Risk assessment and feasibility study of greenhouse humidity control methods in tropical conditions

On-going MSc Thesis study, Biosystems Engineering

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Introduction

- Humid tropical climates
- Consequences of high humidity
- Disease risk assessment: *Botrytis case*

Disease Severity (DS) is highly correlated with the cumulative hours of relative humidity higher than 90% and temperature lower than 10°C, which is unfavourable for the disease, and temperatures between 20 and 25°C, that favours the disease.

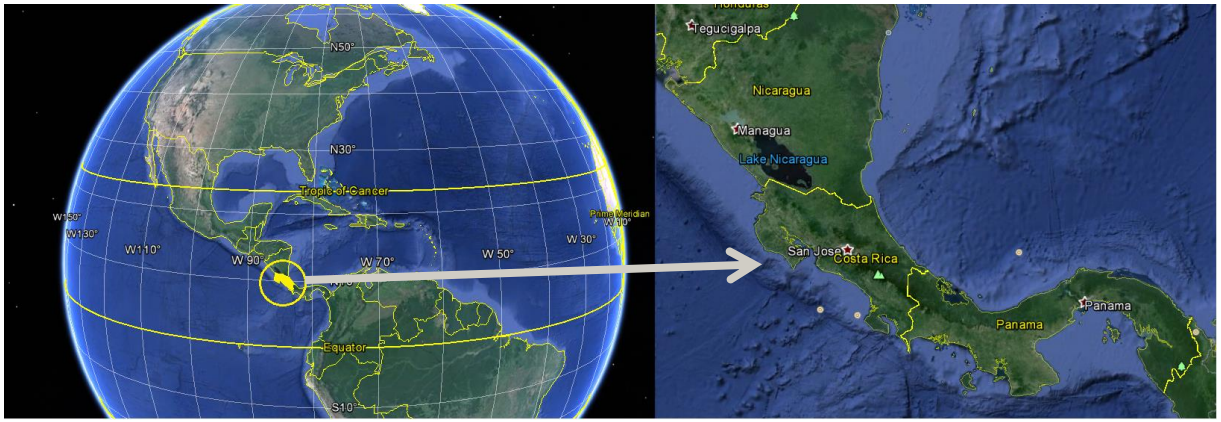
(Baptista et al 2011)

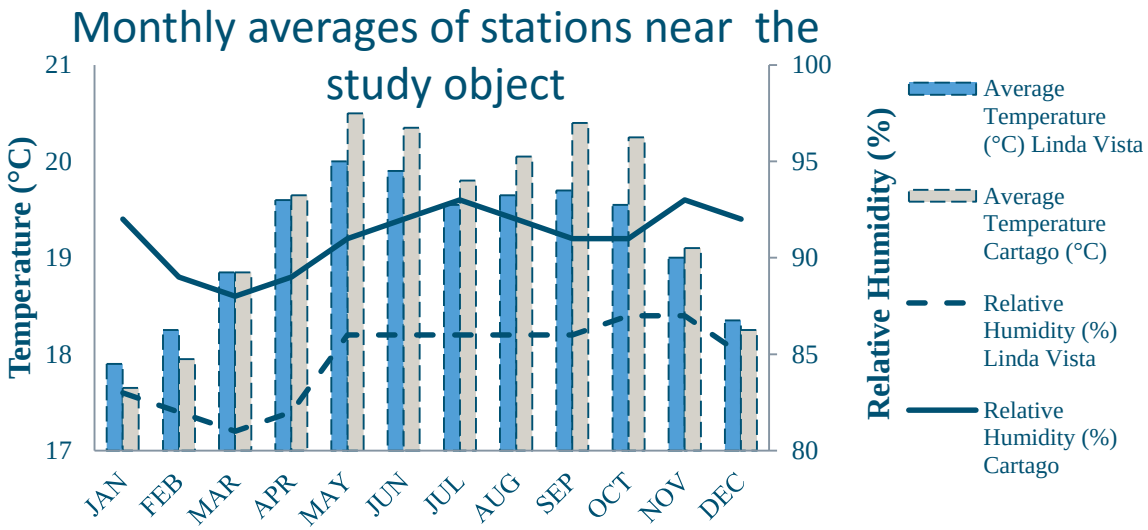
Risk of infection			
HIGH	9 or more	hours/day	RH >90%
MODERATE	4 to 9	hours/day	
LOW	4 or less	hours/day	

Main Objective

Find an economically feasible greenhouse climate control (cc) strategy that minimizes disease risk by minimizing hours with humidity above a given threshold

Study Object: Location





Costa Rica, Cartago, 1638 m.a.s.l

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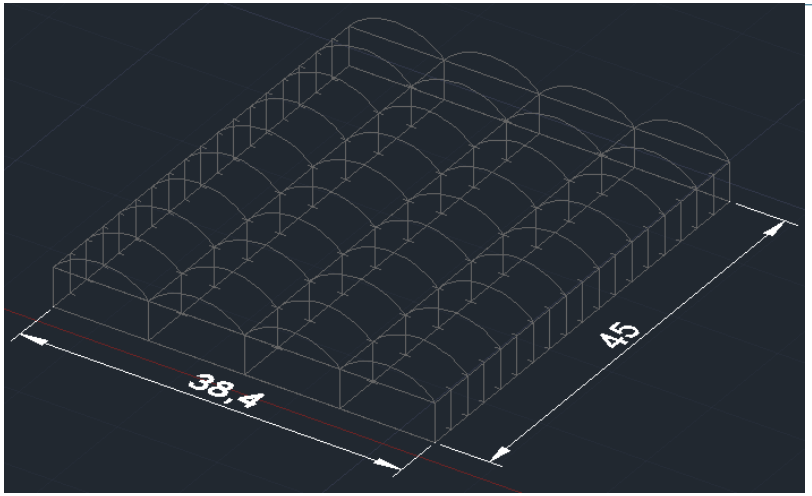
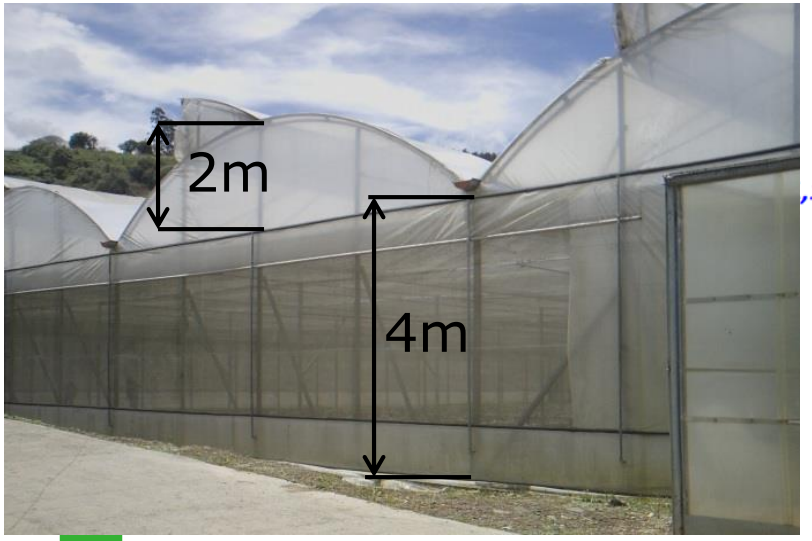
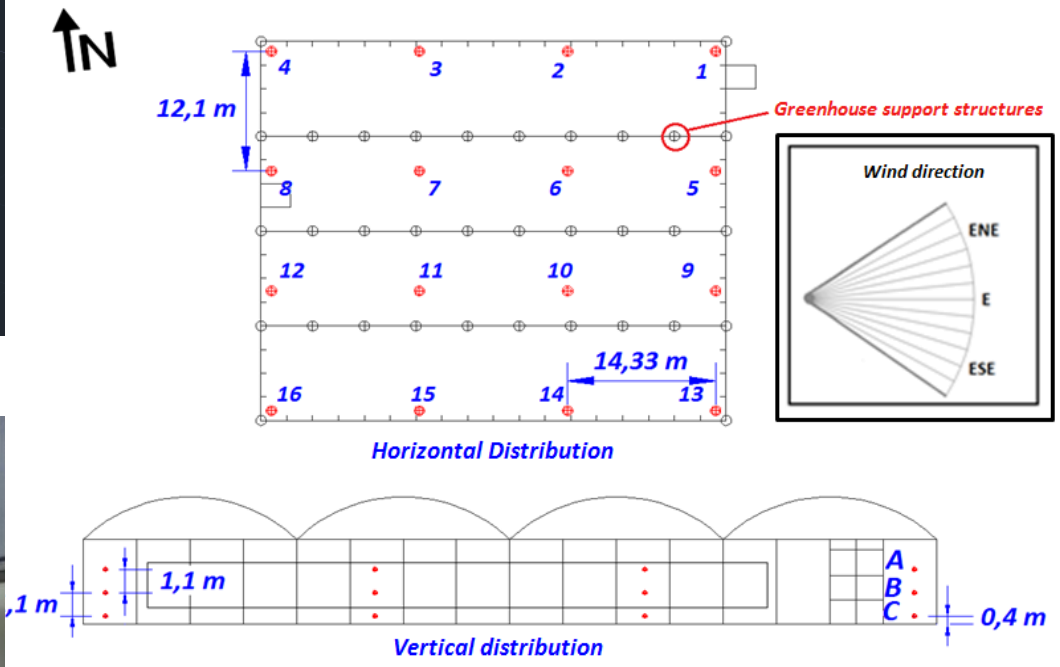
Study Object: Description

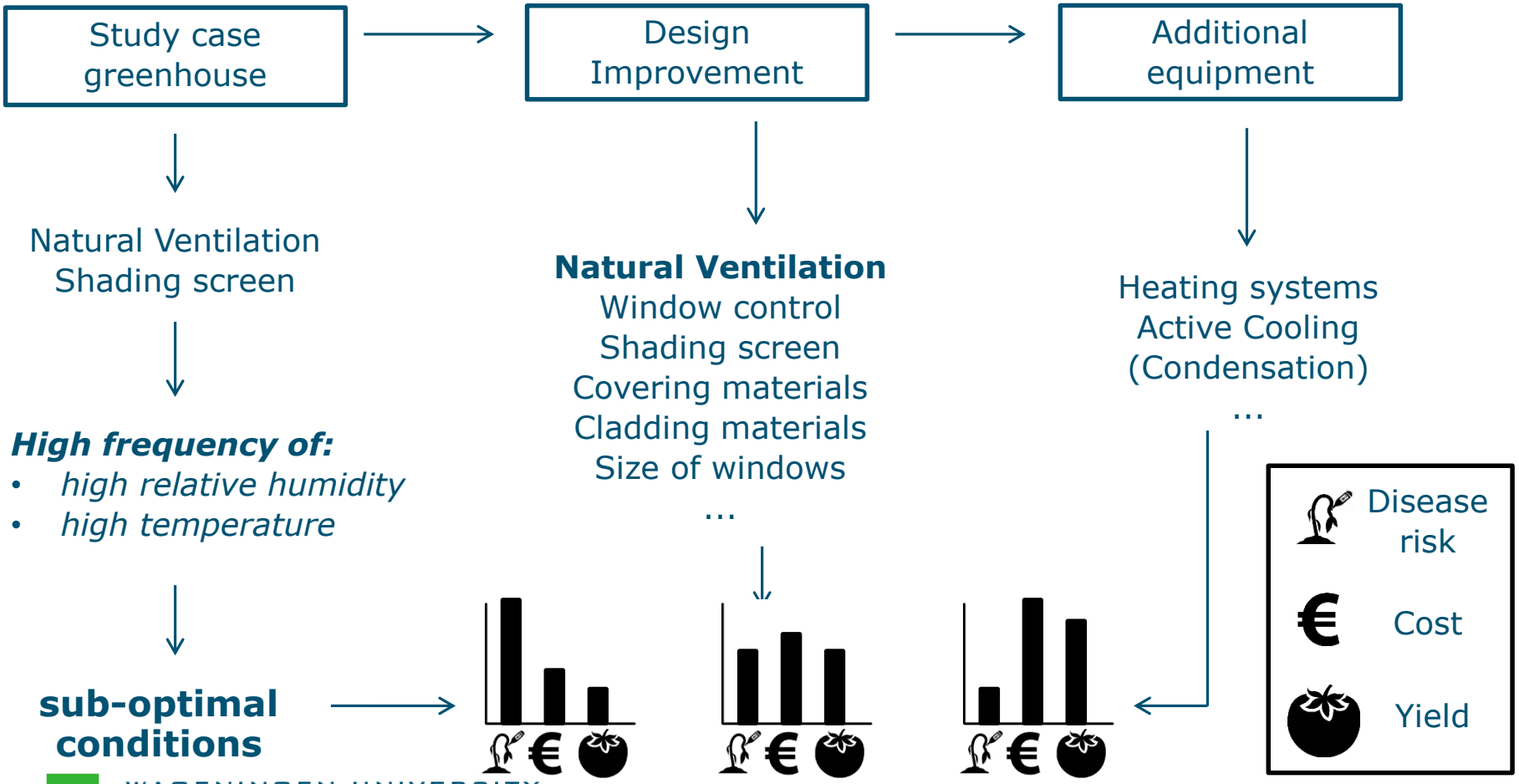




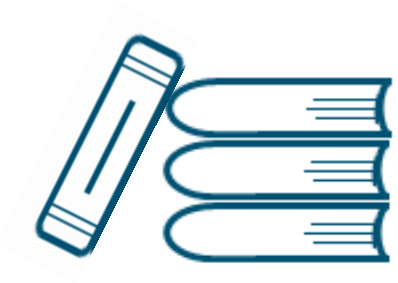
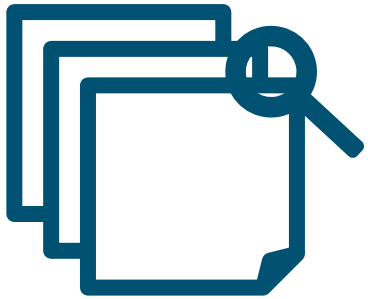
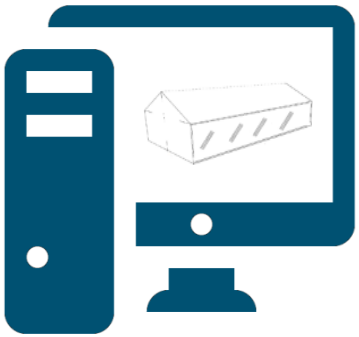


Sensor arrangement

Approach and assumptions



Materials and Methods

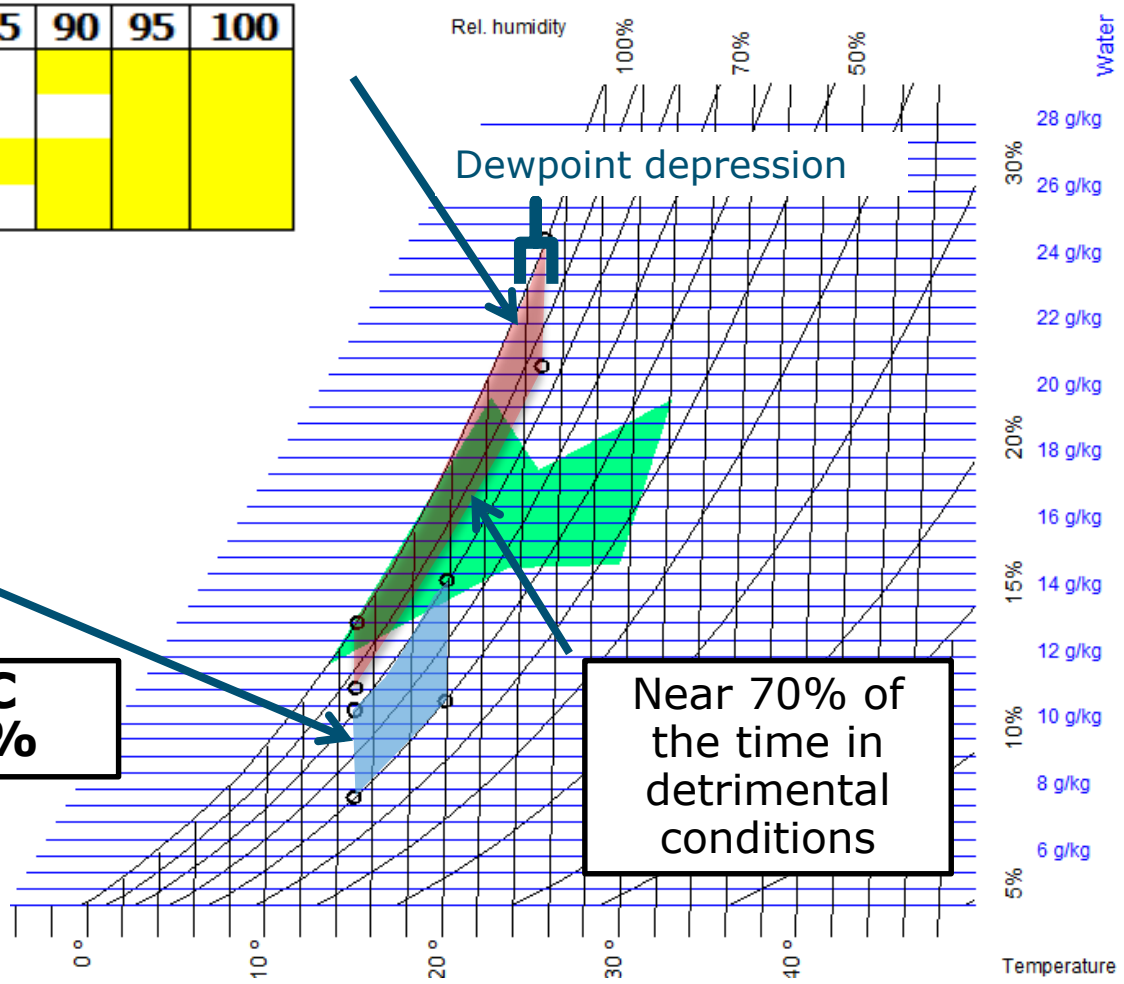
Literature review	Data analysis	modelling	Scenario analysis
			
 Conditions	• Internal microclimatological differences	• Model description	• Scenario development • Disease Risk Analysis

Definition of conditions

Temp. (°C)	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Grey mold																
Powdery mildew																
Downy mildew																
Late blight																

R.H.(%)	80	85	90	95	100
Grey mold					
Powdery mildew					
Downy mildew					
Late blight					

T: 15-20°C
HR: 60-80%

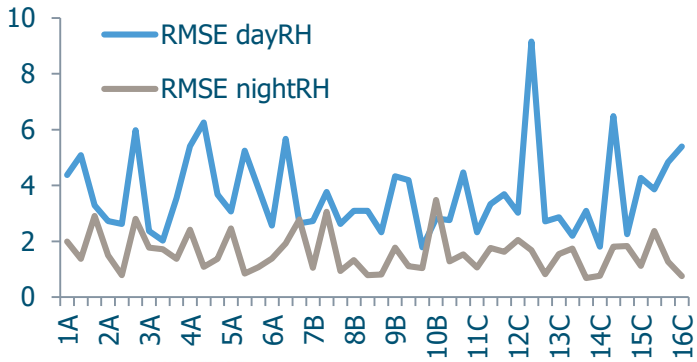


Near 70% of the time in detrimental conditions

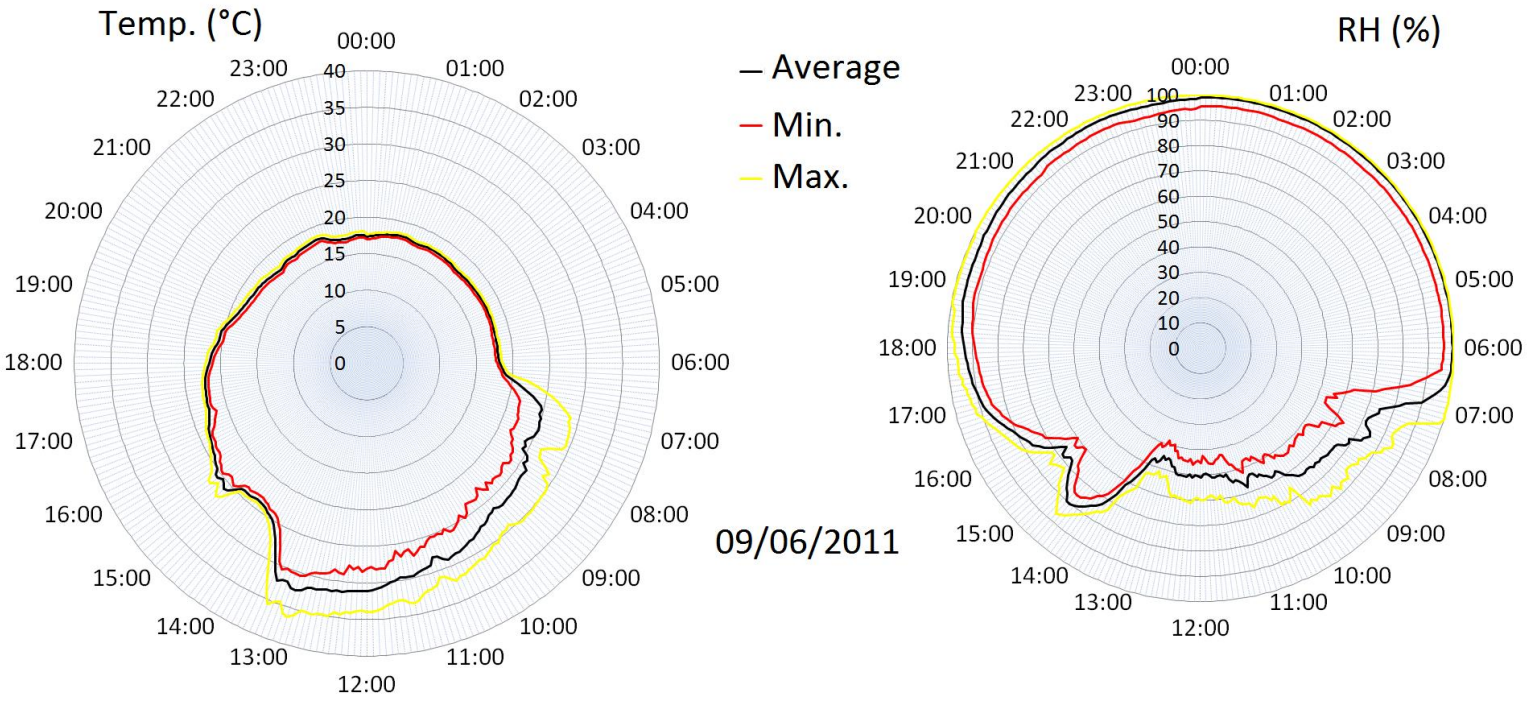
Internal microclimatological differences

Overall RMSE Range:
0,22°C to 1,28°C
1,3% to 5,18%

RMSE Day - Night



Daily differences



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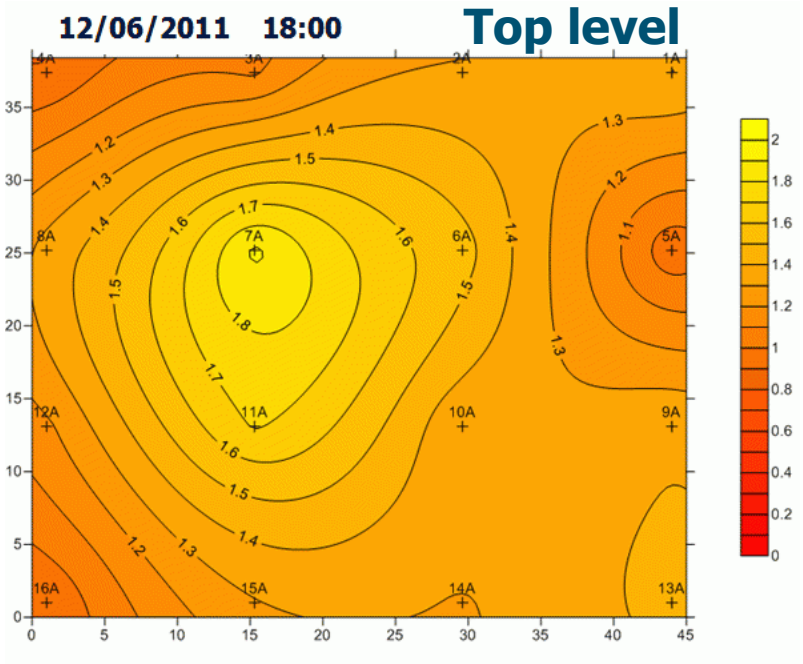
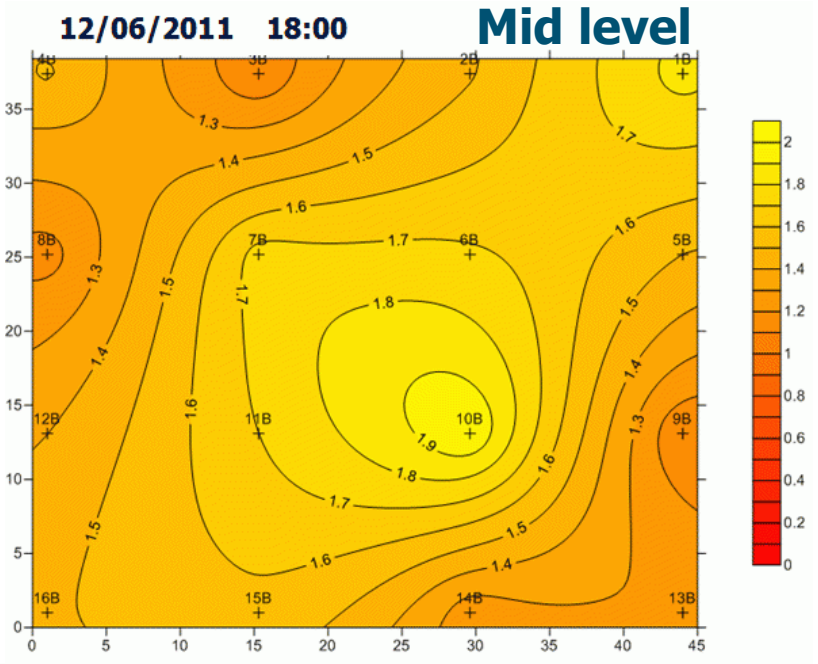
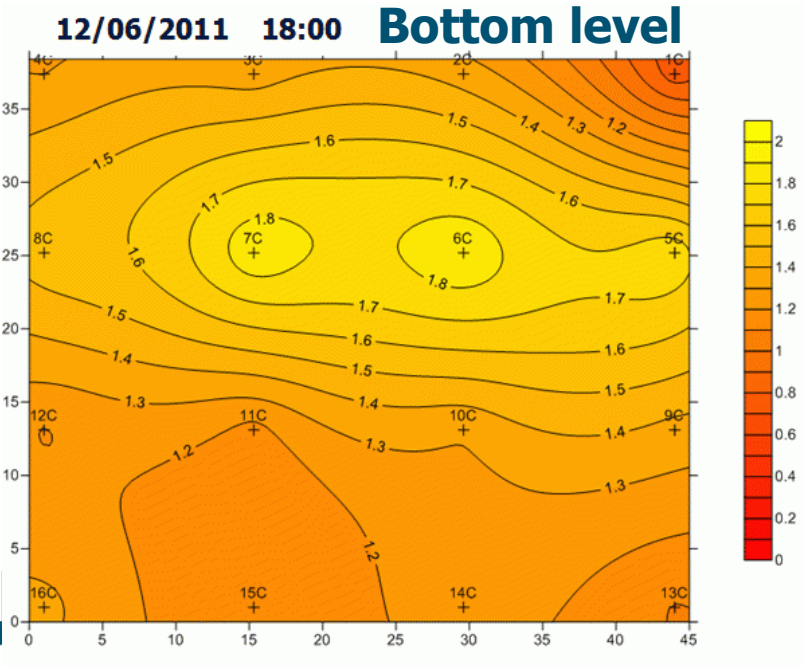
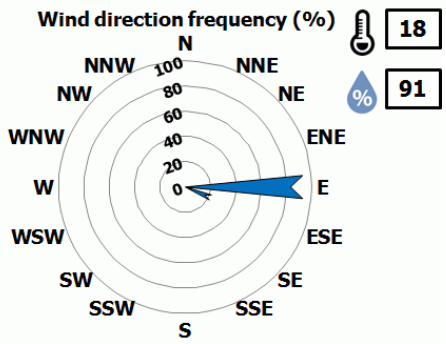








Dew point depression analysis

Climatic conditions

Model Description

Climatic Inputs

Global radiation
Temperature out
Vapour pressure out
CO_2 out
Wind velocity
Sky temperature
Soil temperature outer layer

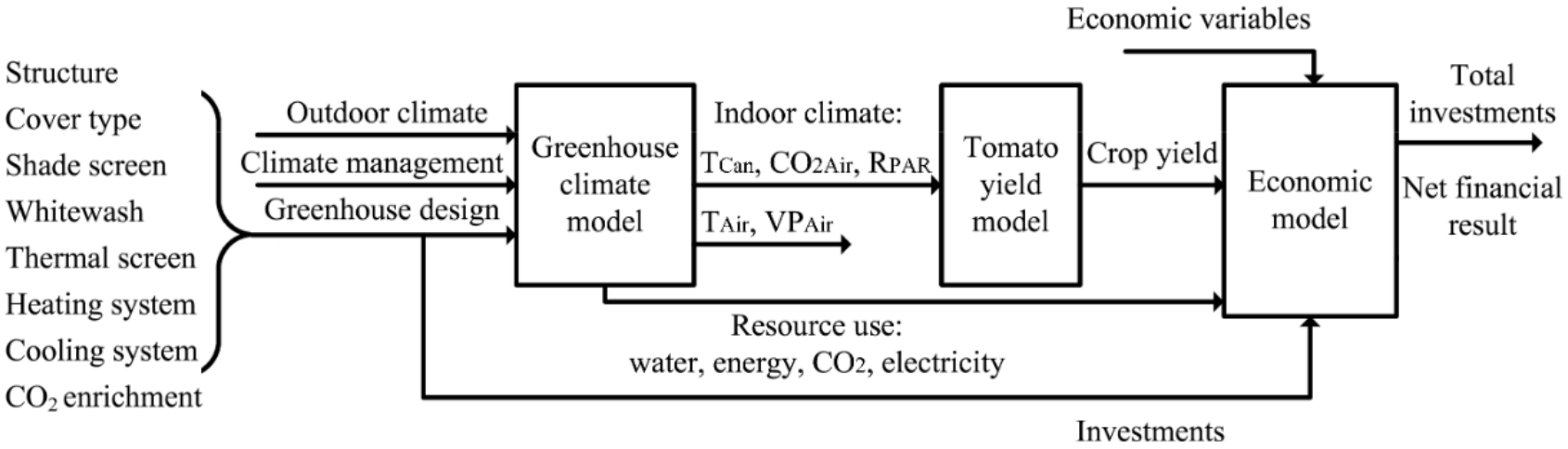
→

Vanthoor (2011) Model

→

Outputs

Temperature in
Vapour pressure in
CO_2 in
Yield
Net Financial Profit (NFP)

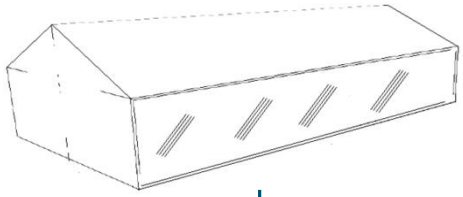


Source: Vanthoor (2011)

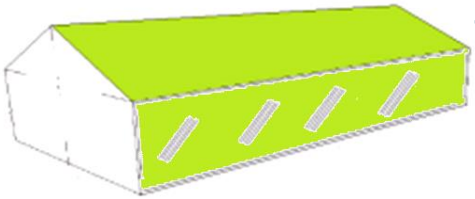
Scenario development

- Focus on night humidity control
- Increase ventilation rate
- Increase capacity of air to take moisture
- Decrease humidity

Nominal Case

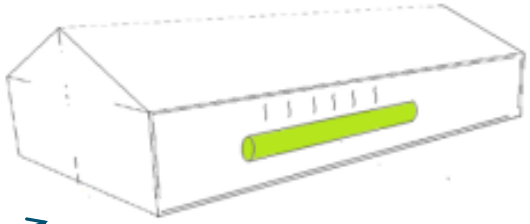


Natural ventilation improvement



Closed greenhouse

Only Heating

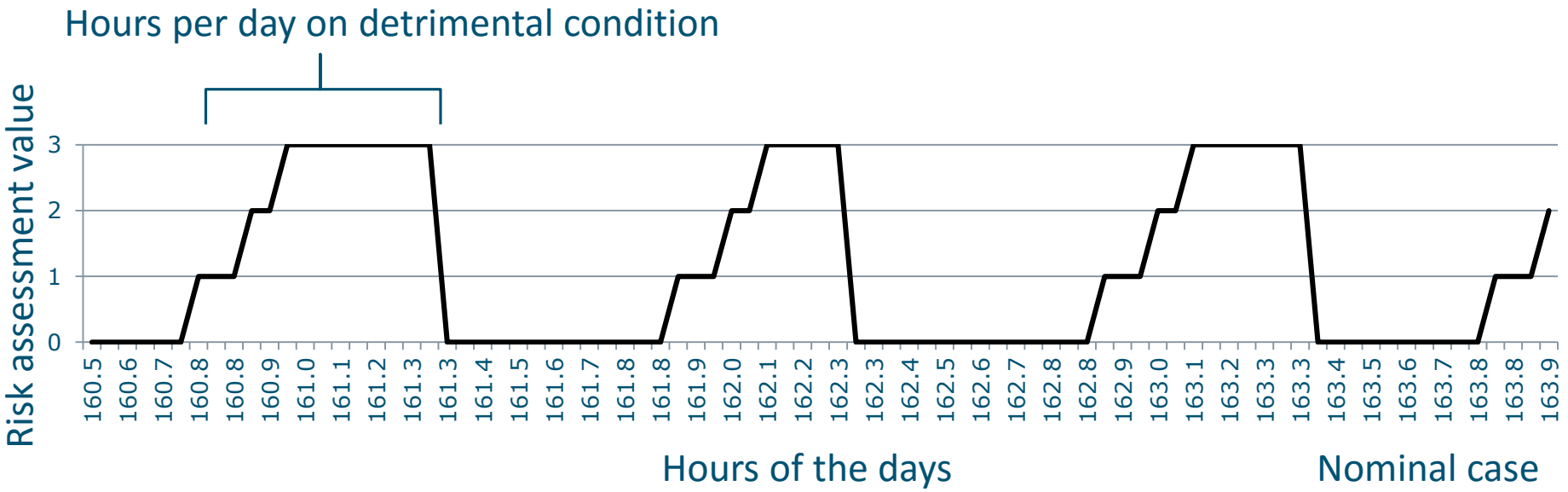


Heat Pump (condensation)

Disease Risk Analysis

Risk of infection	Conditions considered	Risk assessment value
None	Relative humidity outside the disease favorable condition	0
High	Relative humidity inside the disease favorable condition	2
Very high	Relative humidity and temperature inside the disease favorable condition/Conditions for the formation of condensation on the crop.	3

Risk of infection	Cumulative risk assessment value
Very high	18 or more
High	12 to 18
Moderate	8 to 12
Low	Less than 8
None	0



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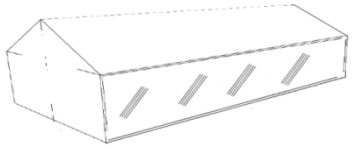
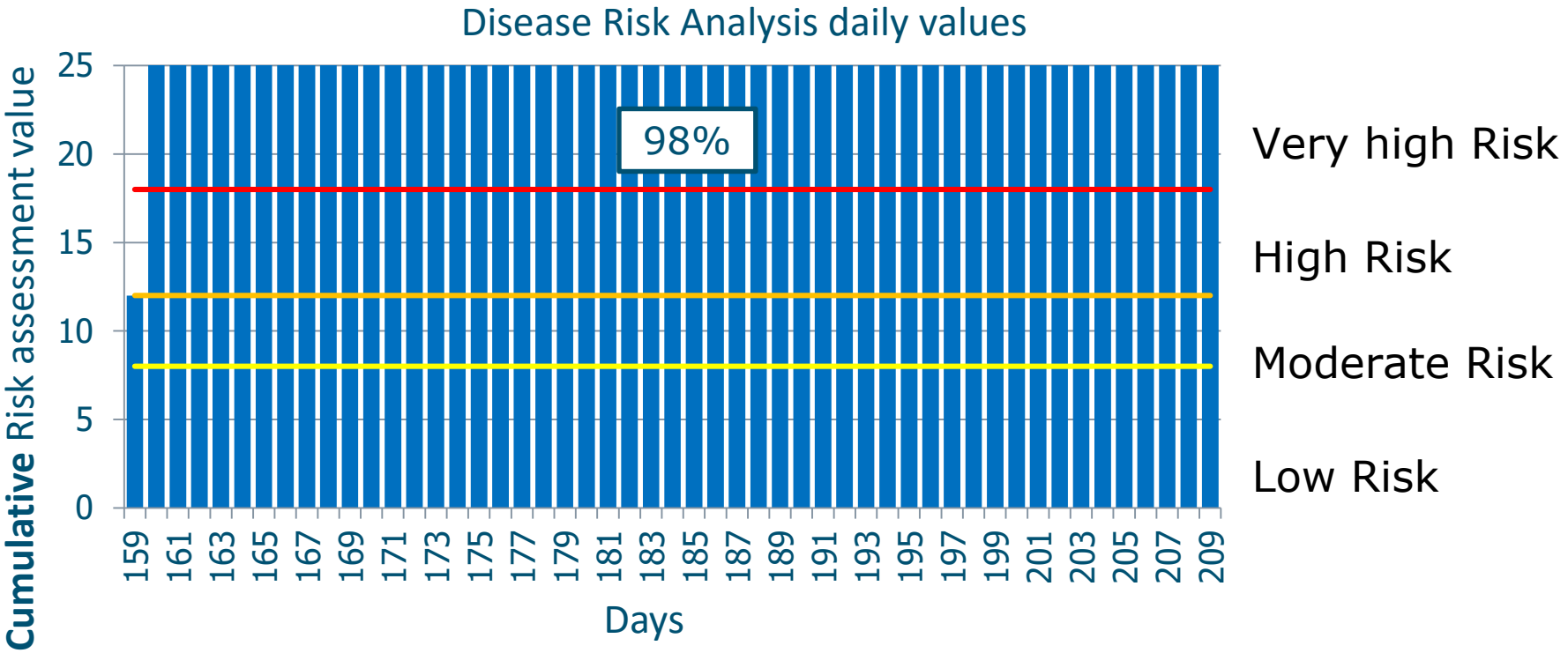
NOMINAL CASE



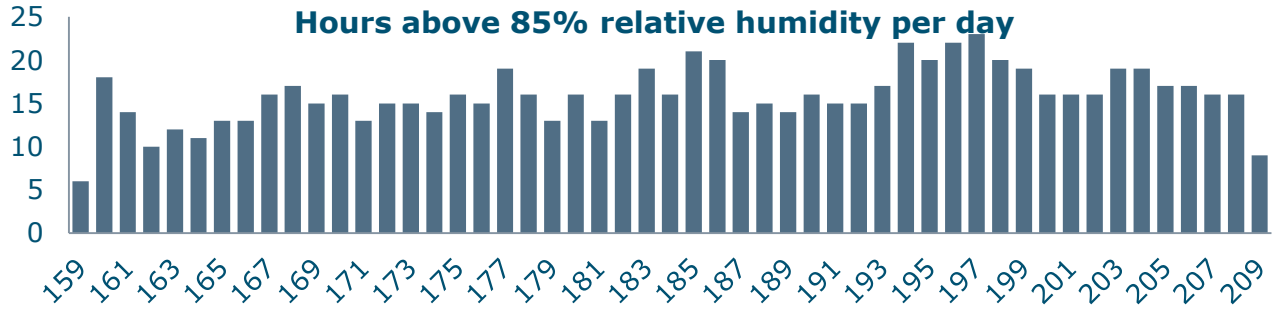


Very high Risk

High Risk

Moderate Risk

Low Risk



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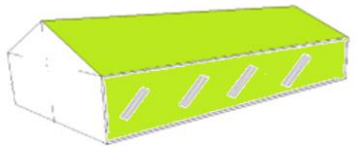
67,5% of the time, above 85%

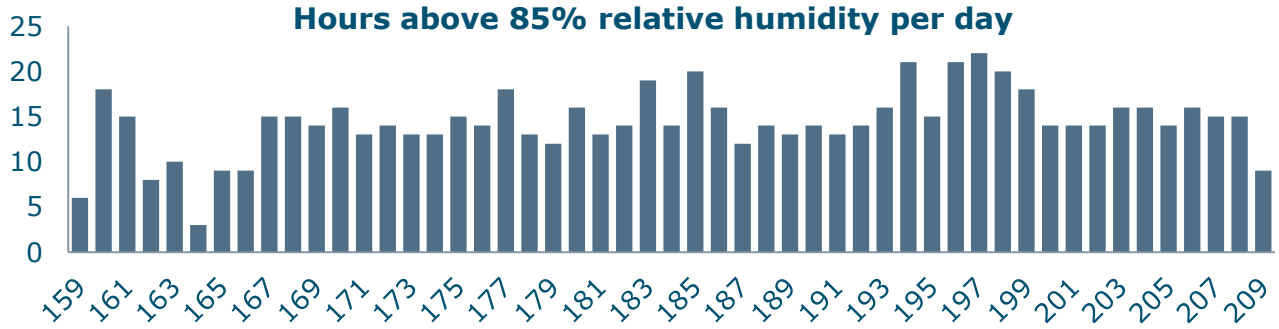
Natural ventilation improv.



Still high risk values for most of the series

Decrease of hours above high relative humidity

The improved natural ventilation mechanism is unable to stop detrimental conditions due to the amount of moisture in the outside air.



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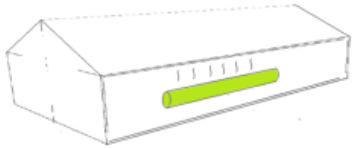
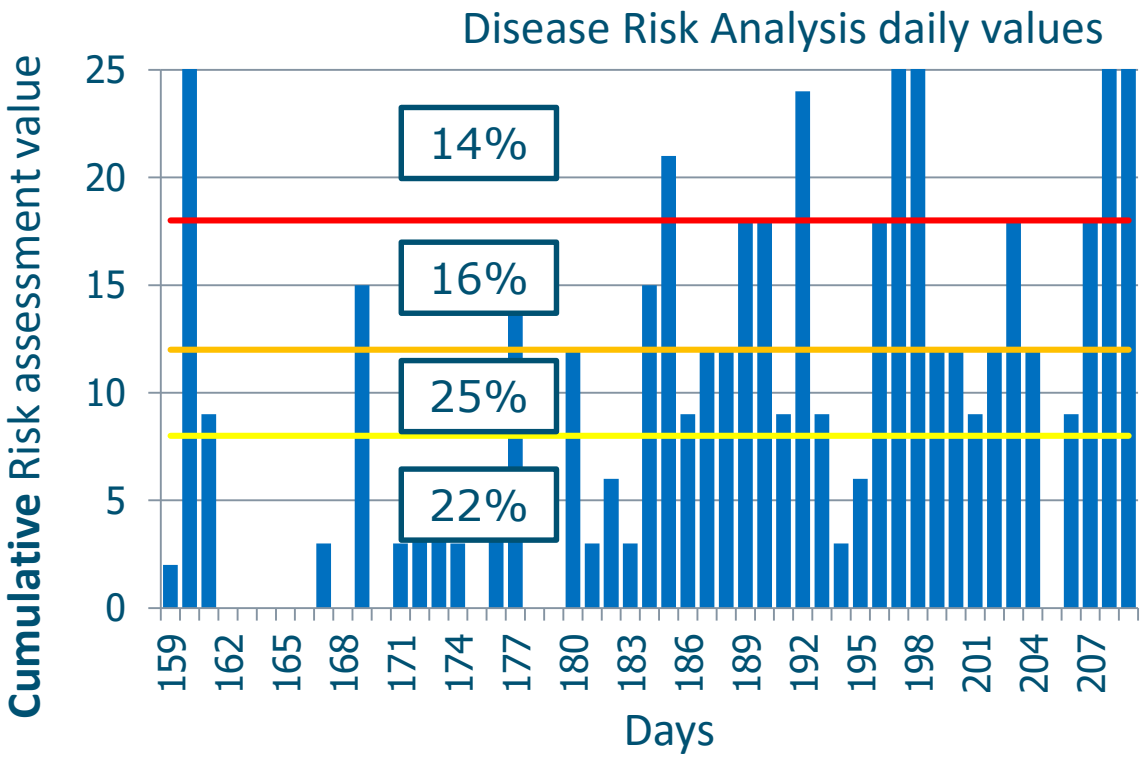
60% of the time, above 85%

Heating: temp in opt. night range.



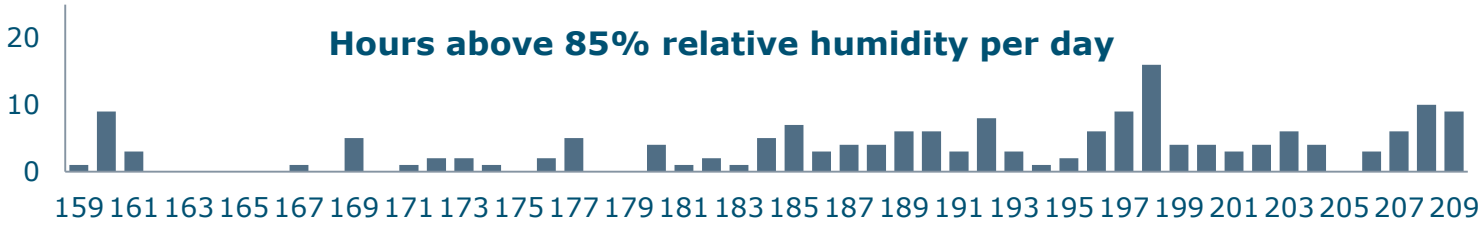


Very high Risk

High Risk

Moderate Risk

Low Risk



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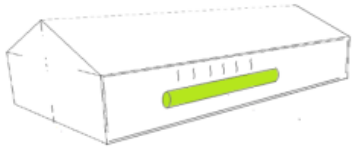
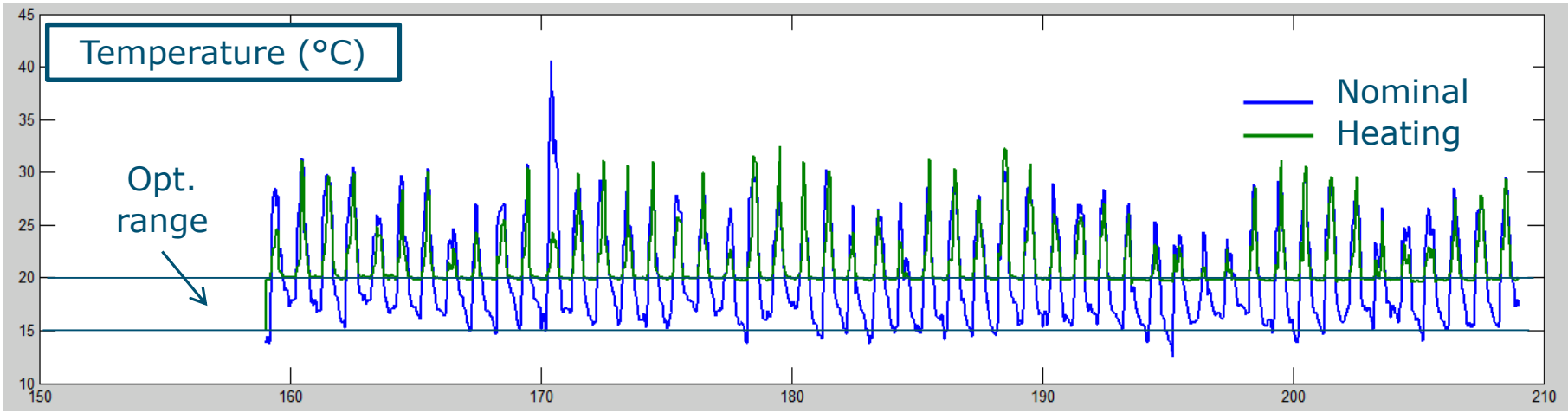
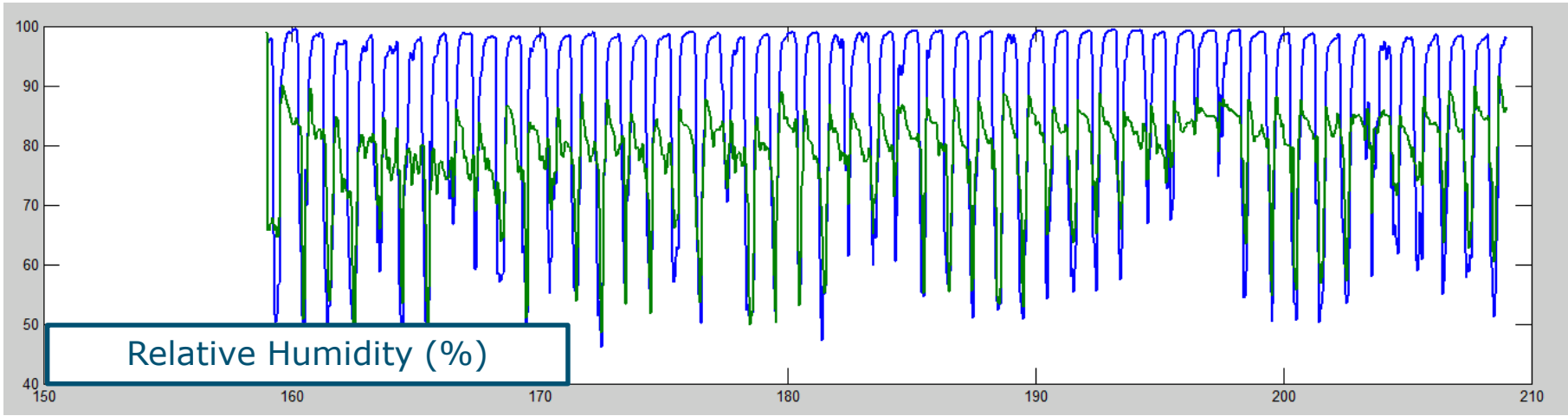
15% of the time, above 85%

Heating: temp in opt. night range.







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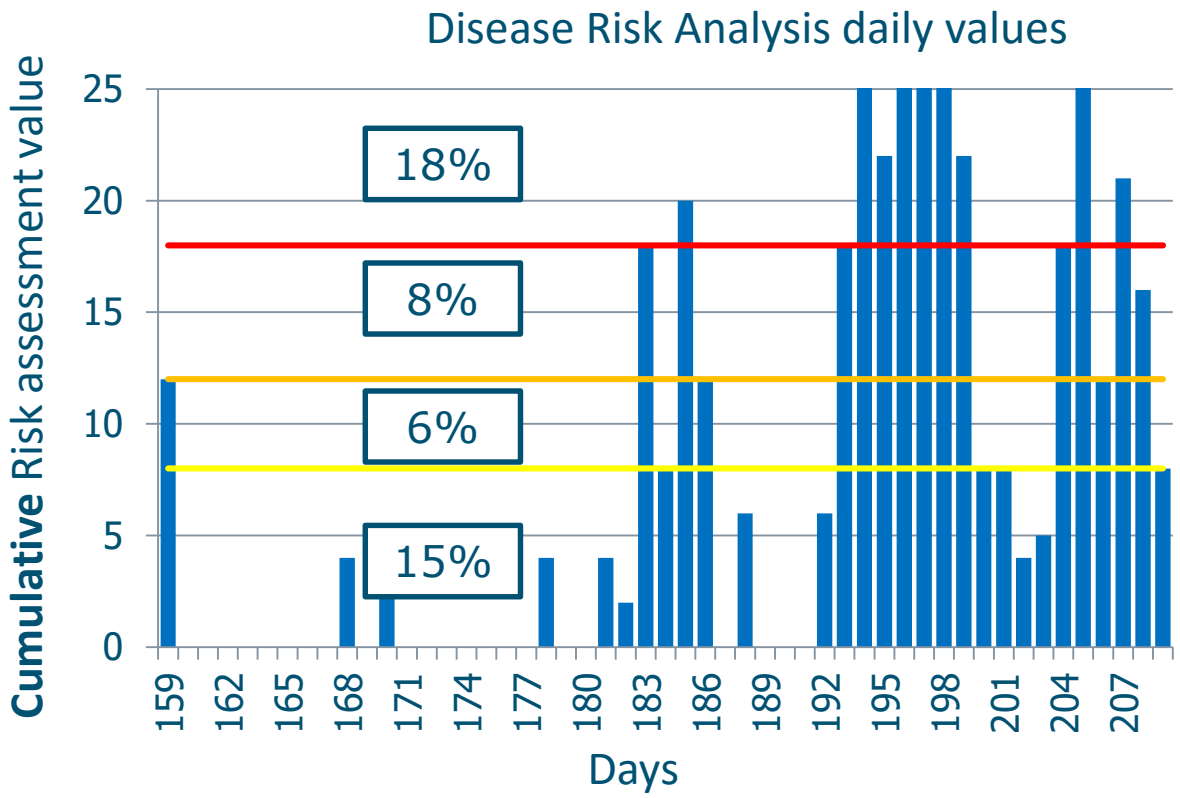
Heat pump: 12°C at evaporator



Very high Risk

High Risk

Moderate Risk

Low Risk

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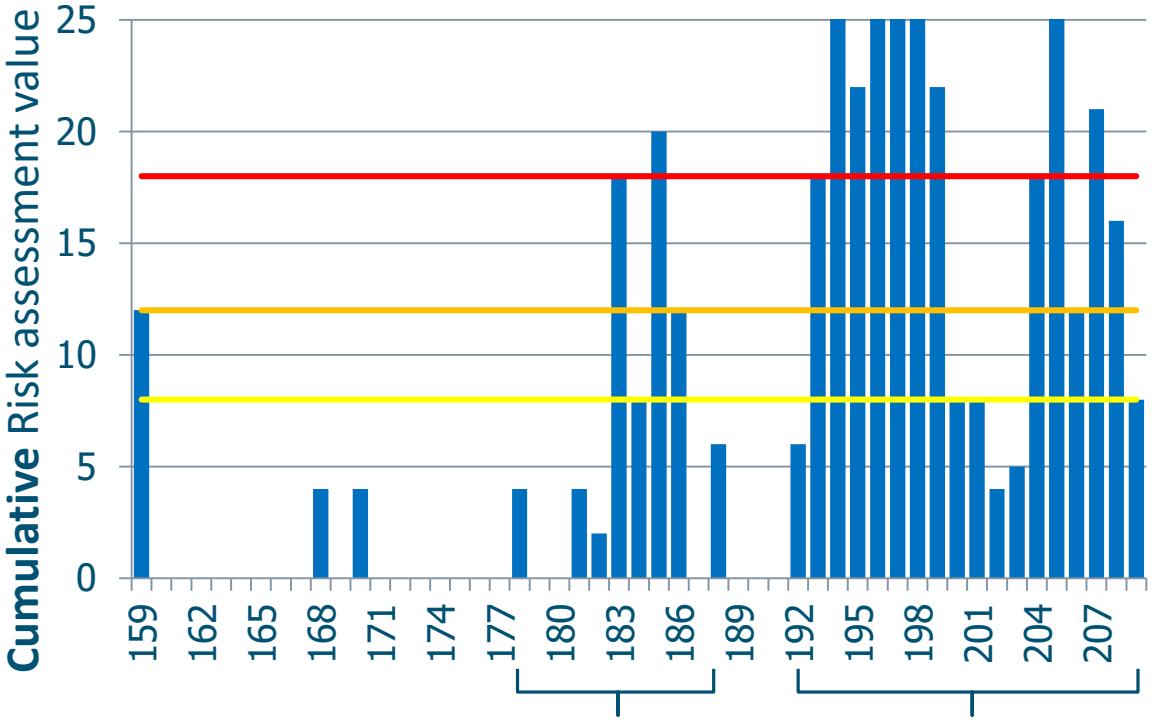
16% of the time, above 85%

Heat pump: lower evap temp.



Very high Risk

High Risk

Moderate Risk

Low Risk

When the temperature of the evaporator is set at 8°C, the risk of diseases is minimal, for the periods of high risk, a lower temperature of evaporator may be applied.

Preliminary conclusions

Natural ventilation ineffective

Solution towards dehumidification or heating (semi closed greenhouse approach)

Lower temperatures of the evaporator are needed to minimize risk

Feasibility analysis needed for implementation

On-going research

- Fixed costs of scenarios
- Water/energy recovery analysis and efficiency performance (detailed variable costs)
- Refining controllers to maximize performance

Thank you for your attention!

Discussion Points

- Other feasible solutions to lower inside relative humidity
- Drying period analysis

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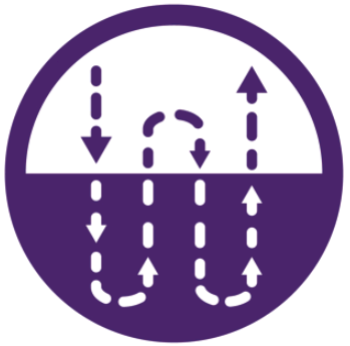
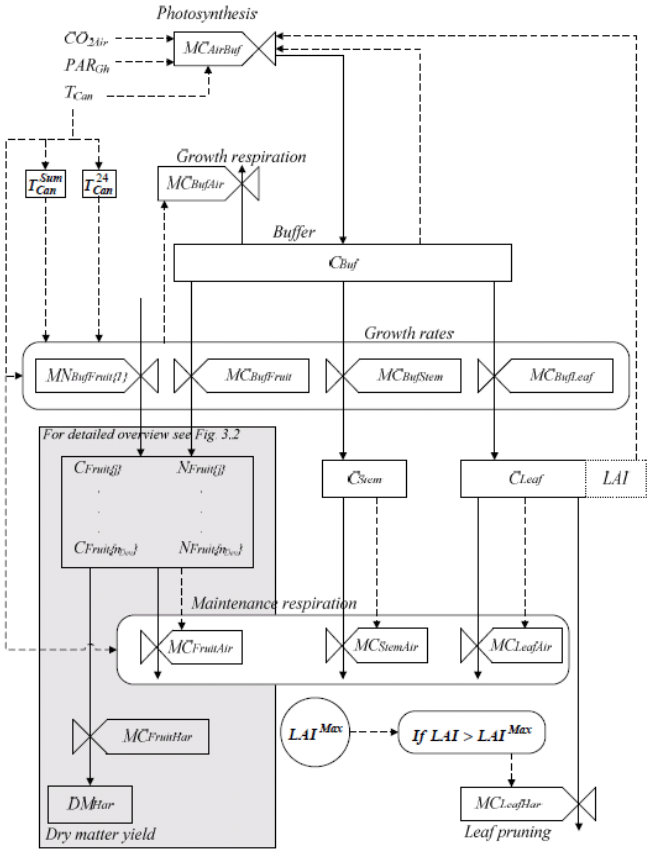
Model adjustment

Change of modelled crop

Implementation of dehumidification routines





Source: Vanthoor (2011)

Model performance

RRMSE:
Temperature: 9.37%
Relative Humidity: 7.96%