AI based decision support systems for sustainable agriculture

prof. dr. Marko Debeljak

Department of Knowledge Technologies, Jožef Stefan Institute
Ljubljana, Slovenia
e-mail: marko.debeljak@ijs.si

AI based Knowledge Technologies

Advanced information technologies:

- Discovering and structuring
- Storage and management
- Use

KNOWLEDGE

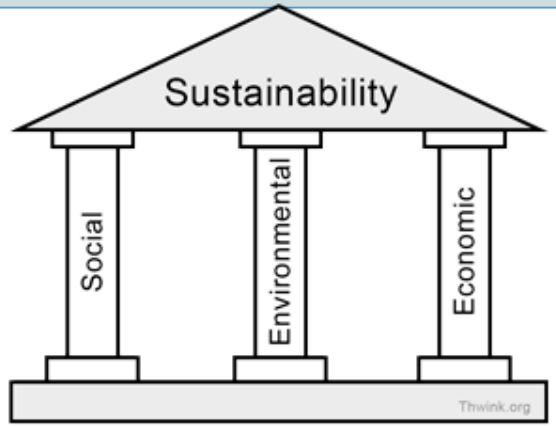
Several AI based knowledge technologies

- **Explainable AI: machine learning, data mining, text mining, network analysis**
- **Decision modelling: integration of expert domain knowledge and knowledge obtained from data**

Our goals:

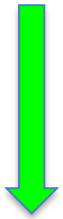
- addressing complex research challenges in agriculture
- development and application of new and improved AI based KT
- applying KT approaches to scientific and practical problems in agriculture

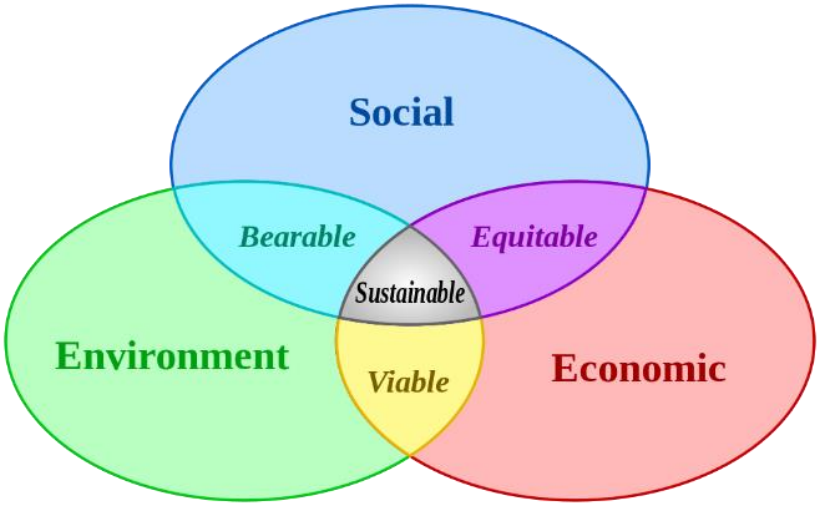
Sustainability



World Summit on Sustainable Development 2002

"meeting the needs of the present without compromising the ability of future generations to meet their own needs."
Brundtland 1987





Environmental pillar
The **environmental functions** to connect the **management** and **conservation** of **natural resources**

Economic pillar
The **economic functions to** provide **prosperity** to the community.

Social pillar
Several social functions which support to **create healthy and livable communities**

Agriculture

Complexity of decision making

Crop management

Consumers

Economic goals

Environmental constraints

Farm to fork

Biodiversity Strategy

SDG

Green deal

data

Knowledge

Agriculture - challenges

Concerned farmers

Decision support systems (DSS)

Optimistic farmers

Decision – Decision support systems

DECISION — The **choice** of one among a number alternatives

A **process** of making the choices — **DECISION MAKING**

DECISION MAKING is a PROCESS

1. Assessing the **problem**
2. Collecting and verifying **information**
3. Identifying **alternatives**
4. **Making** the **choice**
5. Evaluating **decisions**

Making complex decisions

Complex task

Improvements of the **effectiveness** of decisions

Assistance of decision maker

Interactive computer tools

DECISION SUPPORT SYSTEMS

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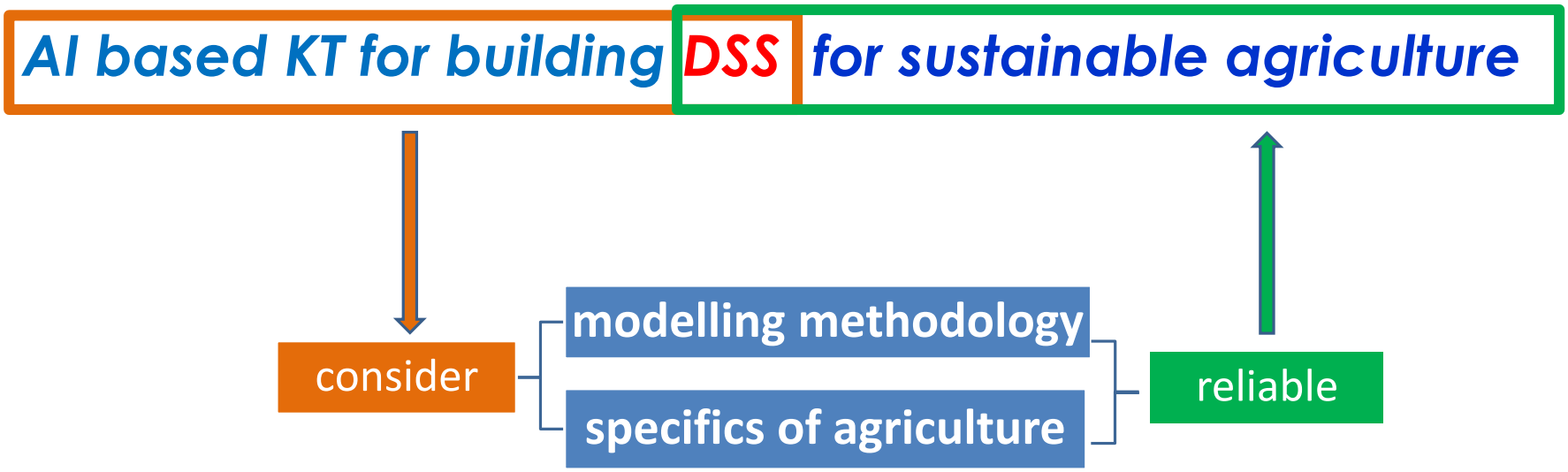
Introduction



Modelling methodology

Steps

- Conceptual framework
- Architecture of DSS
- Modeling procedure
- Integration

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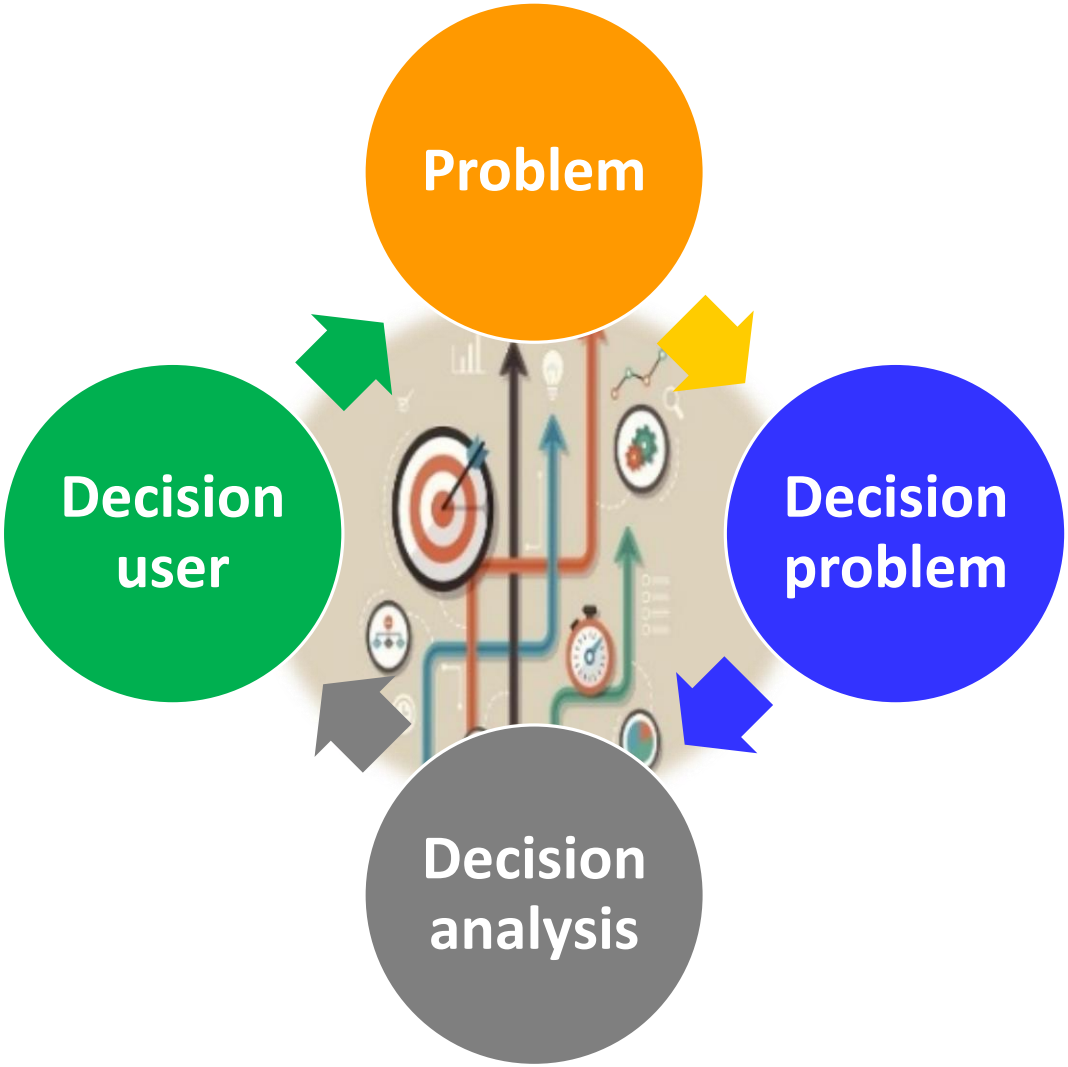
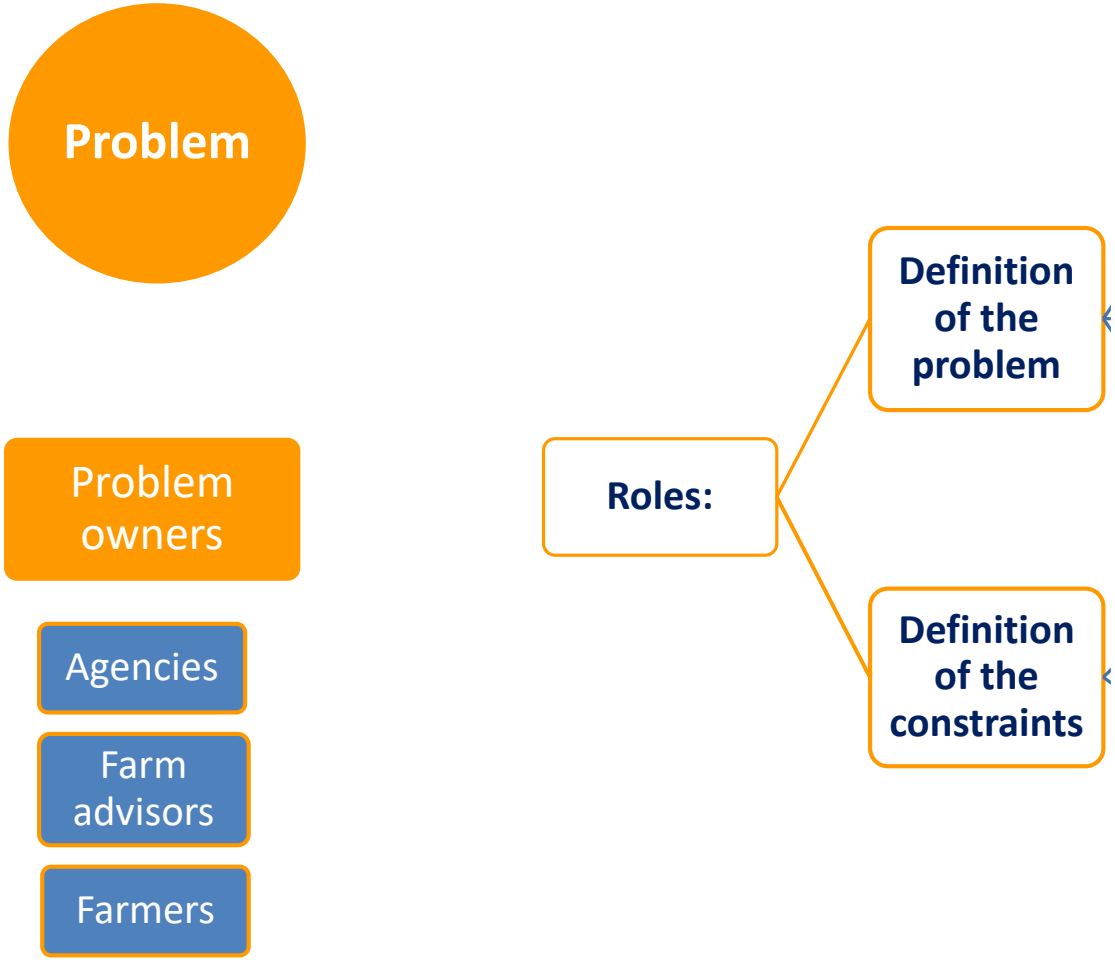
Conceptual framework

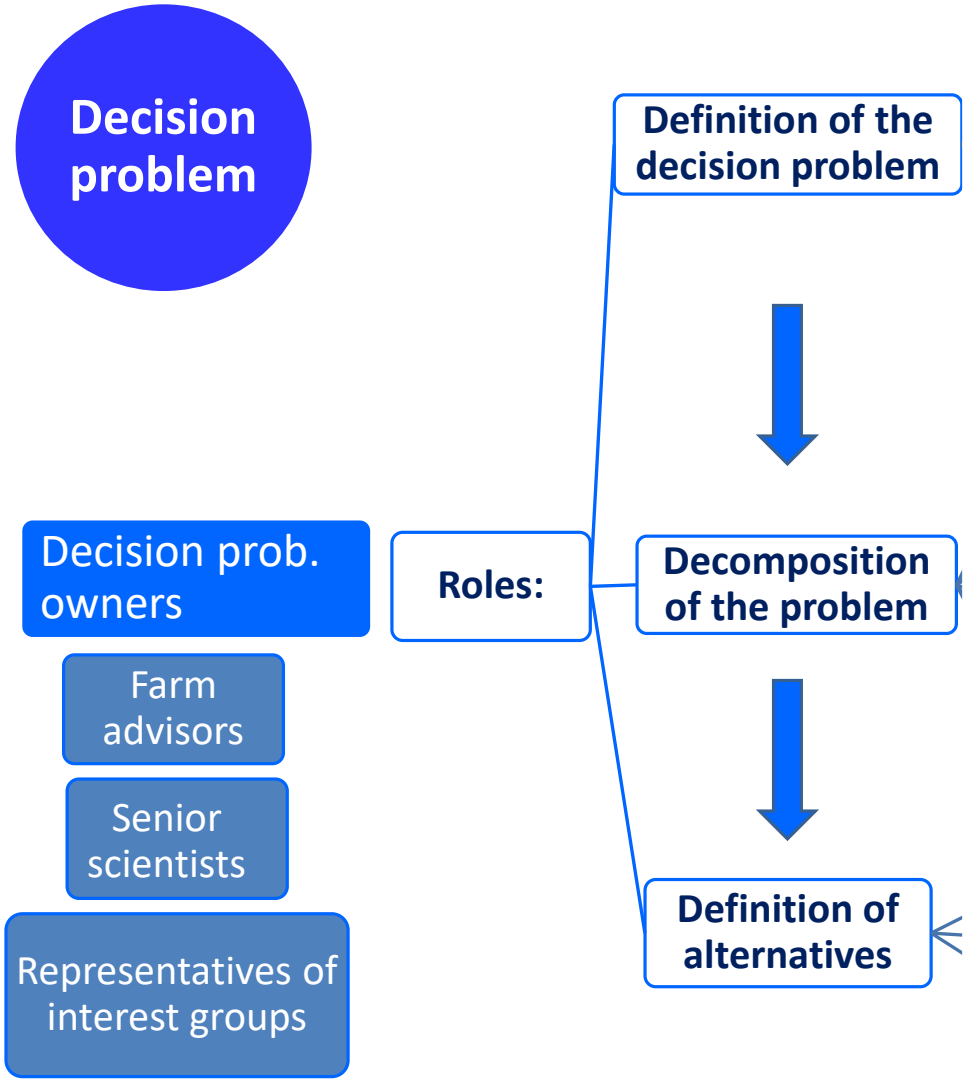


Conceptual framework



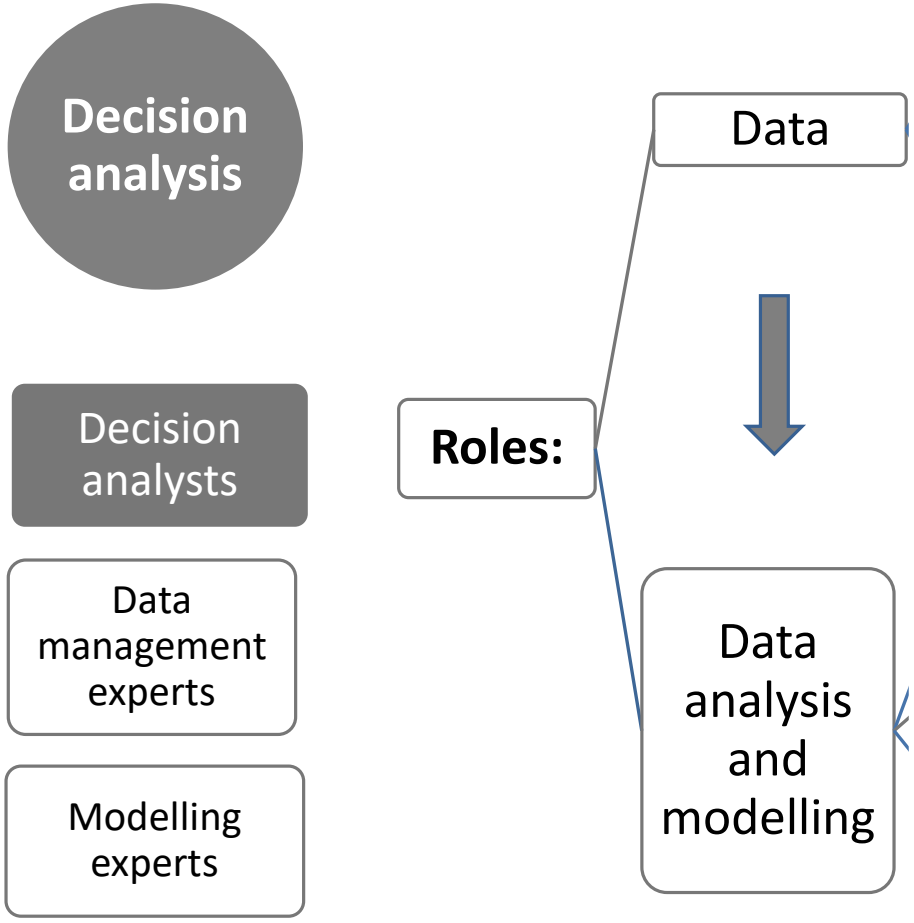
Example: Water pollution with pesticides.

Conceptual framework



Example: Active substance, concentration, time of application.

Conceptual framework



Example: Data mining and qualitative decision modeling

Conceptual framework

Decision user

Users

- Farmers
- Farm advisors
- Students

Roles:

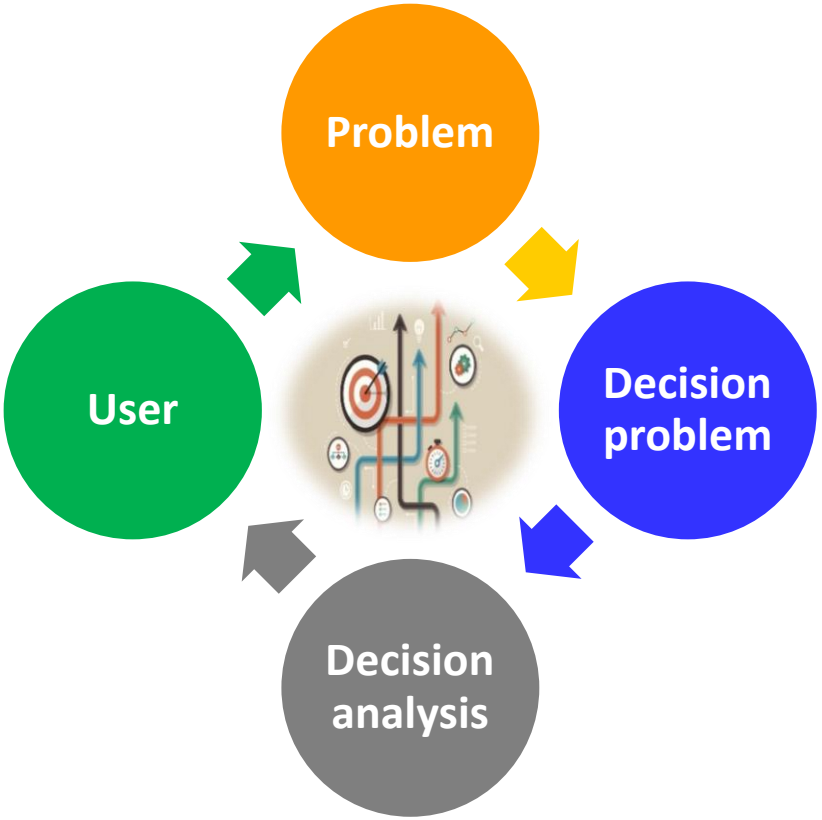
Type of implementation of proposed solutions

- User
- Usage
- Tool
- History

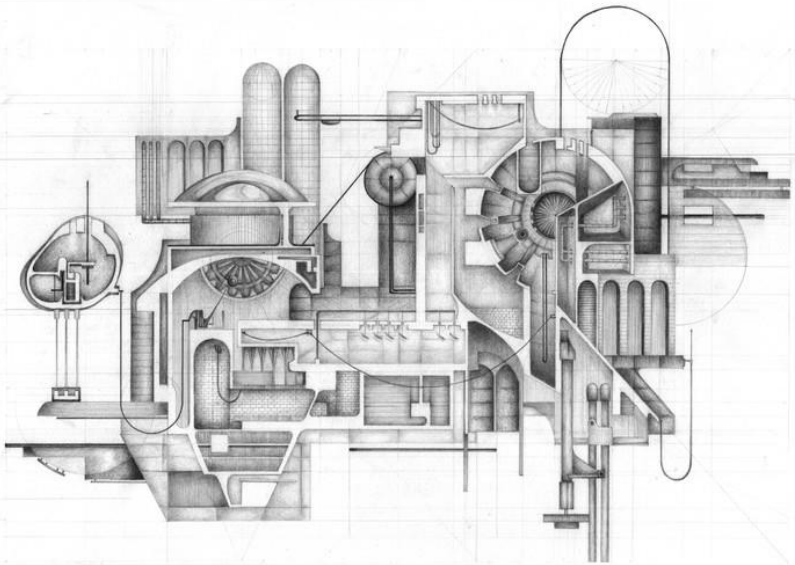
Example: Phone App, personalized support: Isoproturon before drainage period with 50% reduced concentration

Modeling methodology

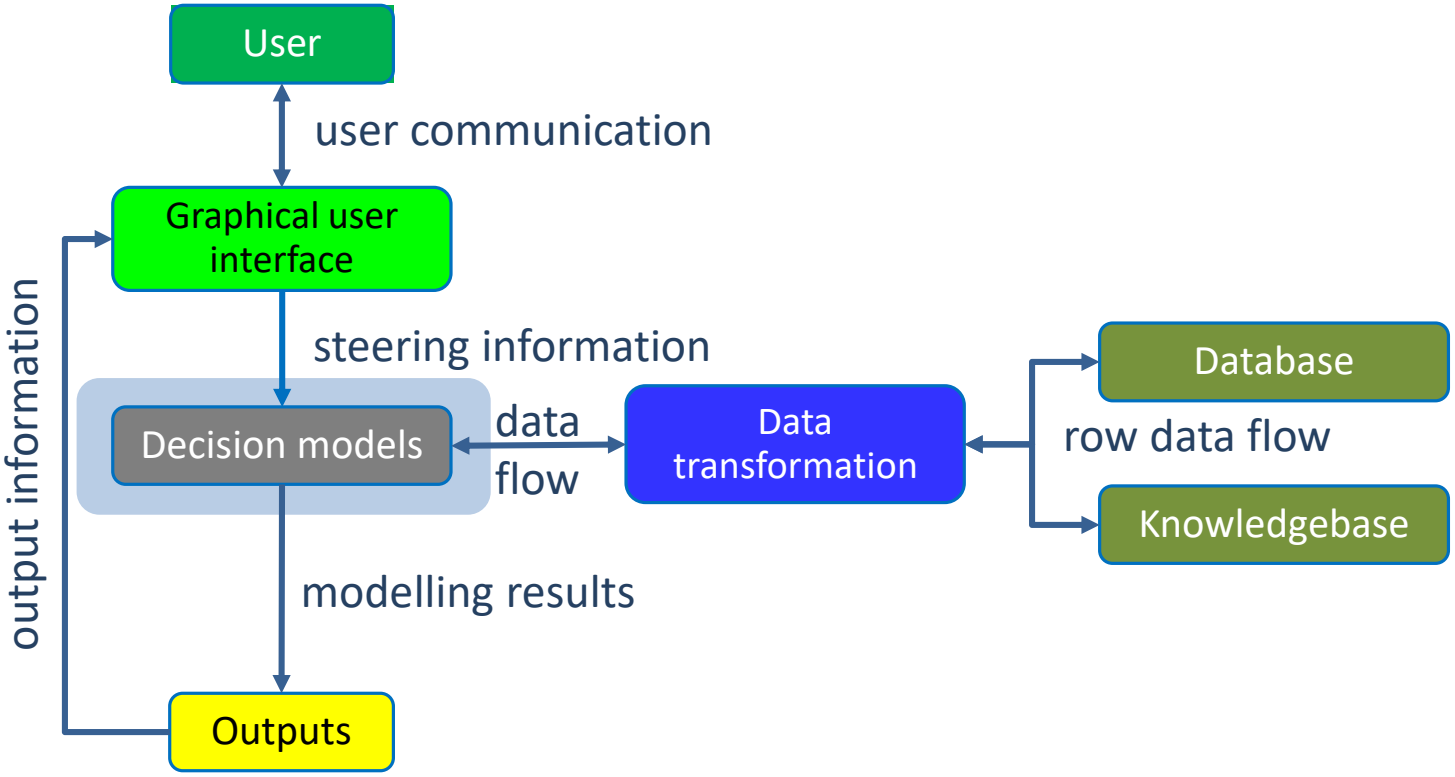
Conceptual framework of DSS



Architecture of DSS



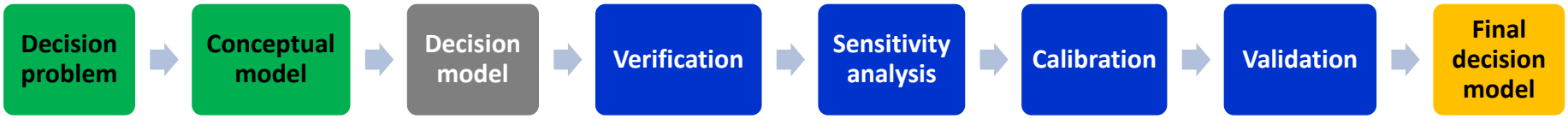
Architecture of DSS



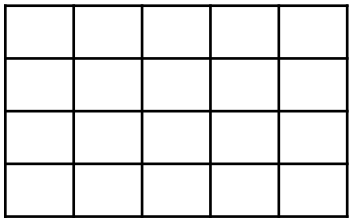
Modeling procedure

Decision models

Golden roles of ecological modelling

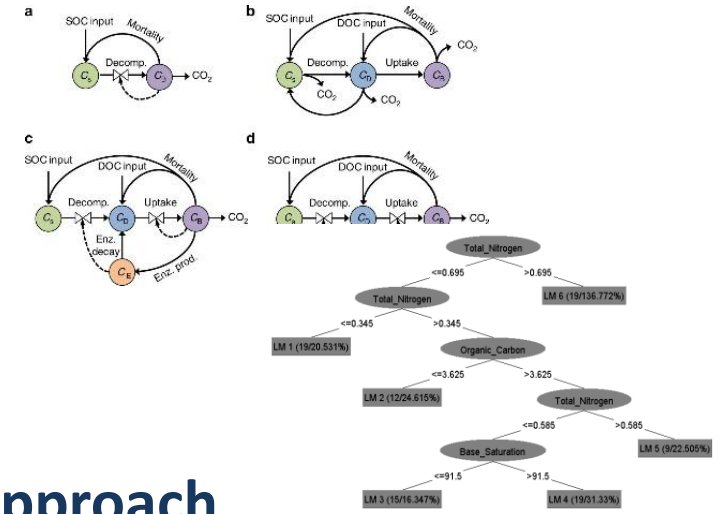


Modeling procedure



Data

Machine learning
Data/Text Mining



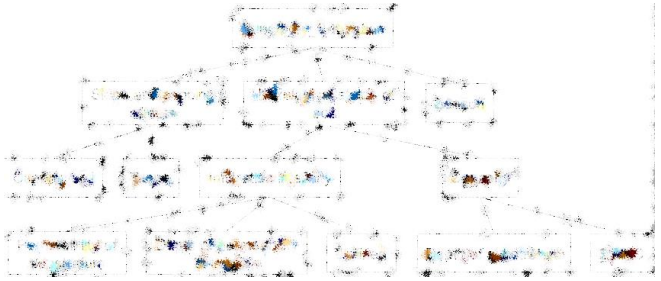
Knowledge discovery from data

Problem driven knowledge based approach

Expert based Knowledge

Domain experts

Knowledge Modelling



Modeling procedure

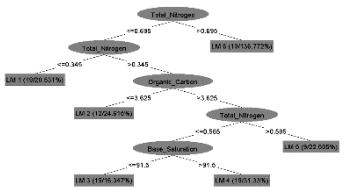
Decision model

Multi Criteria Decision Analysis (MCDA) → to generate → Multi-Attribute Decision Models (MADM) → using → DEX (Decision EXpert) integrative methodology

Experts

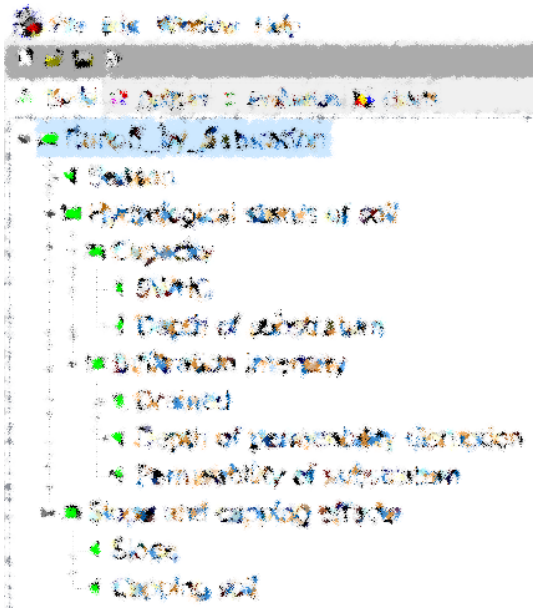
Expert based knowledge

Decision Modelling



AI based knowledge

Data



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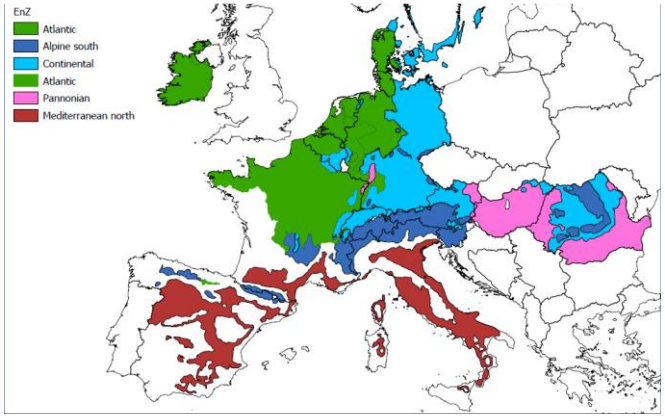
Modeling procedure

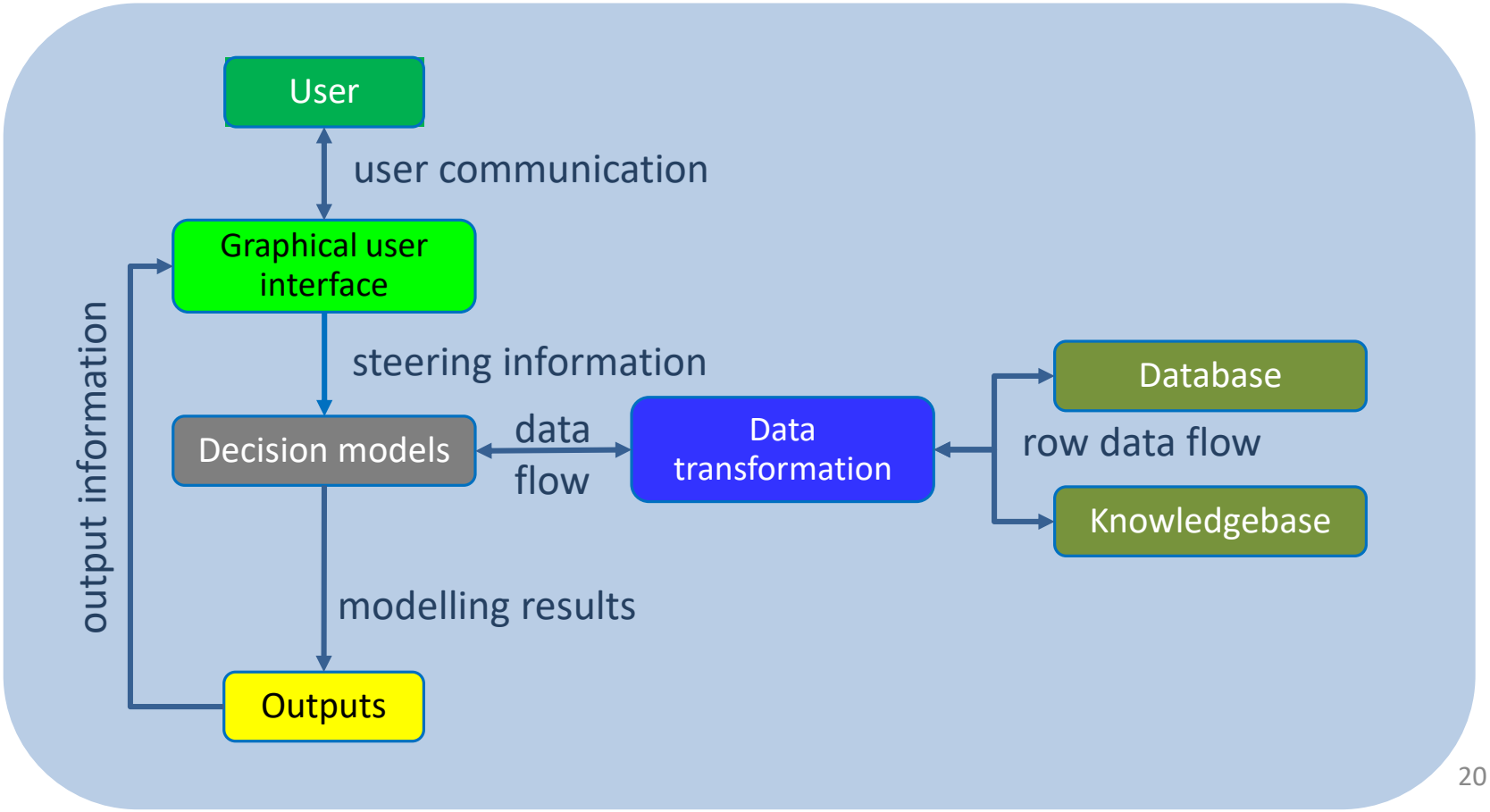
Decision models



Verification → Sensitivity analysis → Calibration → Validation

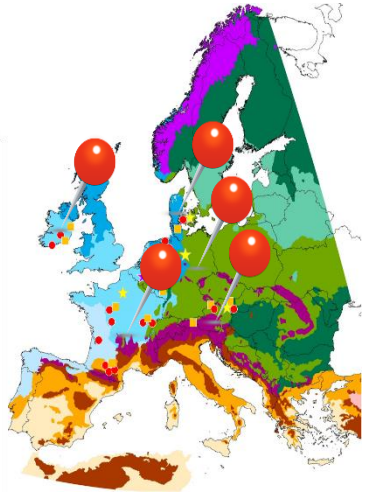
Integration

Linking modules into operational DSS



Integration

9. Validation of DSS



Implementation

Recently finished EU projects:

- EVADIFF
- LANDMARK: Soil Navigator
- TomRes: Resource amplifier
- TRUE: PathFinder

Ongoing EU projects (6)

- IPM decisions
- EUdaphobase
- COCOREADO
- RADIANT
- BENCHMARKS
- WEFE4MED

Implementation of presented decision modeling methodology

DECISION SUPPORT SYSTEM FOR ENVIRONMENTALLY SAFE APPLICATION OF PESTICIDES USED IN AGRICULTURE – EVADIFF

Evaluation de modèles existants et développement de nouveaux outils d'aide à la décision pour la prévention des pollutions diffuses par les produits phytopharmaceutiques - EVADIFF

Marko Debeljak
Vladimir Kuzmanovski
Aneta Trajanov
Sašo Džeroski

Jonathan Marks-Perreau
Benoit Real
Florence Leprince

Modelling constraints

Decision maker: Farmer adviser

Application area: France

Application scale: field

Data and expert knowledge provider

30.000 experimental plots

Biochemical lab: 25.000 research tests / year

Climatic, crop and cultivation data

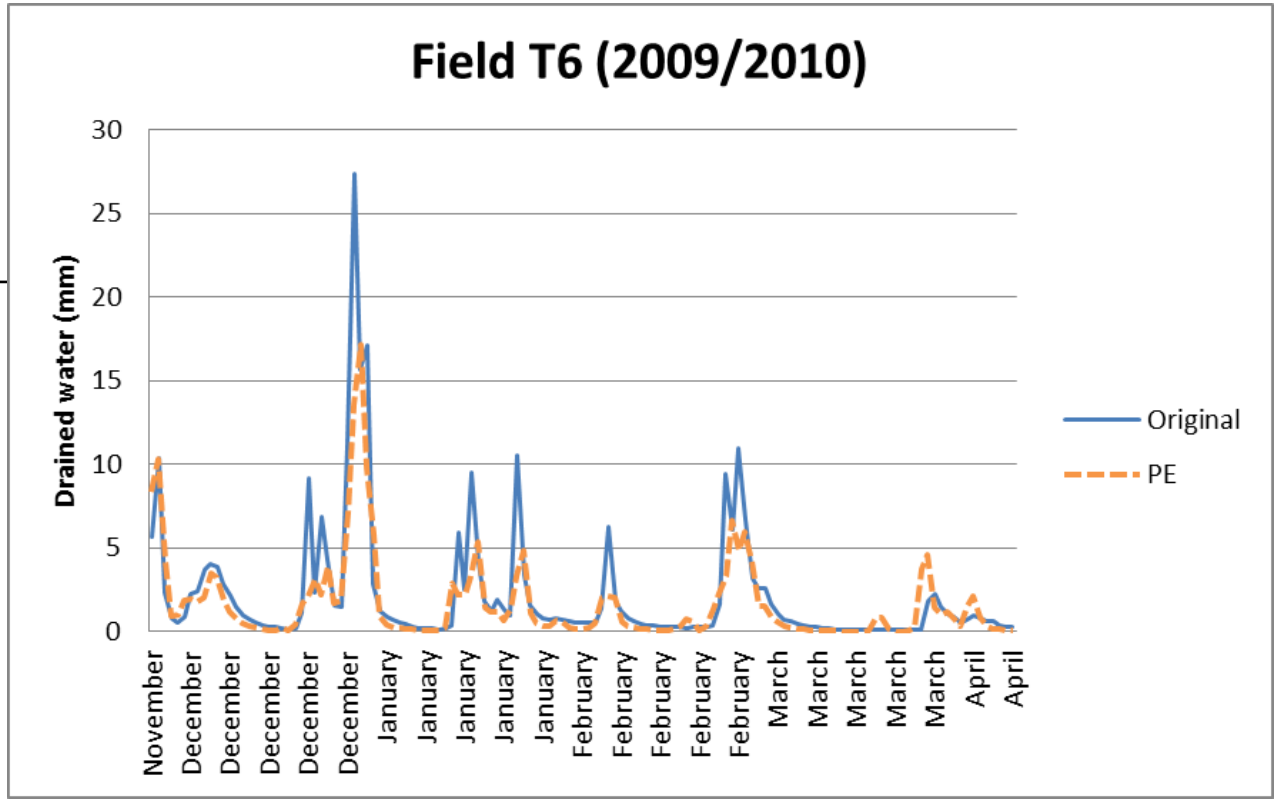
Expert knowledge

Prediction DM models

DRAINAGE WATER FLOW

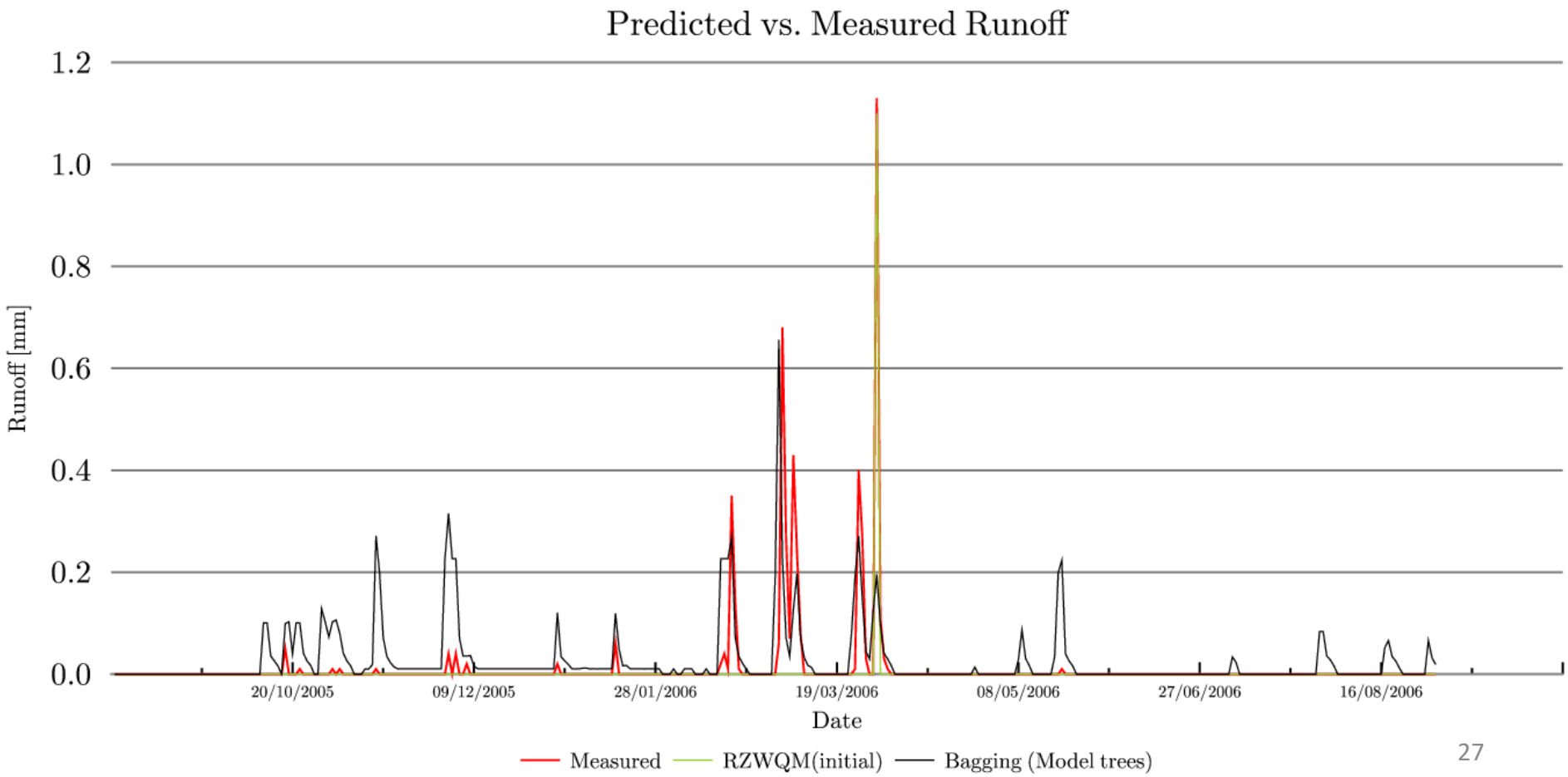
Model (All/T4)

$$
\begin{aligned}
Drainage = {} & 0.0196445 * RainfallA1 * Temp \\
& + 0.33246 * DrainageN1 \\
& + 0.000662861 * CDCoef^2 * RainfallA1^2 * Slope \\
& + 0.00000107253 * Runoff * DrainageN1 * Temp^2 * RainfallA1^2 \\
& - 0.00115983 * Runoff^2 * DrainageN1 * Slope^3 \\
& - 0.00114057 * Temp^2 * RainfallA1 \\
& + 0.00153725 * RainfallA1^2 \\
& + 1.63563 * Runoff * Slope \\
& - 1.90622 * Runoff \\
& - 0.0231748 * Slope^2 * RainfallA1 \\
& + 0.0654042 * RainfallA1 * Slope \\
& - 0.00755737 * Slope^3 * CDCoef^3 * Runoff^2 \\
& + 0.0675951 * Slope \\
& - 0.146702
\end{aligned}
$$



Prediction DM models

RUNOFF WATER FLOW (T4 2005/2006)

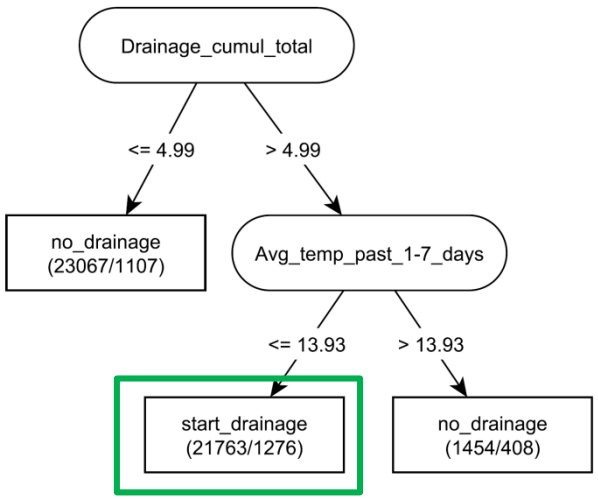


Prediction DM models

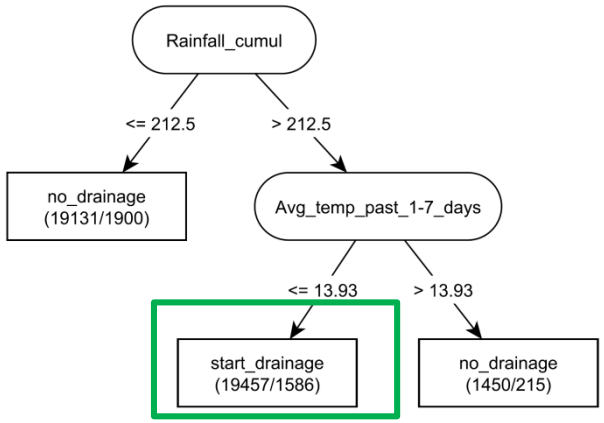
DRAINAGE PERIOD

Start of drainage in the fields of La Jaillière

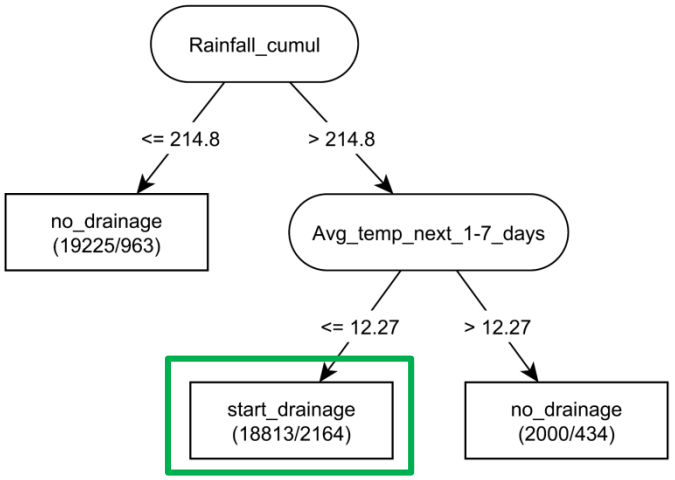
Expert provided date for the start (94.5%)



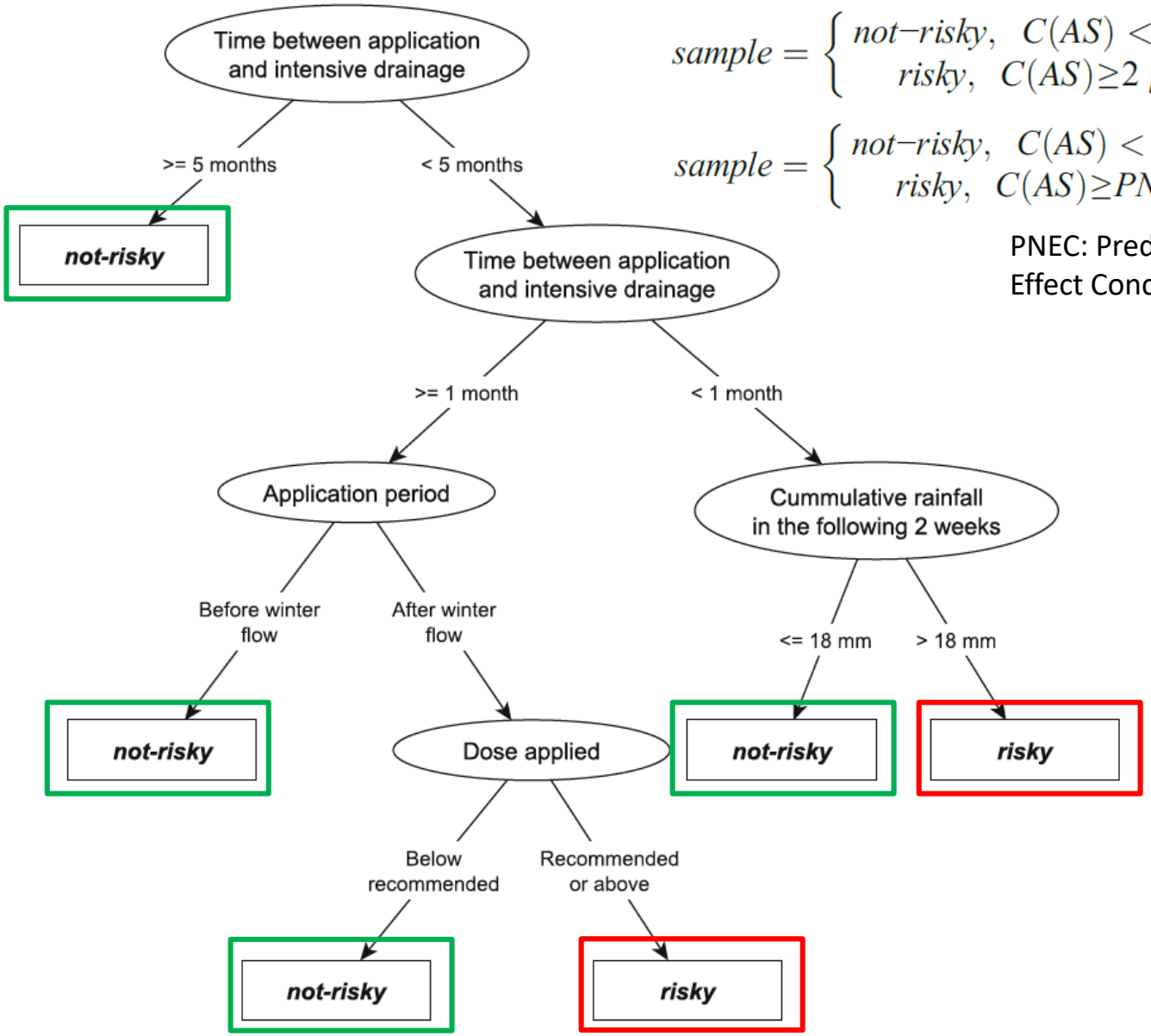
5 mm threshold for the start (90.8%)



10 mm threshold for the start (91.2%)



Risk assessment modelling



$$sample = \begin{cases} not{-}risky, & C(AS) < 2\ \mu g/L \\ risky, & C(AS) \geq 2\ \mu g/L \end{cases}$$

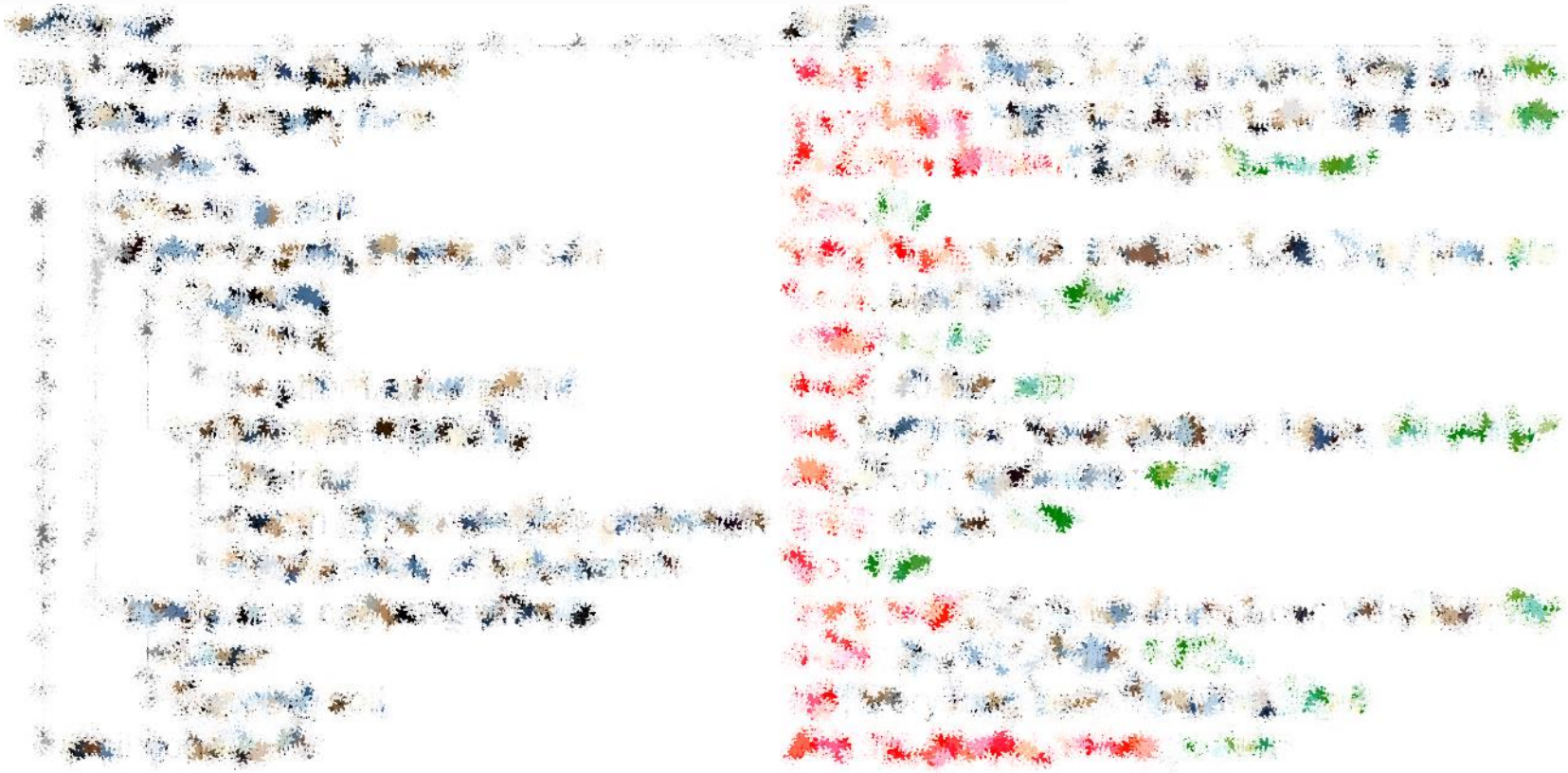
$$sample = \begin{cases} not{-}risky, & C(AS) < PNEC(AS) \\ risky, & C(AS) \geq PNEC(AS) \end{cases}$$

PNEC: Predicted No-Effect Concentration

Decision models

MODELS FOR RISK ASSESSMENT

- Intensity_Drainage_Infiltration
- Intensity_Runoff by saturation
- Intesity_Simple surface runnof_Runnof on capping soil



Decision models

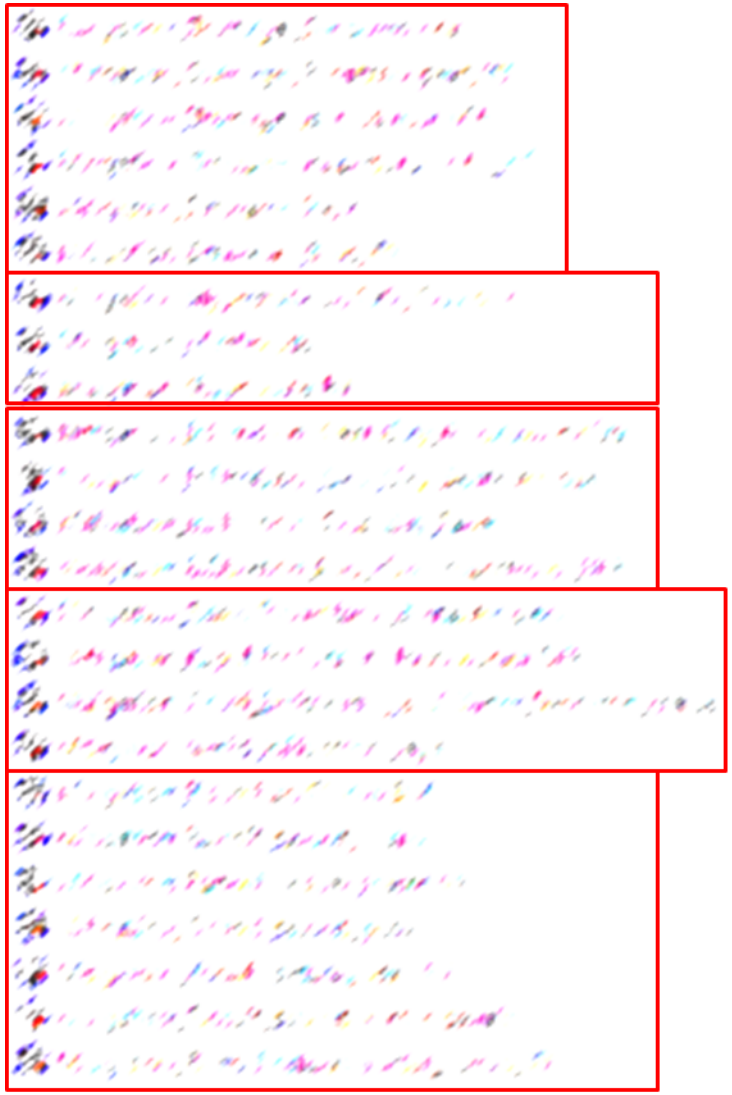
MODELS FOR RISK MANAGEMENT

24 mitigation models

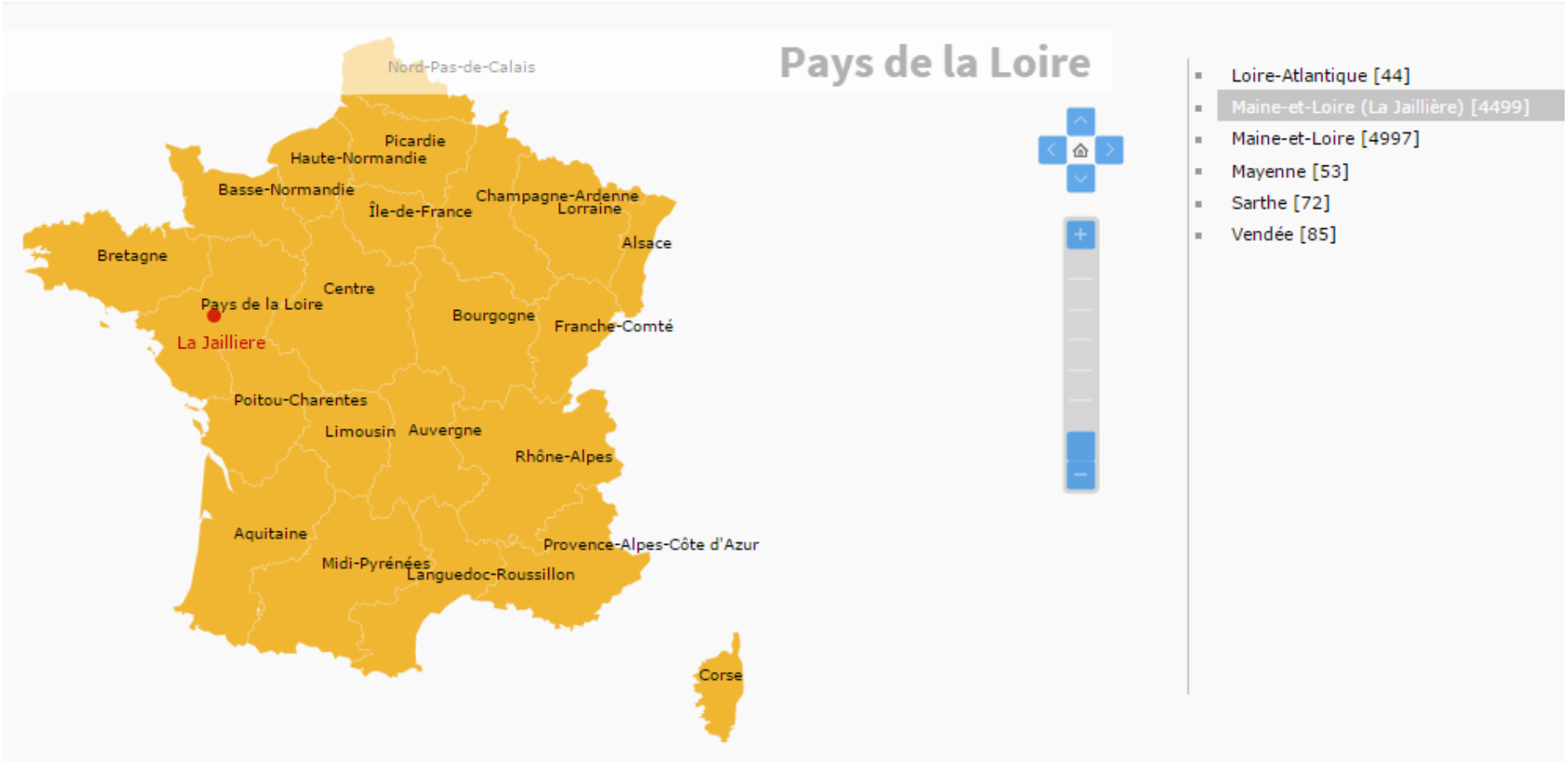
IF the risk assessment is **RISKY**

THEN

perform What-if DSS analysis



DSS tool


Pays de la Loire
Nord-Pas-de-Calais
Picardie
Haute-Normandie
Basse-Normandie
Champagne-Ardenne
Lorraine
Île-de-France
Alsace
Bretagne
Centre
Pays de la Loire
La Jailliere
Bourgogne
Franche-Comté
Poitou-Charentes
Limousin
Auvergne
Rhône-Alpes
Aquitaine
Provence-Alpes-Côte d'Azur
Midi-Pyrénées
Languedoc-Roussillon
Corse
Loire-Atlantique [44]
Maine-et-Loire (La Jaillière) [4499]
Maine-et-Loire [4997]
Mayenne [53]
Sarthe [72]
Vendée [85]

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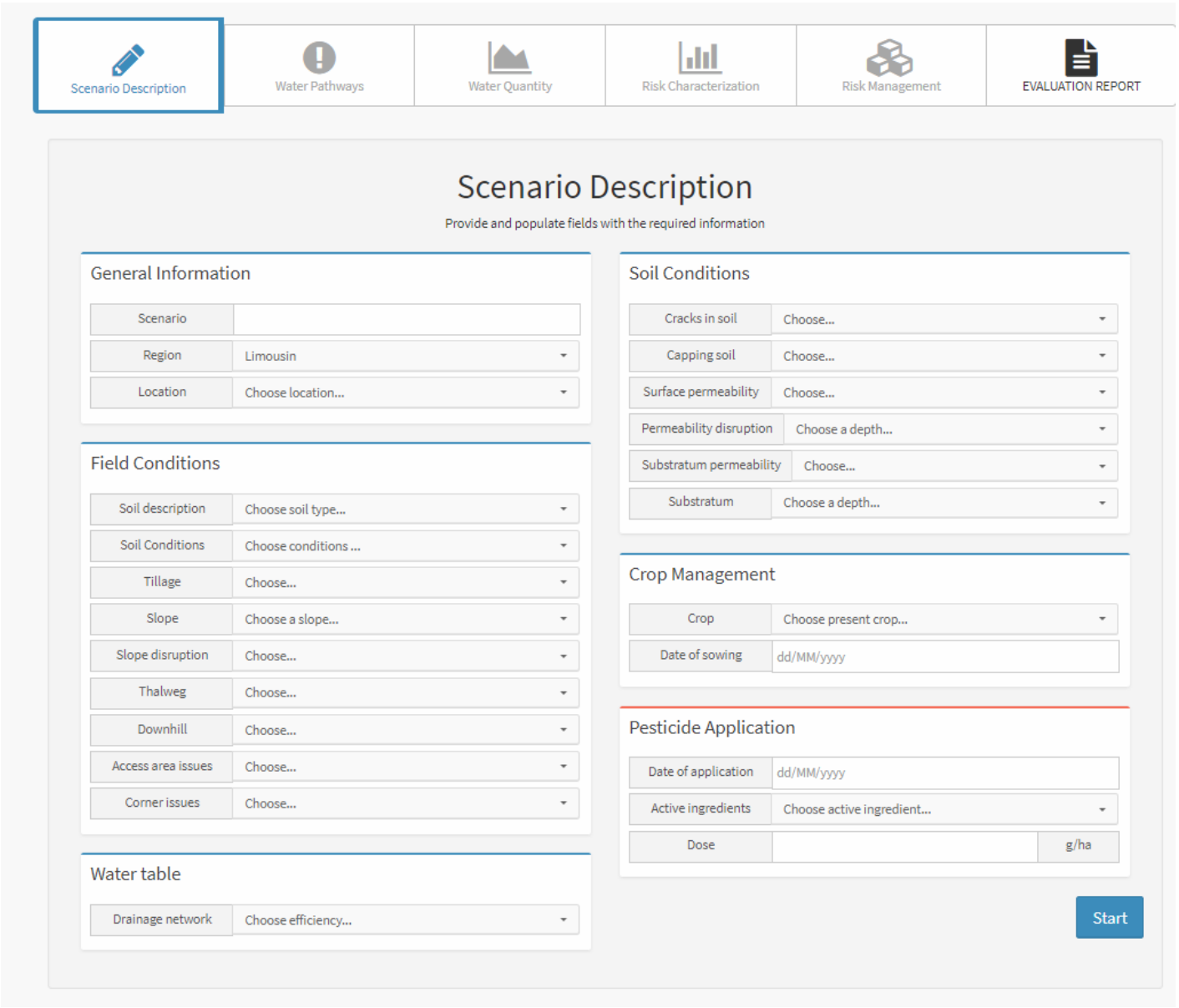
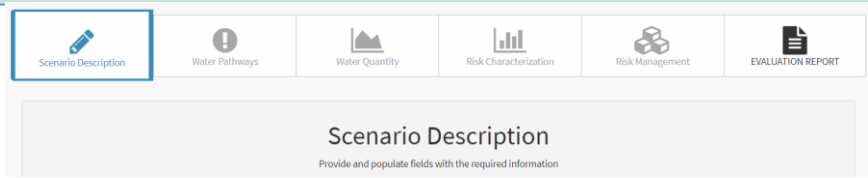
DSS tool



Web based DSS tool



Crop Management

Crop	Maize
Date of sowing	22/04/2018

Pesticide Application

Date of application	03/06/2018	
Active ingredients	bentazone	
Dose	1000	g/ha

DSS tool

RUNOFF ON CAPPING SOIL

Initial State Evaluation

State description
The following state has been estimated during the process of evaluation:

Active ingredient
bentazone

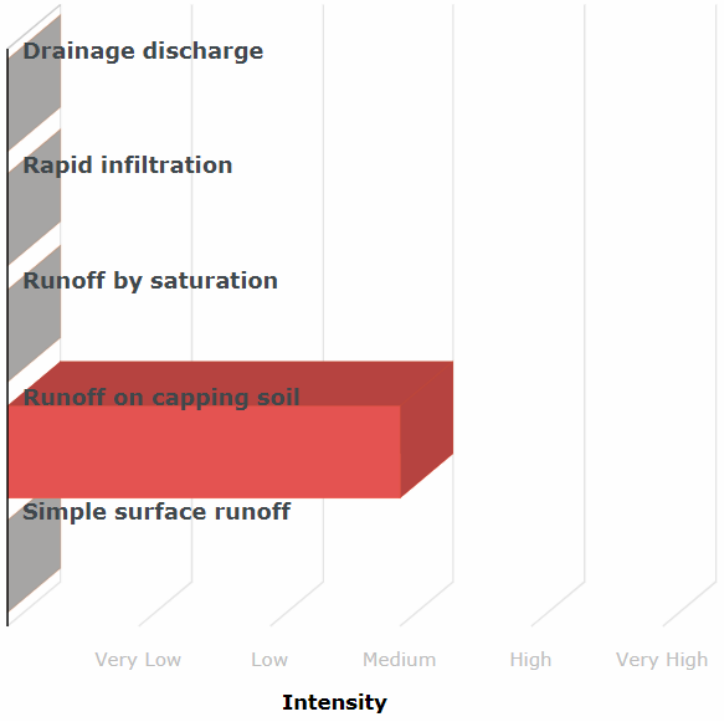
Tillage
Yes

Application time
During Spring with Spring Flow Period
03/06/2018

Crop
Maize

Dosage
Producer recommendation
1000 g/ha

Water Pathways
The assessed intensity of possible water pathways:



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DSS tool

Risk Management

Ranked strategies
The strategies are ordered by the complexity of agricultural practices.

1. Mitigation strategy

Practice required
The following changes are required for risk reduction:

Roughness of seed bed

Should be applied on the field.

Tramline management

Should be applied on the field.

Dammer inter row

Should be applied on the field.

Retention and disperssion facilities

Facilities should be applied on the edge of field.

THE SOIL NAVIGATOR: A DECISION SUPPORT SYSTEM FOR THE ASSESSMENT AND MANAGEMENT OF SOIL FUNCTIONS

Marko Debeljak
Jožef Stefan Institute

Aneta Trajanov, Vladimir Kuzmanovski, Jaap Schröder, Taru Sandén, Heide Spiegel, David P. Wall, Marijn Van de Broek, Michiel Rutgers, Francesca Bampa, Rachel E. Creamer, Christian Bugge Henriksen

THE SOIL NAVIGATOR

Decision support system that operates at the **field level**

Provides **advices** on the management of soils that optimise **5 soil functions**

Water regulation & purification

Carbon sequestration

Biodiversity

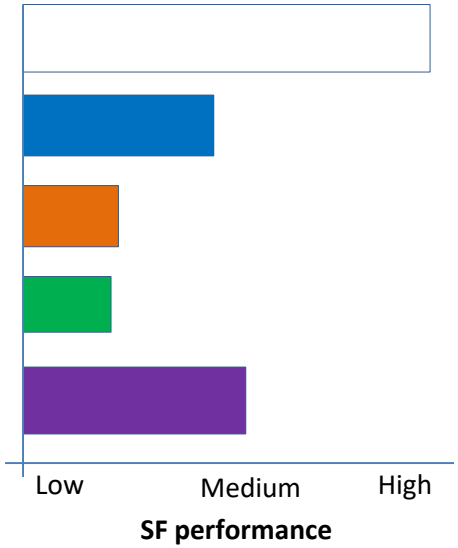
Nutrient cycling

Primary production

DECISION PROBLEM

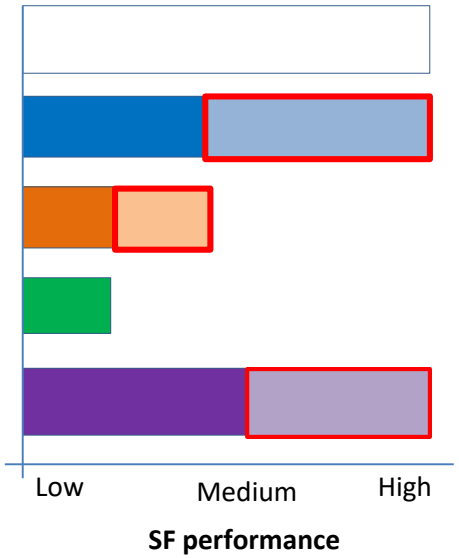
Assessing the performance of the **five soil functions**

- specific management practices,
- environmental/climatic conditions
- soil characteristics



Choosing appropriate management practices that will **improve** the **performance** of the soil functions under:

- climatic conditions
- soil characteristics
- management options



SOIL NAVIGATOR - GRAPHICAL USER INTERFACE

SOIL NAVIGATOR

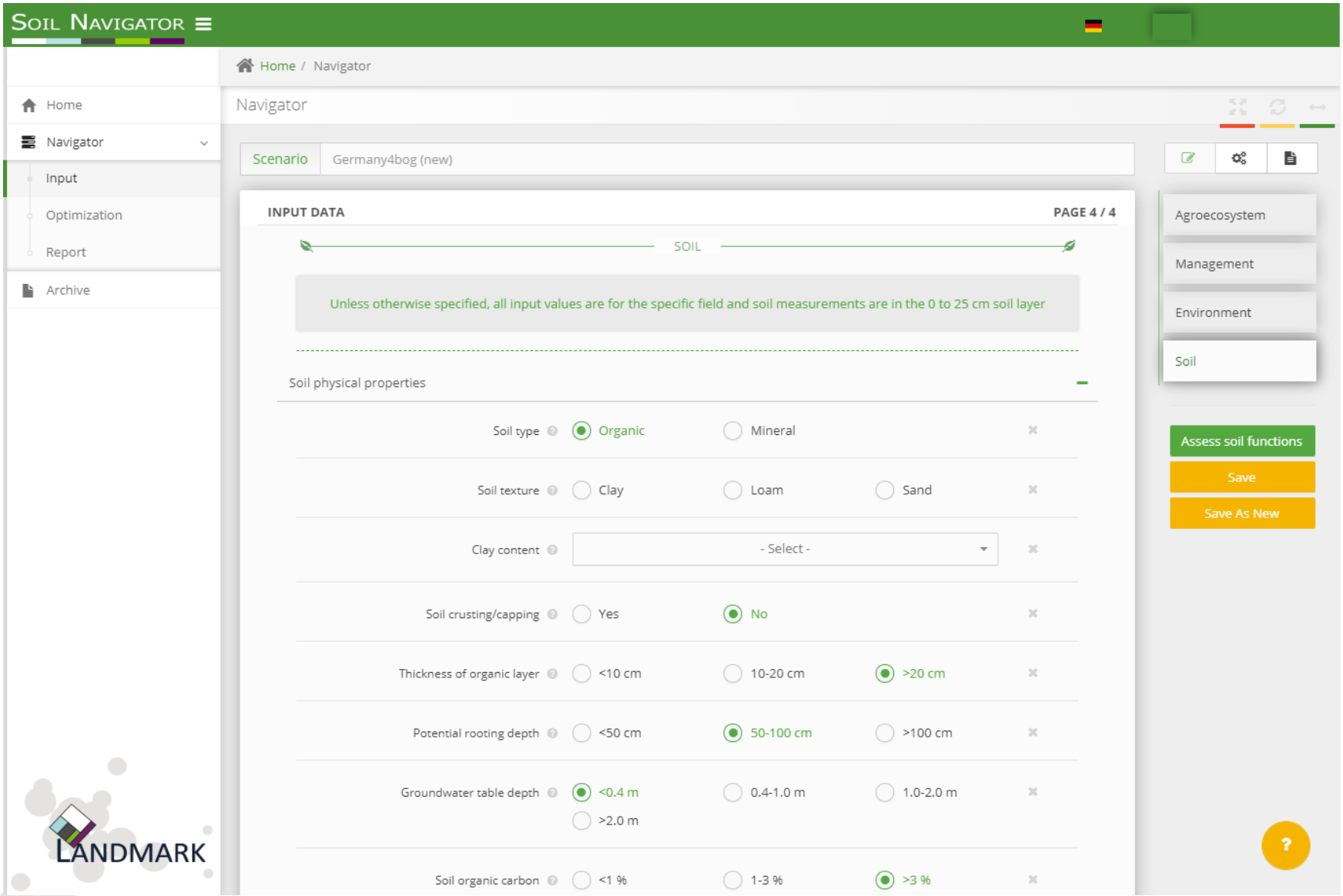
Home | Decision support system | Soil functions | Team | Publications | Tutorials | RUN

A Decision Support System for assessing and optimizing soil functions

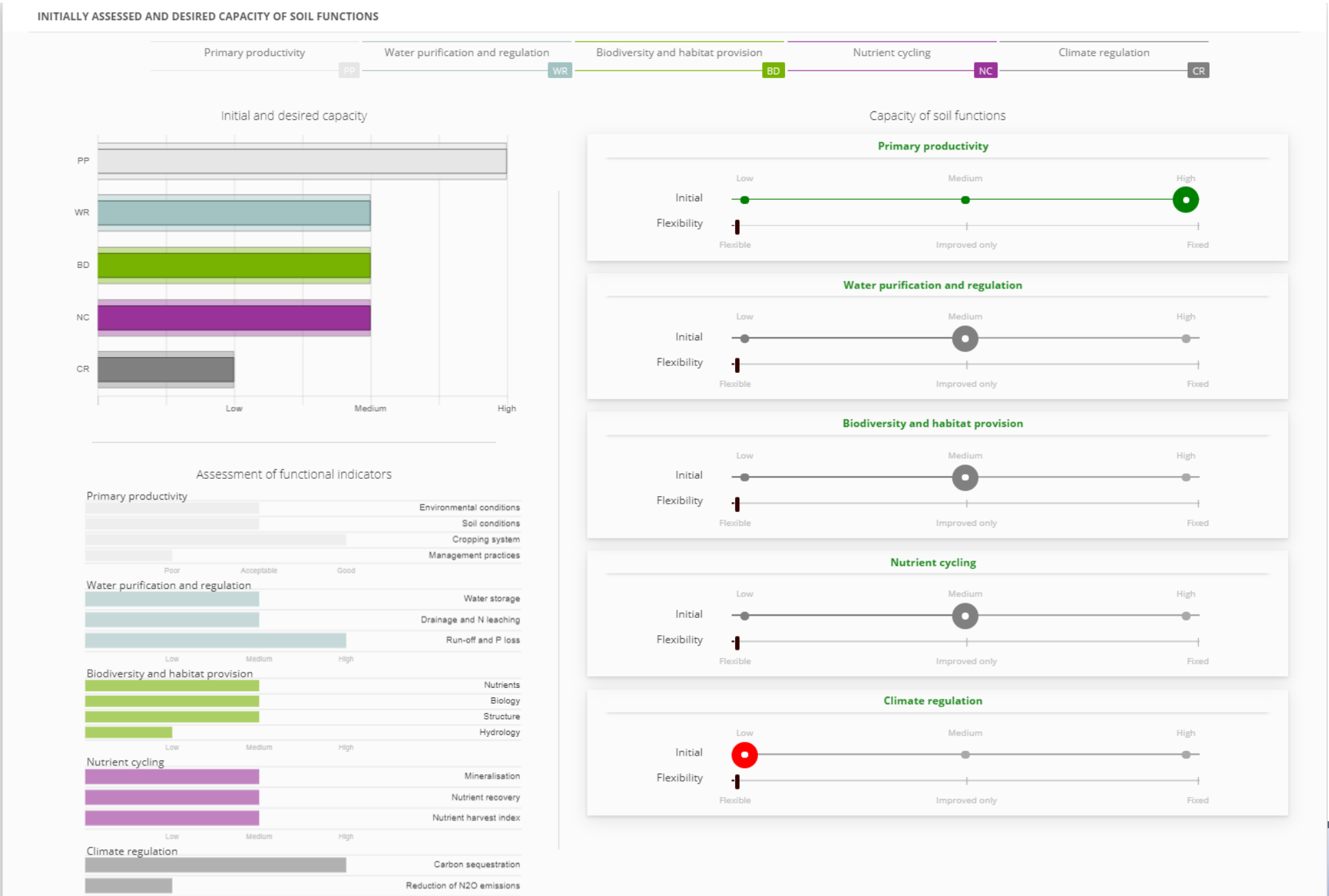
The Soil Navigator decision support system (DSS) was developed in the Horizon 2020 project **LANDMARK**. It assesses the initial capacities of five soil functions within a field including primary productivity, nutrient cycling, water purification and regulation, carbon sequestration and climate regulation, as well as biodiversity and habitat provision. In addition, this evidence based DSS offers targeted solutions and management recommendations to improve the supply of several soil functions simultaneously and assisting farmers and farm advisors to make the right decisions for long term sustainability.

Watch video | Run Soil Navigator DSS

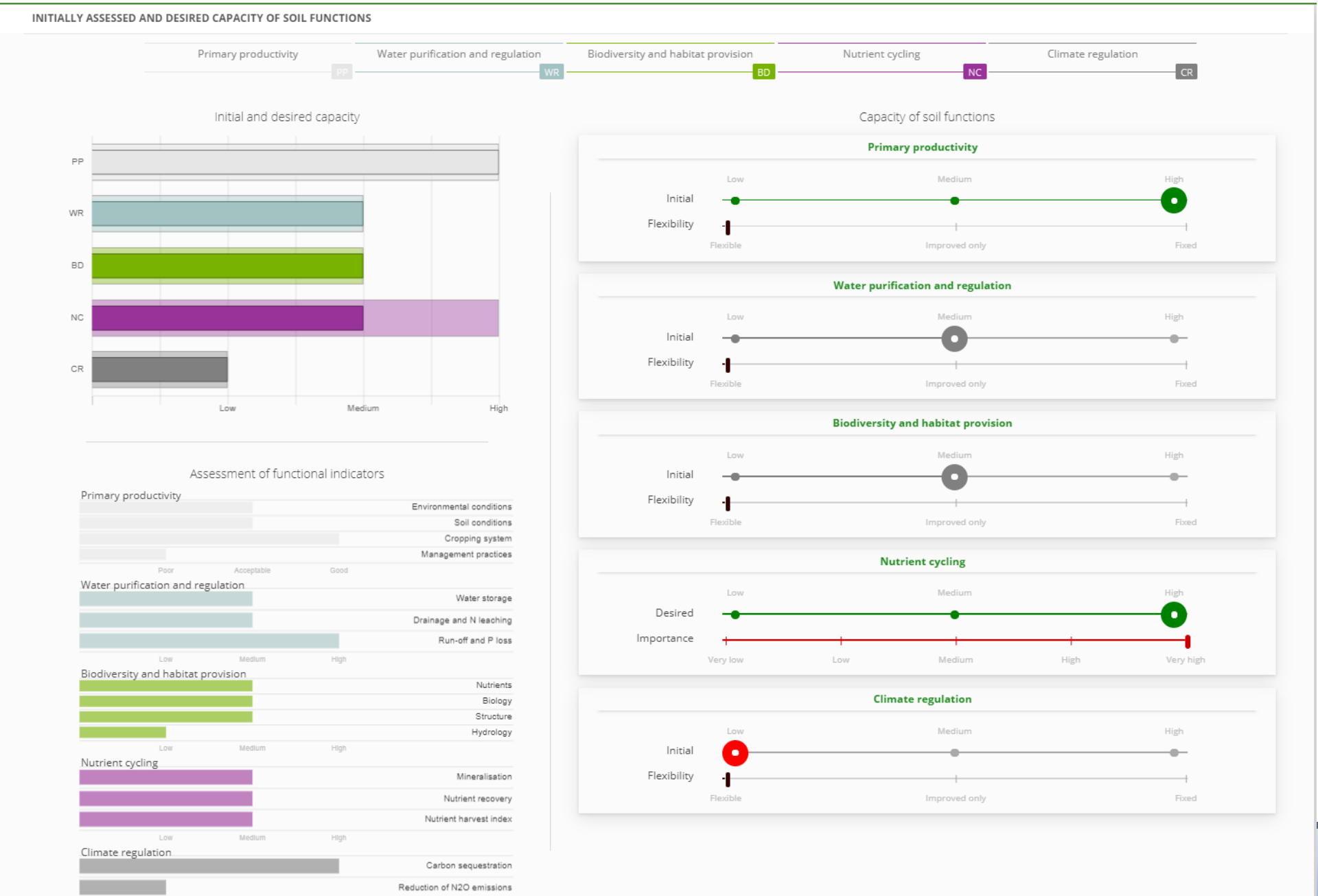
GRAPHICAL USER INTERFACE - DATA ENTRY



GUI– ASSESSMENT OF THE SOIL FUNCTIONS



GUI– ASSESSMENT OF THE SOIL FUNCTIONS

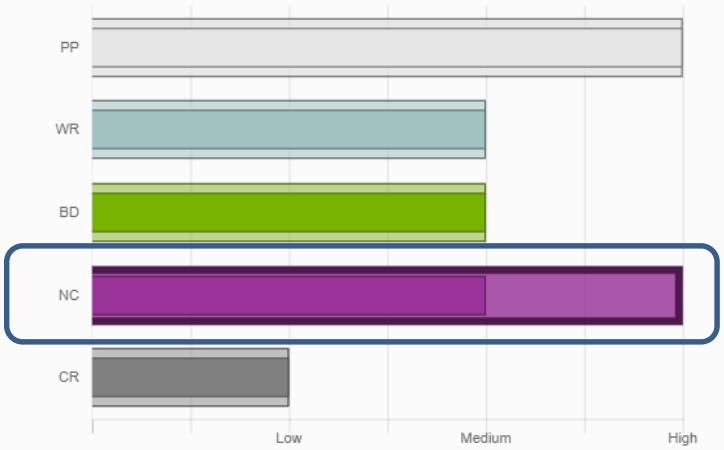


GUI– SUGGESTIONS FOR IMPROVEMENT OF SELECTED SF

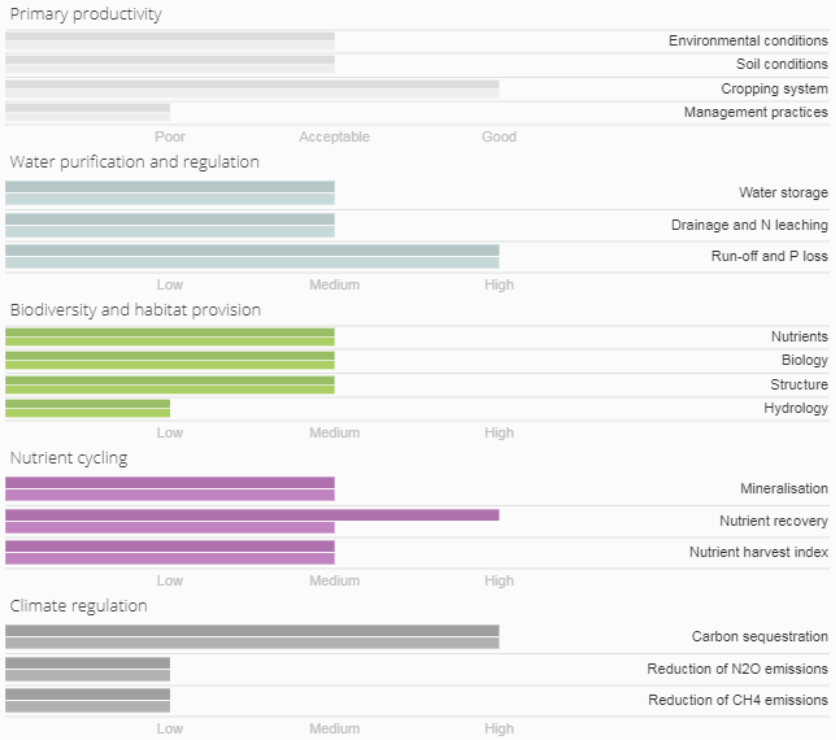
EVALUATION REPORT ON OPTIMIZED CAPACITIES OF SOIL FUNCTIONS

Primary productivity PP | Water purification and regulation WR | Biodiversity and habitat provision BD | Nutrient cycling NC | Climate regulation CR

Initial, desired and achieved capacities



Initial and optimized functional indicators



Management recommendations

NITROGEN FERTILIZATION (MINERAL) LOW | INCREASE

requires significant change (increase) by applying one of the following mitigation strategies:

Increase mineral N fertilization in compliance with national fertilizer regulations

Increase/apply balanced mineral N fertilization in compliance with national fertilizer regulations to meet crop N demand, increase biomass production and sequester carbon in the soil

Requirements for compliance with national law and cross-compliance with GAEC and SMR

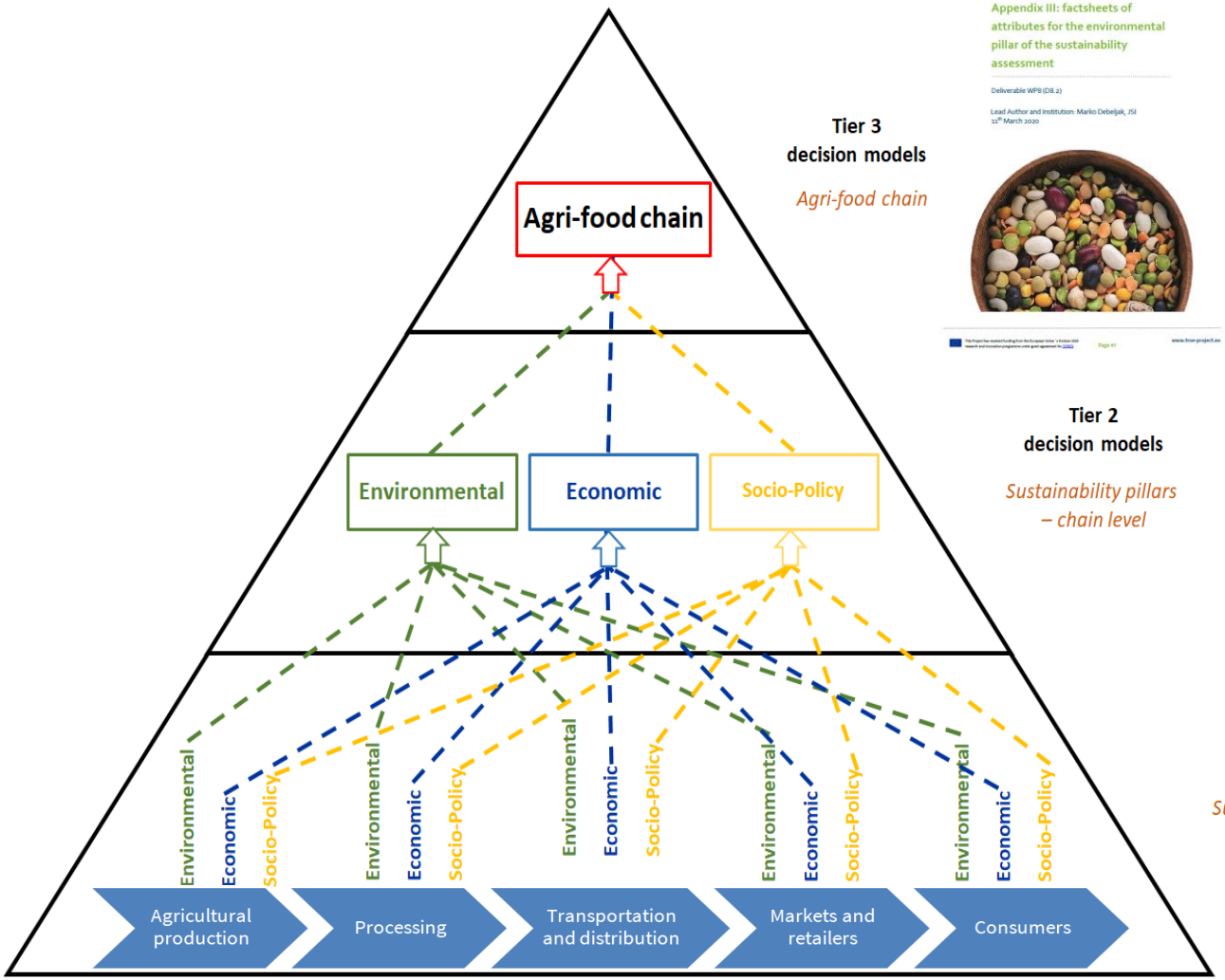
Please note that in order to comply with German law and obtain the GAEC and SMR cross-compliance required for obtaining payments via the Single Payment Scheme the application of fertilizer must follow the national guidelines for fertilizer application (this link) and the national cross-compliance guidelines (this link) / Lower Saxony: this link --> GAEC 6

TRansition paths to sUstainable legume-based systems in Europe

PATHFINDER

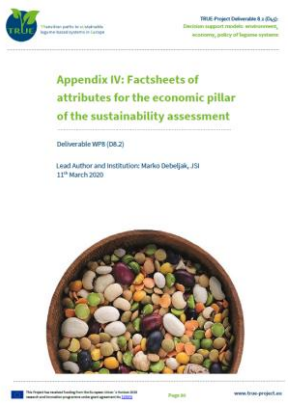
TRansition paths to sUstainable legume-based systems in Europe (TRUE) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 727973

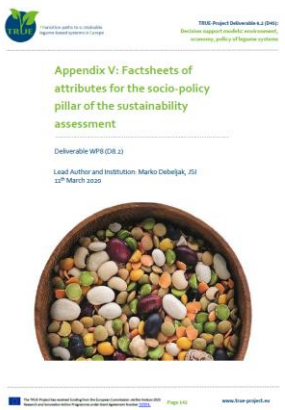
Conceptual structure of PATHFINDER central model



Tier 3 decision models

Agri-food chain





Tier 2 decision models

Sustainability pillars – chain level

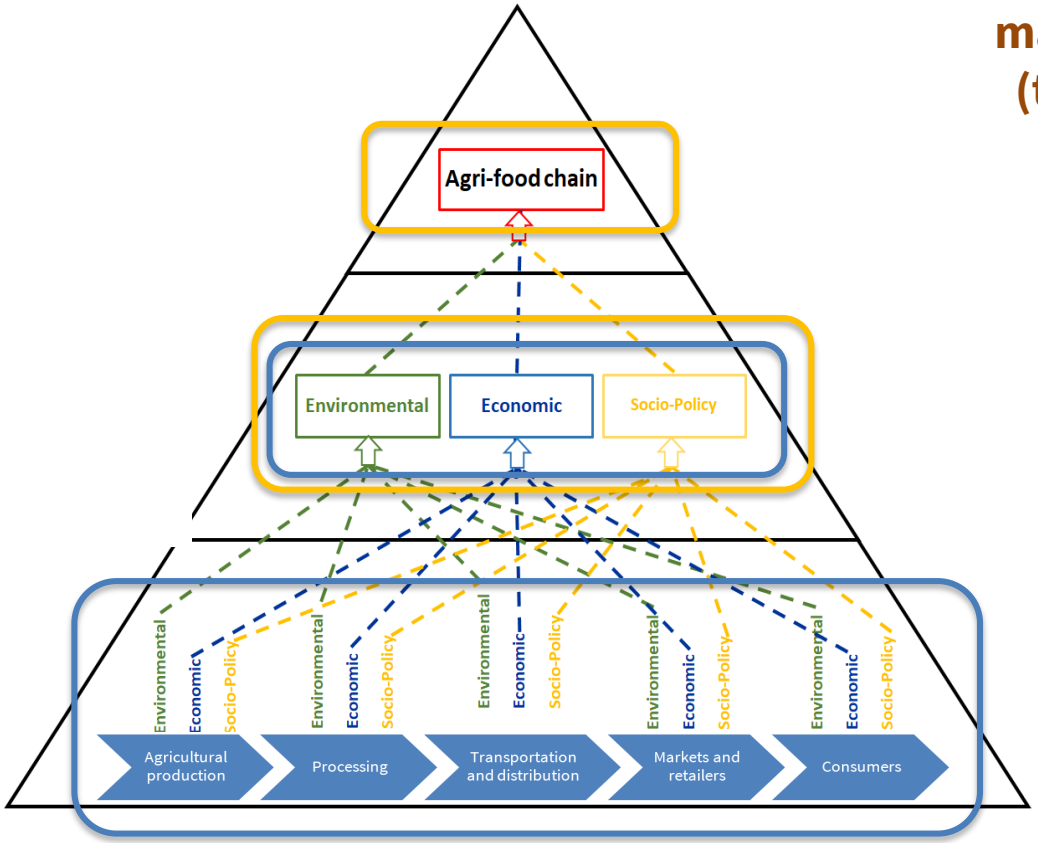
Sustainability pillar	Total
Environmental	27
Economic	44
Socio-policy	34
Total	105

Tier 1 decision models

Sustainability pillars – links level

Operational features of PATHFINDER

Chain sustainability management (top-down)



Chain sustainability Assessment (bottom-up)

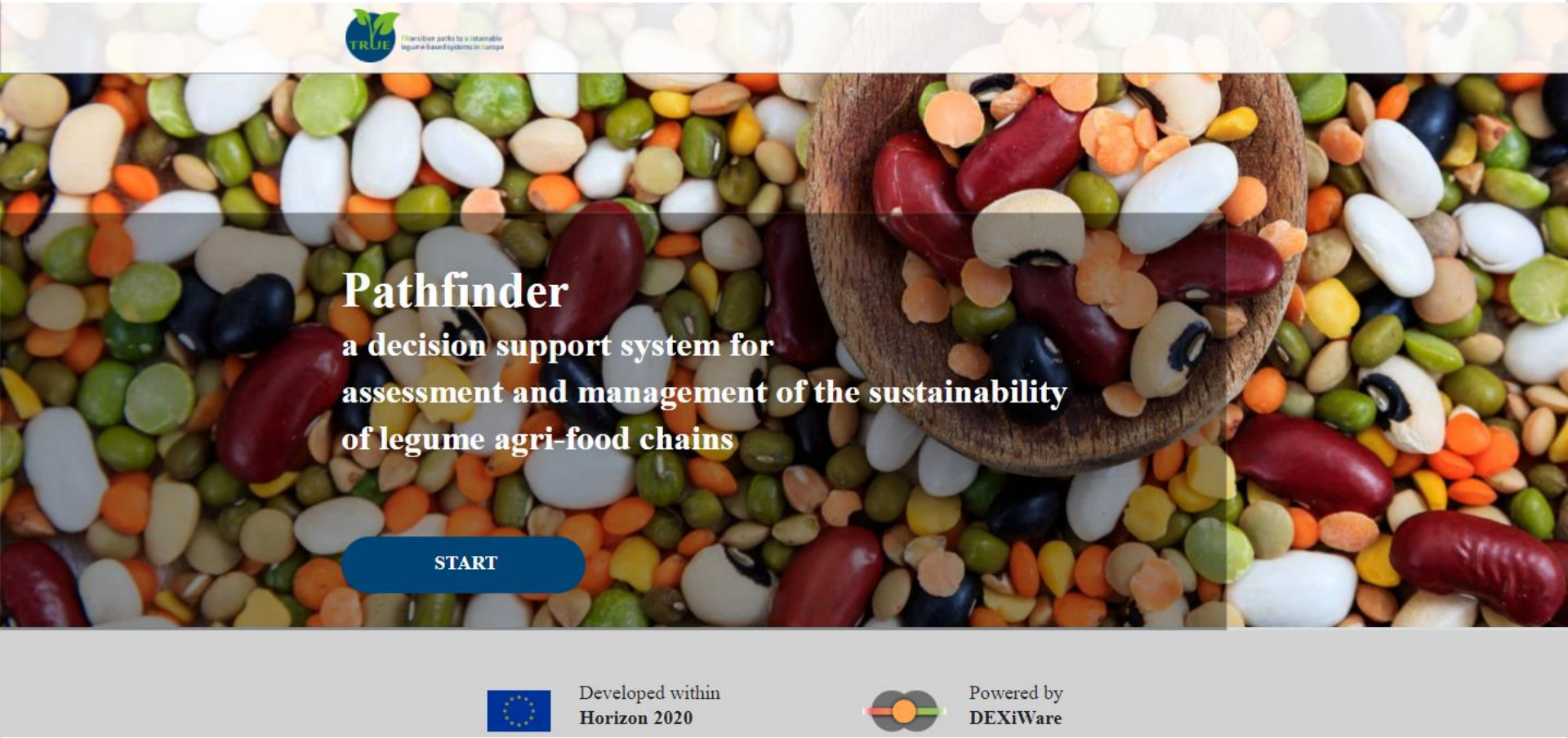
Validation of PATHFINDER

Atlantic cluster
CS 3: Intercrops for food & feed (Arbikie Distilling Ltd./Barney's Beer, UK)
CS 10: Market model development for organic pork (IFAU, Denmark)
CS 12: Vegetarian food formulation (IFAU, Denmark)

Continental cluster
CS 16: Policy for sustainable development (Regionalna Razvojna Agencija Medimurje, Croatia)
CS 17: Sustainable short supply chains delivering novel legume products to reconnect producers and urban consumers (Agri Kulti Kft., Hungary)

Mediterranean cluster
CS 18: Ancient & heritage variety screening for higher nutritive value (Sociedade Agrícola do Freixo do Meio, Portugal)

overall accuracy: 94.7%



Marko Debeljak, WP8 Leader, JSI

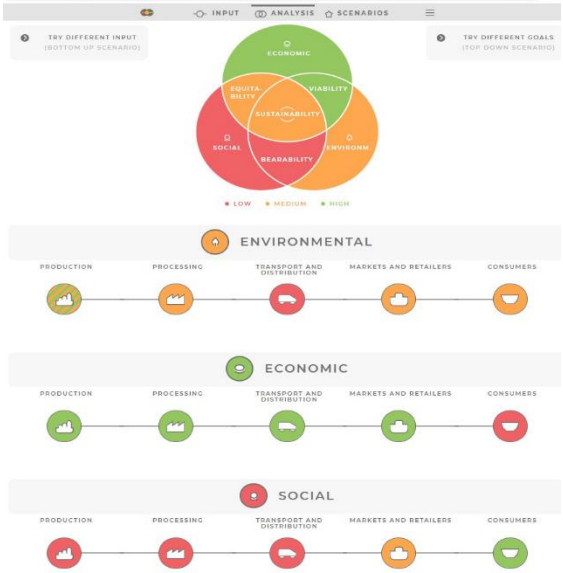
Task 6: Building a web-based sustainability assessment tool (Transition path-finder)

Data entry

Analysis

Bottom-up

Top-down



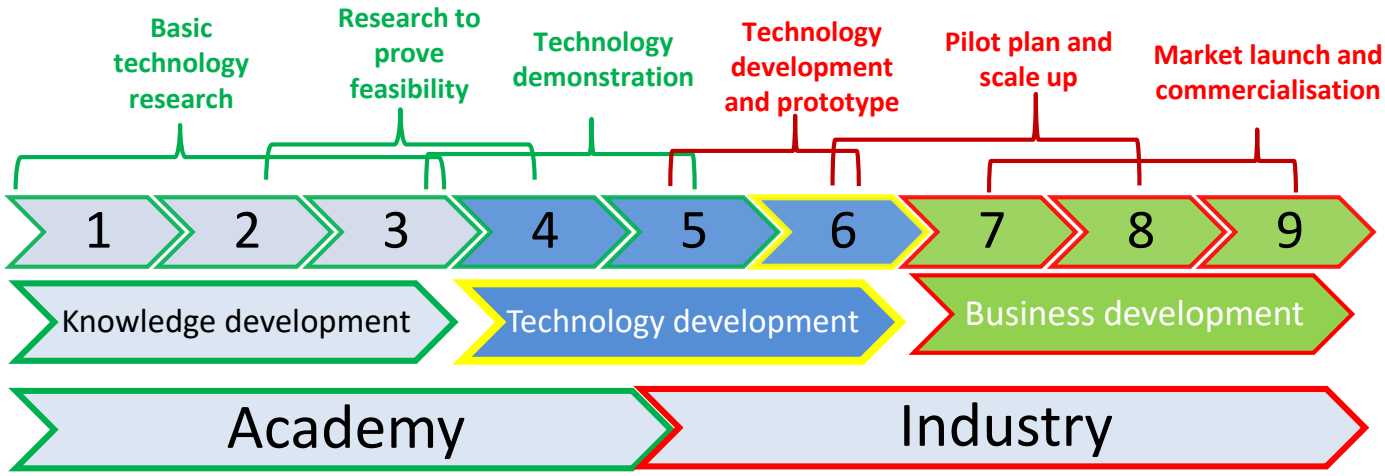
DEPARTMENT OF KNOWLEDGE TECHNOLOGIES
Jožef Stefan Institute

Final remarks

- **Methodology** for development DSS in agriculture is confirmed
- Large **synergistic** effects between data driven and knowledge driven modelling (**knowledge hybridization**)
- Advanced **information technology** is needed for integration of modules into DSS
- Knowledge of **UX design** of interface is crucial
- Digitalization and use of AI-based KT **support** development of reliable DSS for **modern agriculture** challenged by increasing societal demands (heathy food, sustainability, climate change, biodiversity, soil health, ….)
- Development of DSS in agronomy is **transdisciplinary** task

Challenges

Technology readiness level - exploitation



The team

Tanja Dergan
Jurij Marinko
Vid Podpečan
Bojan Blažica
Peter Novak
Aneta Trajanov
Vladimir Kuzmanovski