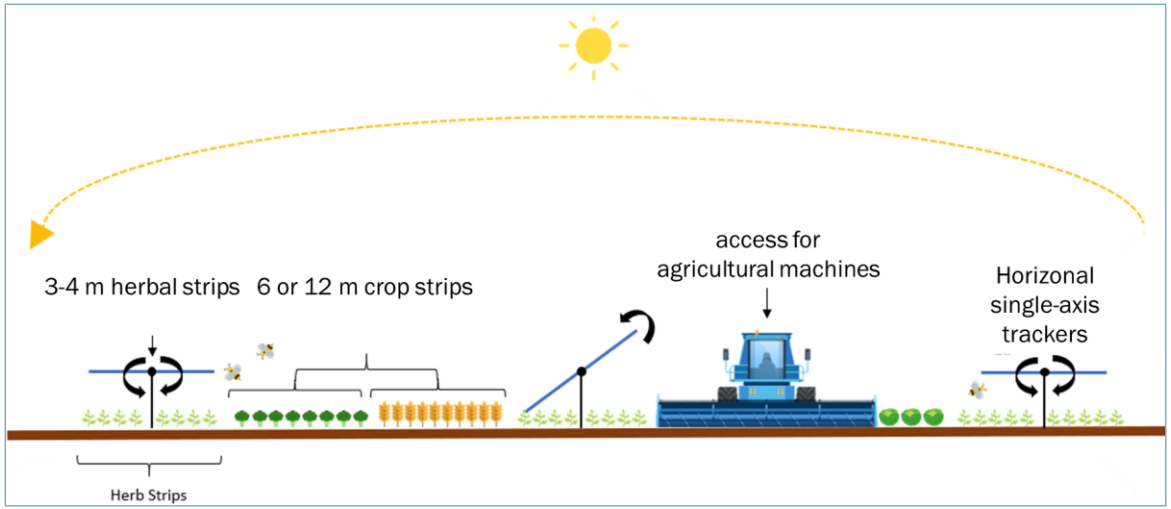
POTATO FARM WITH OVERHEAD PV INSTALLATION

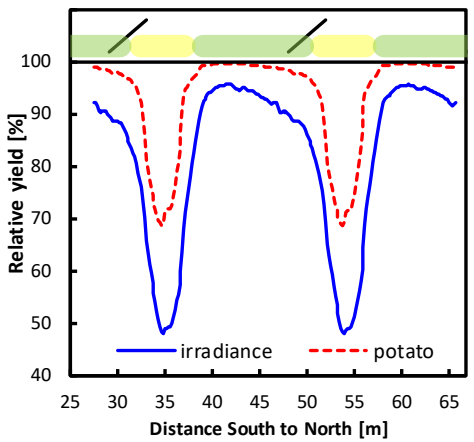


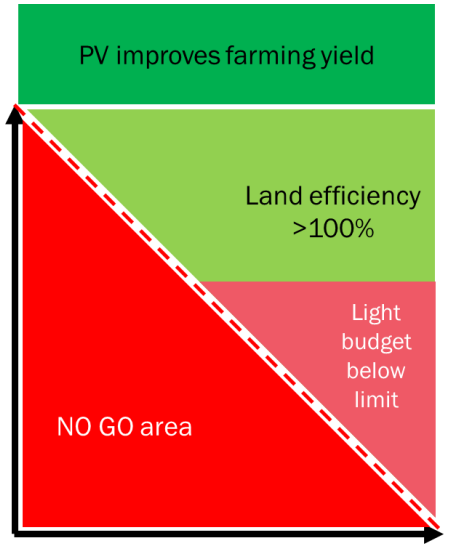


CONCLUSIONS AND OUTLOOK

- Light budget first step to classify agrivoltaic systems
- Solar trackers can also supply shade/sun
- Irradiance is important, but
  - Coincide with leaf coverage
  - Water distribution
- More knowledge and expertise needed
  - Response of crops to reduced light
  - Effect of sunlight / hard shadow on crops
  - Identify the right combinations of crop, climate, solar park design and local conditions





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YOUR TIME
TNO innovation for life