DAKIS – Digital Agricultural Knowledge and Information System

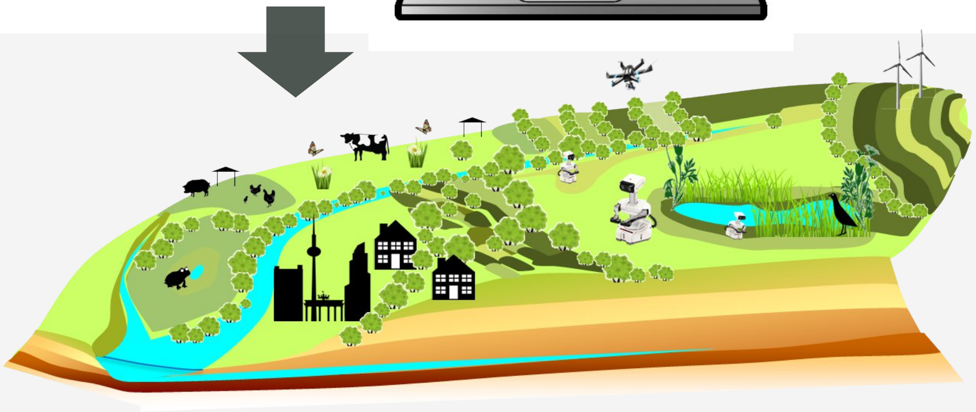
Seyed-Ali Hosseini-Yekani, **Peter Zander**
and many colleagues of the DAKIS proj

FDS7 ‘ November 2022

Datum 01.11.2022
:

DAKIS Objectives

- Support future agricultural land use by digital tools to integrate ecosystem services and biodiversity goals
- Analyze the potential for provision of conservation objectives.
- Provide farmers with suggestions on improved management at subfield including alternatives like strip cropping, agroforestry etc.
- DSS to optimize production pattern given policy and market conditions, largely based on public databases



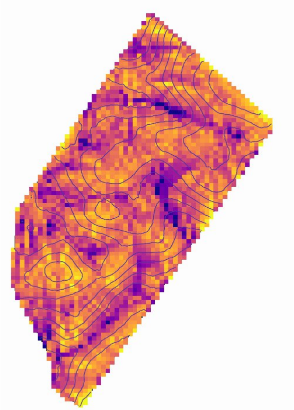
Functionally and spatially diversified agricultural systems combining the provision of ESS and biodiversity with stable incomes for farmers.

Biomass potentials

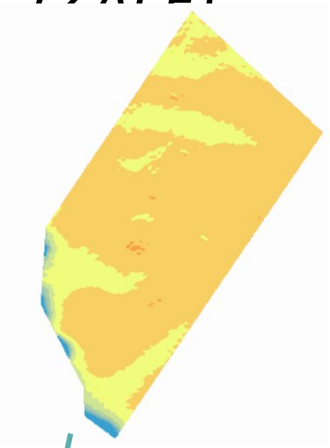
Marco Donat (ZALF)

Soil points

Slope angle

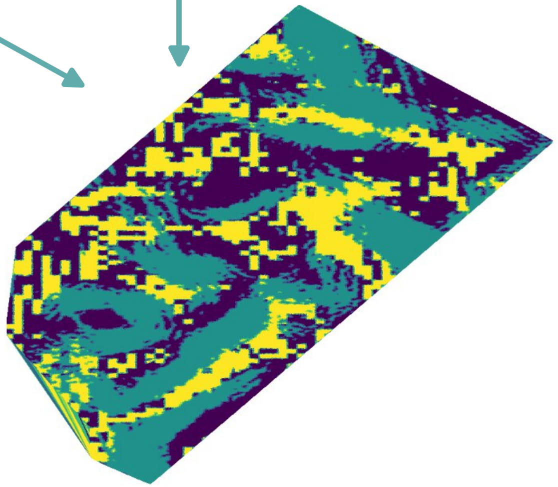


Soil humidity



Solar radiation

Identification of biomass potentials at subfield level at the Dahmsdorf site



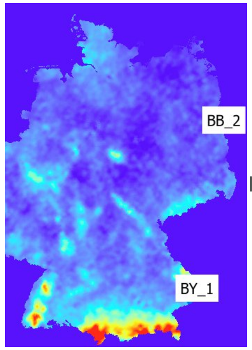
High soil quality

Moderate soil quality

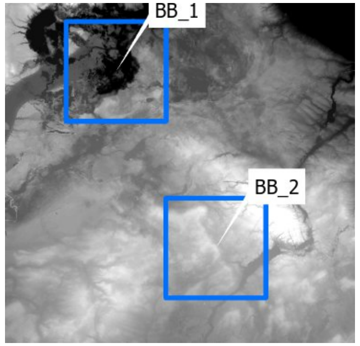
Moderate soil quality at

Erosion control potentials

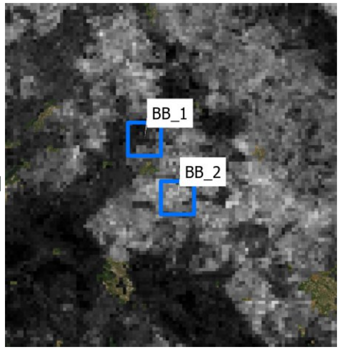
Marvin Melzer (ZALF)



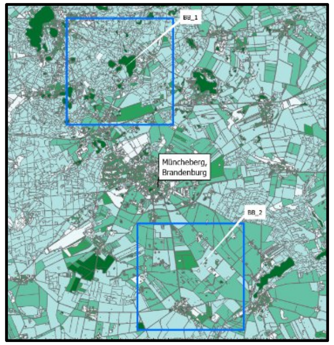
Climate



Relief



Soil



Land use

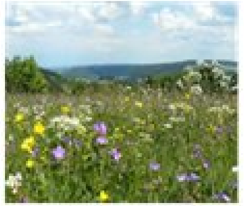
Waterbodies

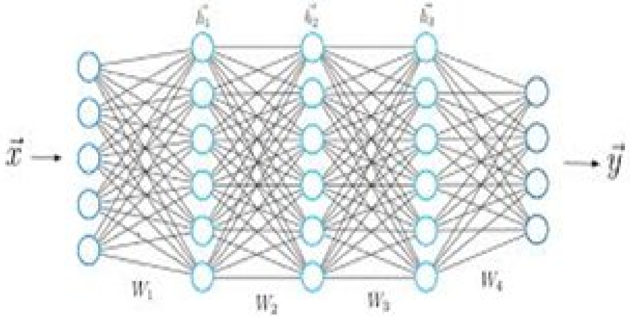
Identification of potential to reduce soil erosion and erosion hotspots at subfield level for four landscape windows (5x5 km) in Brandenburg and Bavaria

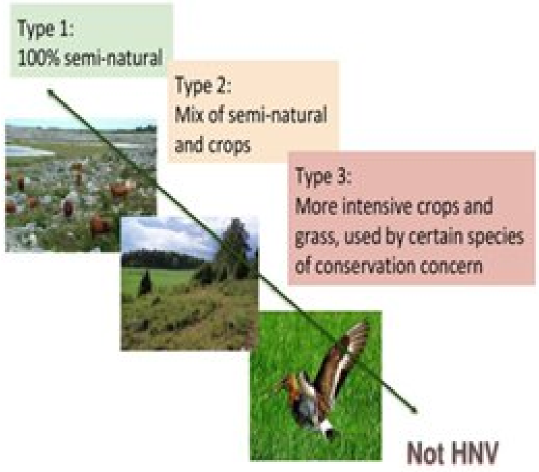
Biodiversity potentials ‘ floristic biodiversity

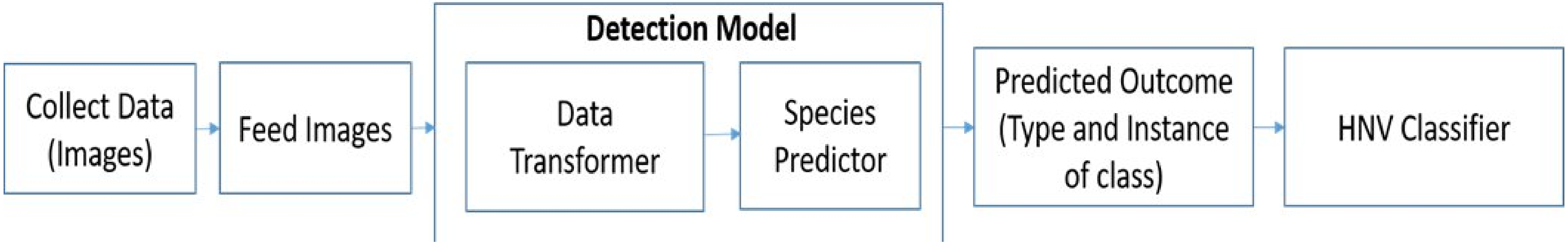
Monitoring floristic biodiversity and identifying high nature value farmland and effects of management

Deepak Basavegowda (ATB), Inga Schleip (HNEE)









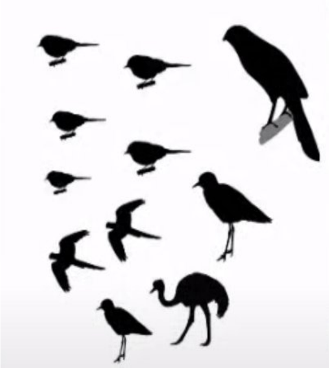
Biodiversity potentials ‘ faunistic biodiversity

Markos Krull (ZALF)

Monitoring faunistic biodiversity and modelling how land use and different management treatments affect it

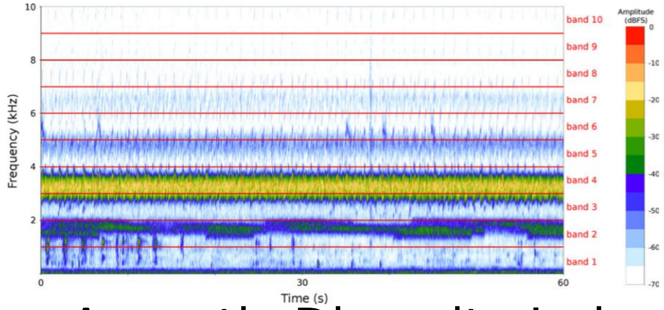
Bird, frog & land animal recorders

Bird community



Species richness

Soundscape ecology



e.g. Acoustic Diversity Index (ADI)

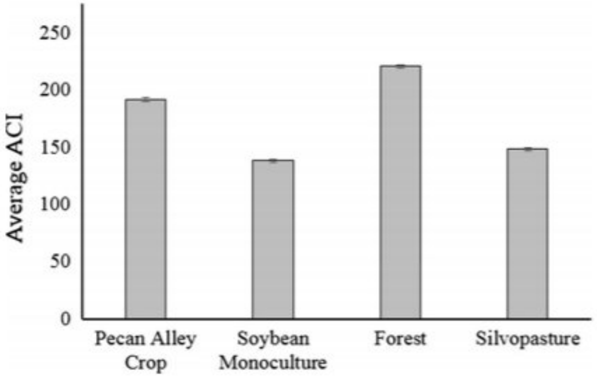


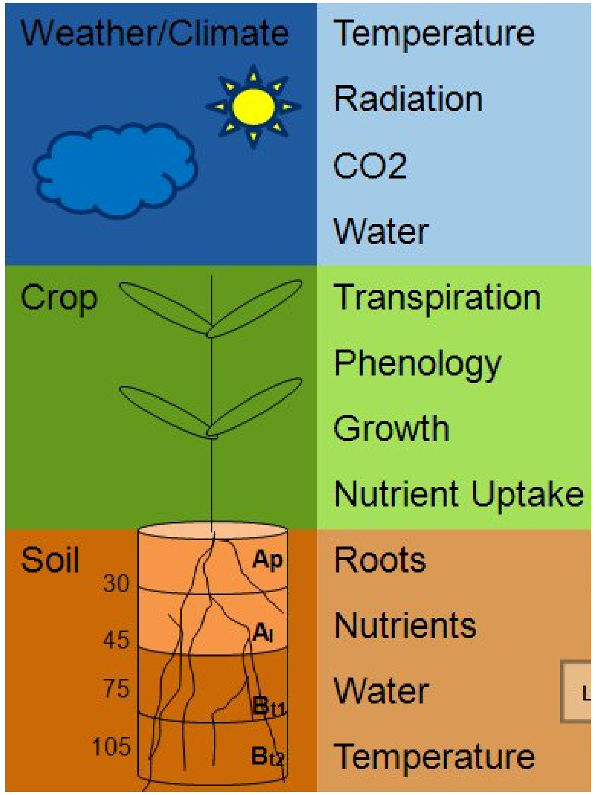
Fig. 4 Average acoustic complexity index (ACI) values with standard errors for all four land-use systems

Villanueva-Rivera et al., 2011
Bobryk et al., 2016

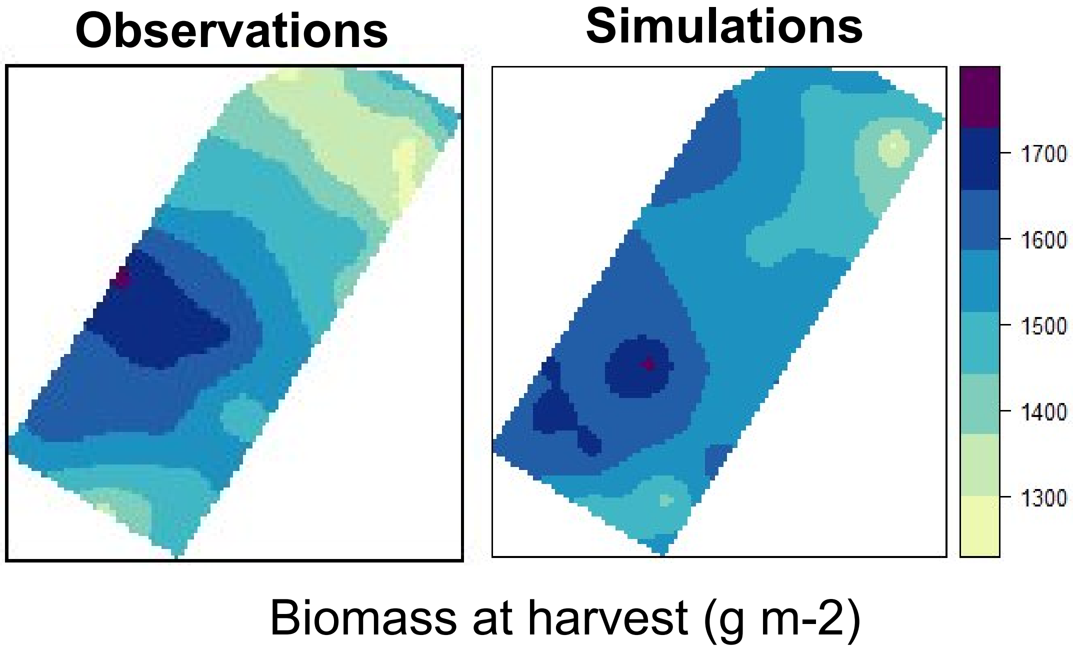
Agroecosystem modelling ‘ SIMPLACE

A toolbox to build agroecosystem models based on SimComponents =>Application of model solutions from subfield to regional scale

Thomas Gaiser (Uni Bonn)
Andreas Tewes (FZ Jülich)



Assimilation of remotely sensed LAI data into SIMPLACE model runs to improve spatially explicit yield simulations at the subfield scale



Gaiser/Krauss/Enders (UBonn) www.simplace.net

DAKIS management options

Based on the analytics before and additional rules DAKIS generates production activities at subfield level:

- Buffer strips and hedge rows
- Specific crop management for single, mixed, relay cropping etc.
  with site specific seed and fertilization recommendations for all crops
  and management specific yields and yield risks

Production activities with known ESS and biodiversity impact

Multi-Objective Decision support tool for Agro-ecosystem Management **(MODAM)**

DAKIS Digital Agricultural Knowledge and Information System

Scenarios
(climate, technologies, policies, markets)

Simulations, Forecasts

Land use options

Data Collection Monitoring

Sensors

Historical

Updates

DAKIS Front-end

Propose options

- **Farmer decides on production plan**
- **Reconsider or adapt operation during season**

Initially planned operations

Continued monitoring

S. Zachäus

MIRO User Interface

GUI allows to

- view/modify input data
- execute GAMS jobs
- Results directly visualised
- Sensitivity analysis
- Scenario comparison

Farm Model MODAM

Mathematical programming modules

- **Policies**
- Biogas plants
- Livestock activities
- Feeding / substrate use
- Plant production activities
- Manure management
- Investments and Cash Flow
- Environmental Accounting

Ali Hosseini Yekani

Scientific challenge: What policies and subsidies support ESS and Biodiversity most efficiently ?

In the absence of a market for pricing ESs, economic valuations that assign a monetary value to ESs are good tools to prioritize ESs (Müller et al., 2019). Typical approaches for the **economic valuation of ESs**, are e.g. **Contingent Valuation Method (CVM)** and **Choice Experiment (CE)** to determine **Stated Preferences (SP).**

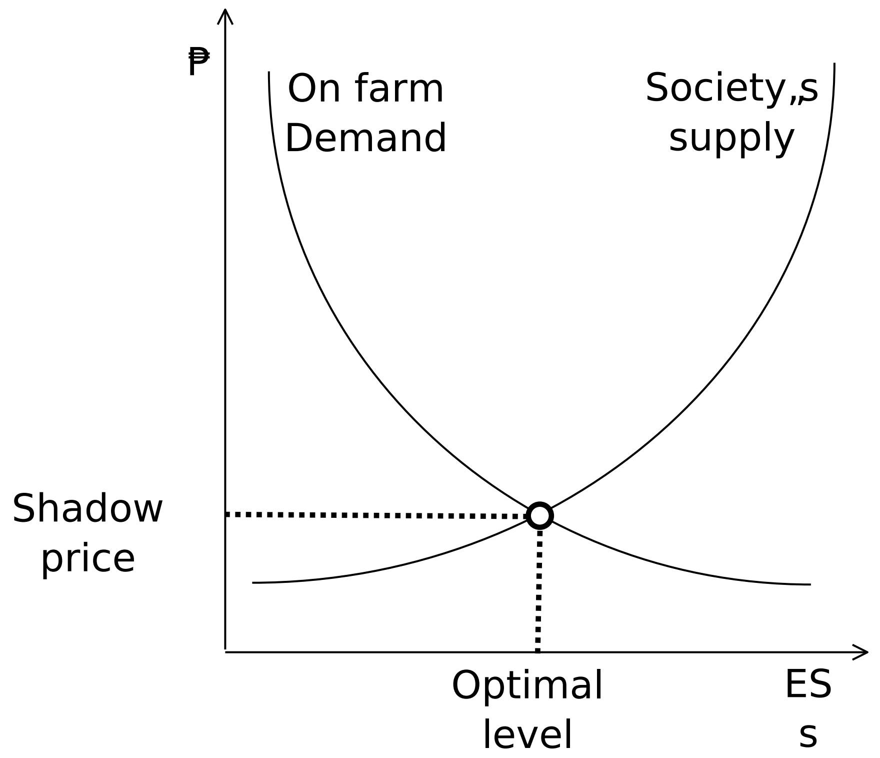
Two significant limitations of these economic valuation methods of ESs:

1. Despite the existence of an obvious trade-off between ESs, **they are valued separately**, leading to unwanted trade-offs
2. These evaluations are based solely on the **opinions of their consumers or producers about their willingness to pay or to accept**.

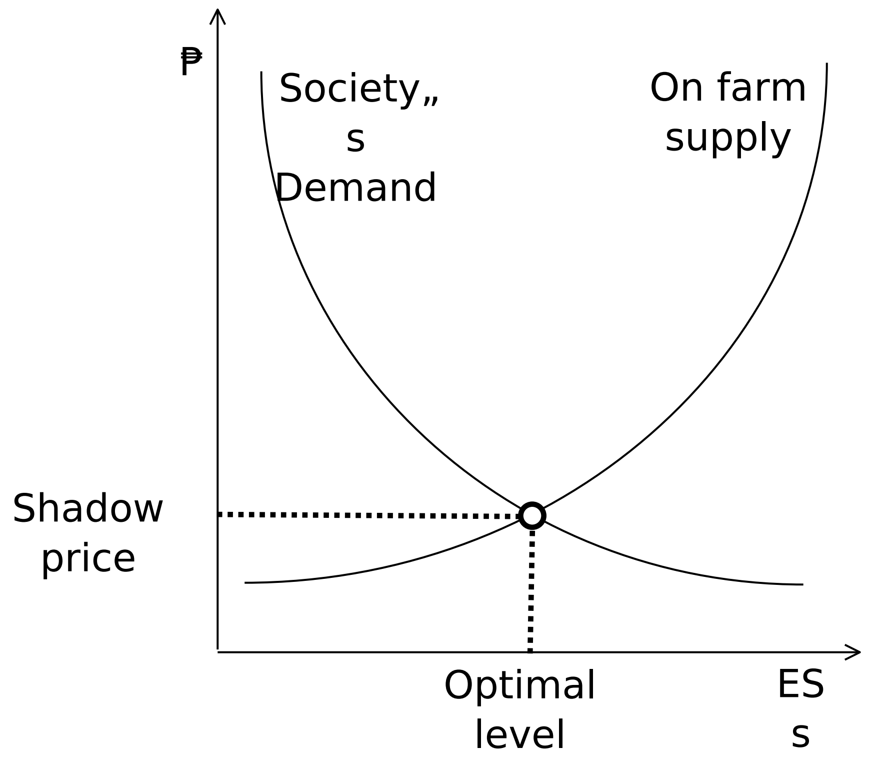
The internal economic value of ecosystem services at farm level depends on farm internal relations and dependencies and should be the basis of any subsidy system

Calculating the shadow values of ESs

We propose **to calculate the shadow values of ESs** in MODAM considering physical interactions (production possibility) and economic ratios (input-output price relations).



Agriculture as a consumer of ecosystem services e.g. Nitrate leaching



Agriculture as a producer of ecosystem services e.g. Erosion control

Simplified form of whole farm mathematical model within DAKIS

$$\max_{X} \quad GM = \sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{j=1}^{J}(1+r)^{-t} gm_{t,j} X_{t,f,j}$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} a_{t,i,f,j} X_{t,f,j} \le b_{t,i} \qquad for\ t = 1,2,\dots,T\ and\ i = 1,2,\dots,I$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} \le ess_{t,s} \qquad for\ t = 1,2,\dots,T\ and\ s = 1,2,\dots,S$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} \ge esd_{t,d} \qquad for\ t = 1,2,\dots,T\ and\ d = 1,2,\dots,D$$

$$X_{t,f,j} \ge 0$$

GM: Maximized net present value of farmer's total gross margin during the planning years
r: Discount rate
$gm_{t,j}$: Gross margin of one unit of crop *j* in year *t*
$X_{t,f,j}$: Optimal cultivation area of crop *j* at the field *f* in year *t*
$a_{t,i,f,j}$: Technical coefficient of constraint *i* for producing one unit of crop *j* at field *f* in year *t*
$b_{t,i}$: Total available amount of constraint *i* in year *t*
$c_{t,s,f,j}$: Consumption of ESs *s* for producing one unit of crop *j* at field *f* in year *t*
$ess_{t,s}$: Total society's supply of ESs *s* in year *t*
$p_{t,d,f,j}$: Provision of ESs *d* by producing one unit of crop *j* at field *f* in year *t*
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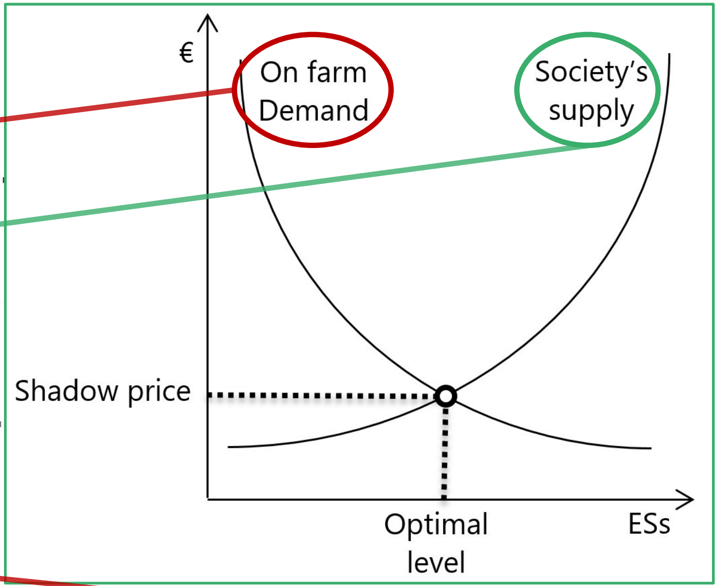

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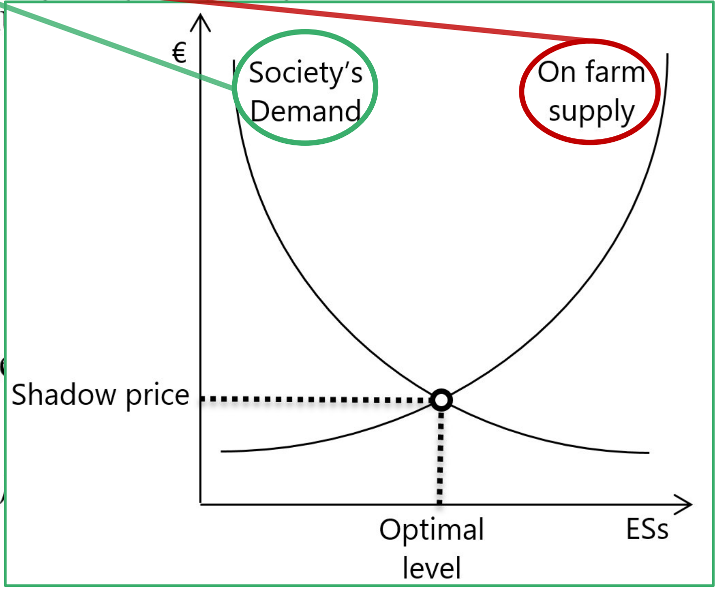

Simplified form of whole farm mathematical model within DAKIS

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Amount of nitrate which enters the soil as a result of farm production

Nitrate threshold allowed by society to enter the soil through the farm

$$GM = \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=} \ldots$$

$$\ldots a_{t,i,f,j} X_{t,f,j} \le b_{t,i} \ldots$$

$$\sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} \le ess_{t,s} \qquad for\ t = 1,2, \ldots$$

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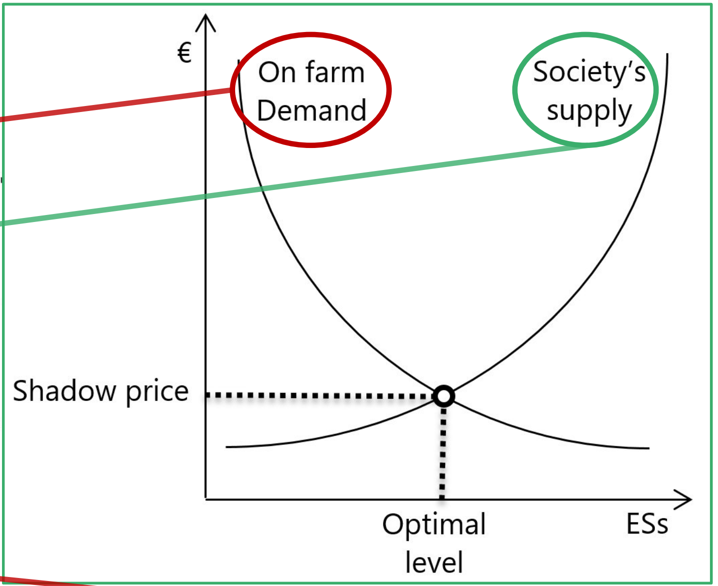

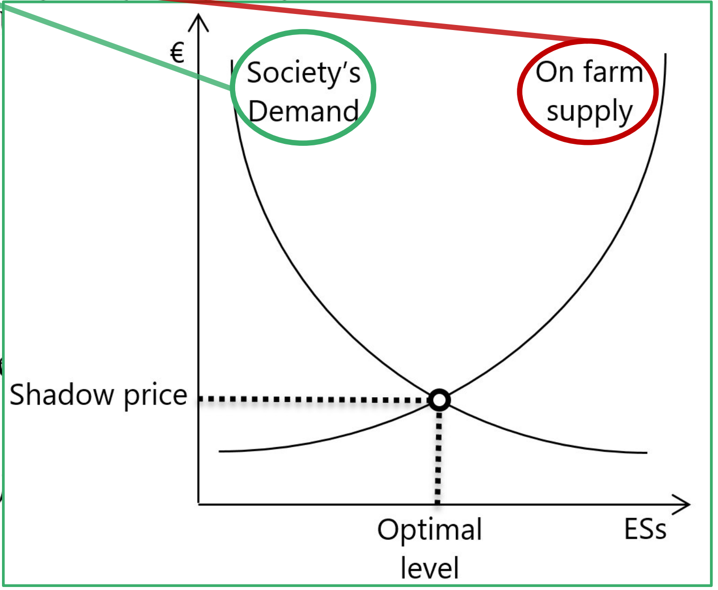

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$$\sum_{f=1}^{F}\sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} \geq esd_{t,d} \qquad for\ t = 1,2, ...$$

$$X_{t,f,j} \geq 0$$

Level of biodiversity provided by farm

Required level of biodiversity which society expects from the farm

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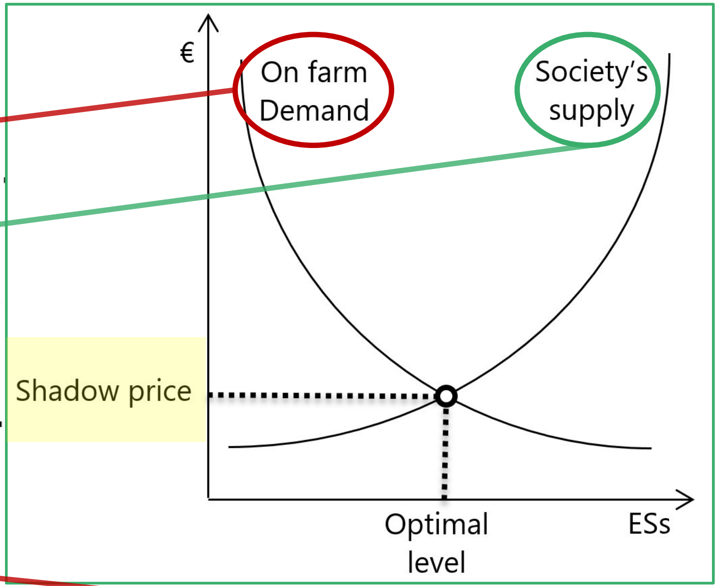

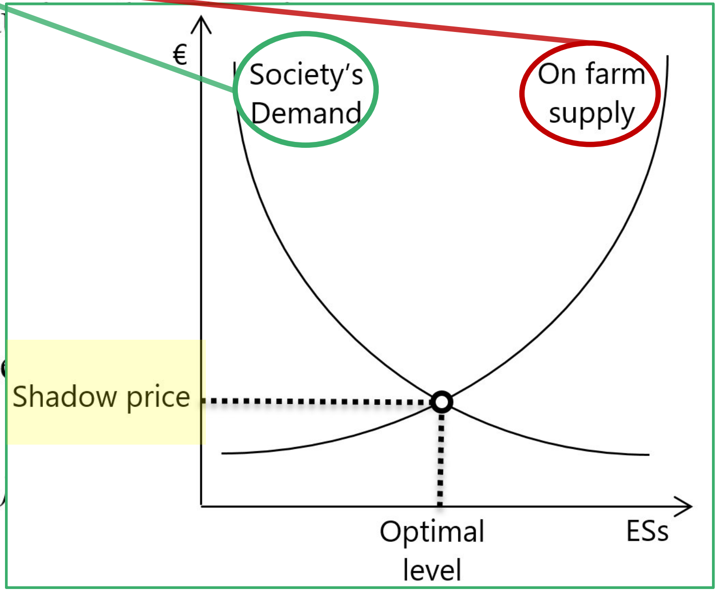

New model: Determination of optimal consumption and provision of ESS by introduction of the shadow prices of consumed and produced ESS

$$\underset{X,ESS^c,ESS^p}{\text{Max}} \quad SGM = \sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{j=1}^{J}\sum_{s=1}^{S}\sum_{d=1}^{D}(1+r)^{-t}\left[gm_{t,j}X_{t,f,j} - \overline{SR}_{t,s}ESS_{t,s}^{c} - \overline{SC}_{t,d}ESS_{t,d}^{p}\right]$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} a_{t,i,f,j}X_{t,f,j} \le b_{t,i} \qquad for\ t = 1,2,\dots,T\ and\ i = 1,2,\dots,I$$

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$$\sum_{f=1}^{F}\sum_{j=1}^{J} p_{t,d,f,j}X_{t,f,j} = ESS_{t,d}^{p} \qquad for\ t = 1,2,\dots,T\ and\ d = 1,2,\dots,D$$

$$ESS_{t,s}^{c} \le ess_{t,s} \qquad for\ t = 1,2,\dots,T\ and\ s = 1,2,\dots,S$$

$$ESS_{t,d}^{p} \ge esd_{t,d} \qquad for\ t = 1,2,\dots,T\ and\ d = 1,2,\dots,D$$

$$X_{t,f,j} \ge 0, ESS_{t,s}^{c} \ge 0\ and\ ESS_{t,d}^{p} \ge 0$$

SGM: Maximized net present value of social gross margin during the planning years

$ESS_{t,s}^{c}$: Optimal amount of consumption of ESs s in year t

$ESS_{t,d}^{p}$: Optimal amount of provision of ESs d in year t

SC - shadow cost, related to the consumed ESS

SR - shadow revenue, related to the produced ESs

New model: Determination of optimal consumption and provision of ESS by introduction of the shadow prices of consumed and produced ESS

$$\max_{X,ESS^c,ESS^p} SGM = \sum_{t=1}^{T}\sum_{f=1}^{F}\sum_{j=1}^{J}\sum_{s=1}^{S}\sum_{d=1}^{D}(1+r)^{-t}\left[gm_{t,j}X_{t,f,j} - \overline{SR}_{t,s}ESS^c_{t,s} - \overline{SC}_{t,d}ESS^p_{t,d}\right]$$

Explicit private return of farmer

Implicit public cost (Social cost) of consumption of ESs

Implicit public income (Social income) of provision of ESs by f

Green

Payments for Ecosystem Services (PES)

$$\sum_{f=1}^{F}\sum_{j=1}^{J} a_{t,i,f,j}X_{t,f,j} \le b_{t,i} \qquad for\ t = 1,2,\dots,T\ and\ i = 1,2,\dots,I$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} c_{t,s,f,j}X_{t,f,j} = ESS^c_{t,s} \qquad for\ t = 1,2,\dots,T\ and\ s = 1,2,\dots,S$$

$$\sum_{f=1}^{F}\sum_{j=1}^{J} p_{t,d,f,j}X_{t,f,j} = ESS^p_{t,d} \qquad for\ t = 1,2,\dots,T\ and\ d = 1,2,\dots,D$$

$$ESS^c_{t,s} \le ess_{t,s} \qquad for\ t = 1,2,\dots,T\ and\ s = 1,2,\dots,S$$

$$ESS^p_{t,d} \ge esd_{t,d} \qquad for\ t = 1,2,\dots,T\ and\ d = 1,2,\dots,D$$

$$X_{t,f,j} \ge 0,\ ESS^c_{t,s} \ge 0\ and\ ESS^p_{t,d} \ge 0$$

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$ESS^c_{t,s}$: Optimal amount of consumption of ESs s in year t

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SC - shadow cost, related to the consumed ESS

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Conclusion

The proposed method allows us to incorporate ESs into the farm optimization in order

- To examine the costs and benefits of ESs as well as the trade-offs between different objectives.
- To support farmers decision making regarding the inclusion of ESs.
- To prepare a production plan / cropping pattern for individual farms taking into account ESs and non-commodity markets as well as the commodity markets.
- To create a benchmark for calculating the optimal amount of Green Taxes and PES.

Thank you for your attention.

Leibniz Association

Leibniz Centre for
Agricultural Landscape Research
(ZALF)

6. Key references

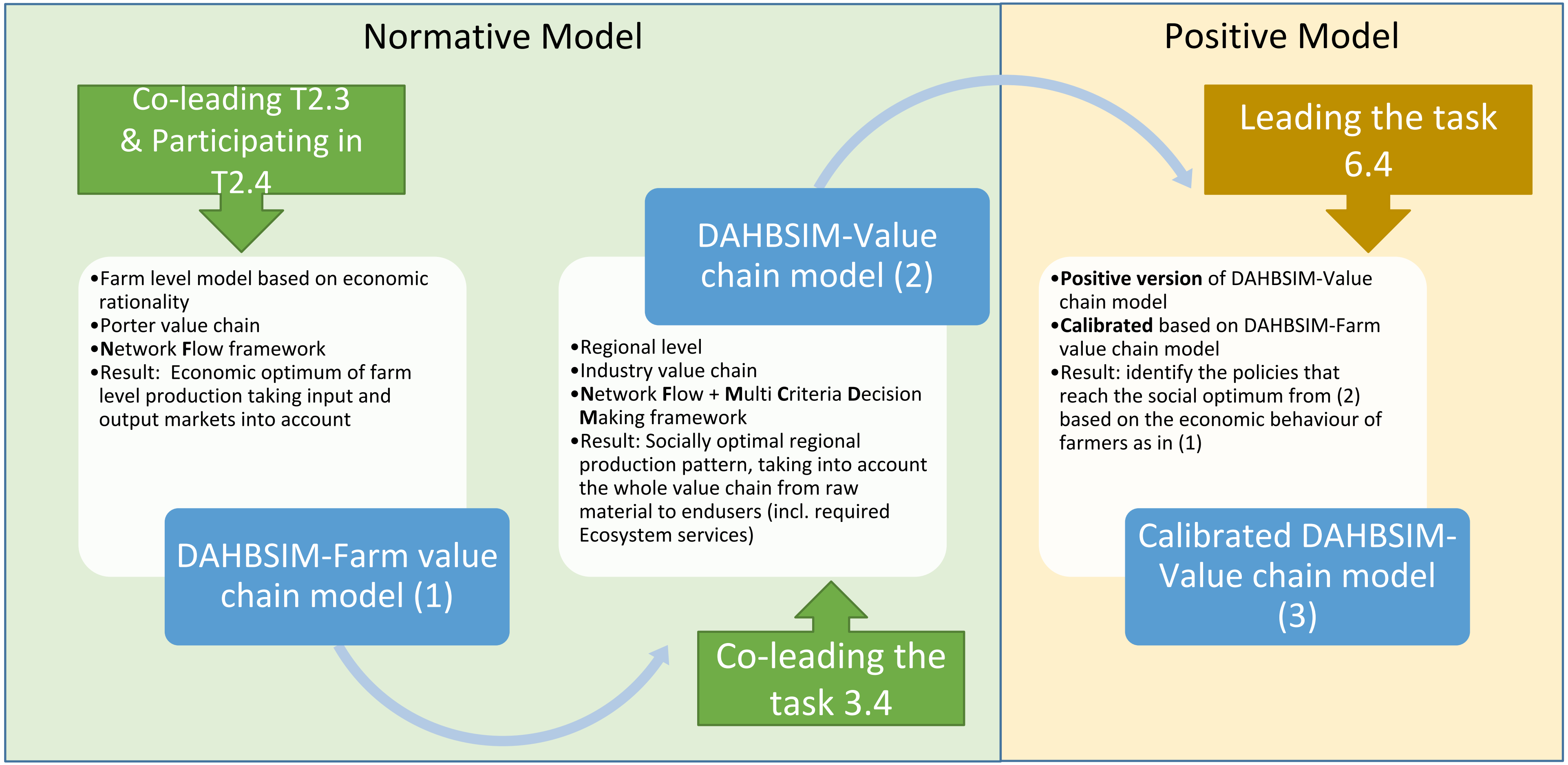
Hosseini-Yekani, S.A. & Zander, P., (2021). A mathematical model to quantitatively calculate the trade-offs between ESs within a DSS. In: Meyer-Aurich, A., Gandorfer, M., Hoffmann, C., Weltzien, C., Bellingrath-Kimura, S. & Floto, H. (Hrsg.), 41. GIL-Jahrestagung, Informations- und Kommunikationstechnologie in kritischen Zeiten. Bonn: Gesellschaft für Informatik e.V.. (S. 157-162).

Schuler, J.; Adelhart Toorop, R.; Willaume, M.; Vermue, A.; Schläfke, N.; Uthes, S.; Zander, P.; Rossing, W.: Assessing climate change impacts and adaptation options for farm performance using bio-economic models in southwestern France. Sustainability 12 (18): Article 7528, 2020.

Vilvert, E.; Lana, M.; Zander, P.; Sieber, S.: Multi-model approach for assessing the sunflower food value chain in Tanzania. Agricultural Systems 159: 103-110, 2018.

If related to a project provide website address:

https://adz-dakis.com/en/



T2.3 Conceptualisation and development of integrated modelling chain to identify and assess optimal combinations of AEP in different farming systems and scenarios (M1-M36)
(Lead: IAMM, Co-lead: ZALF; Participants: INAT, WUR, IAV, ENAM, CREAD, RIAM)

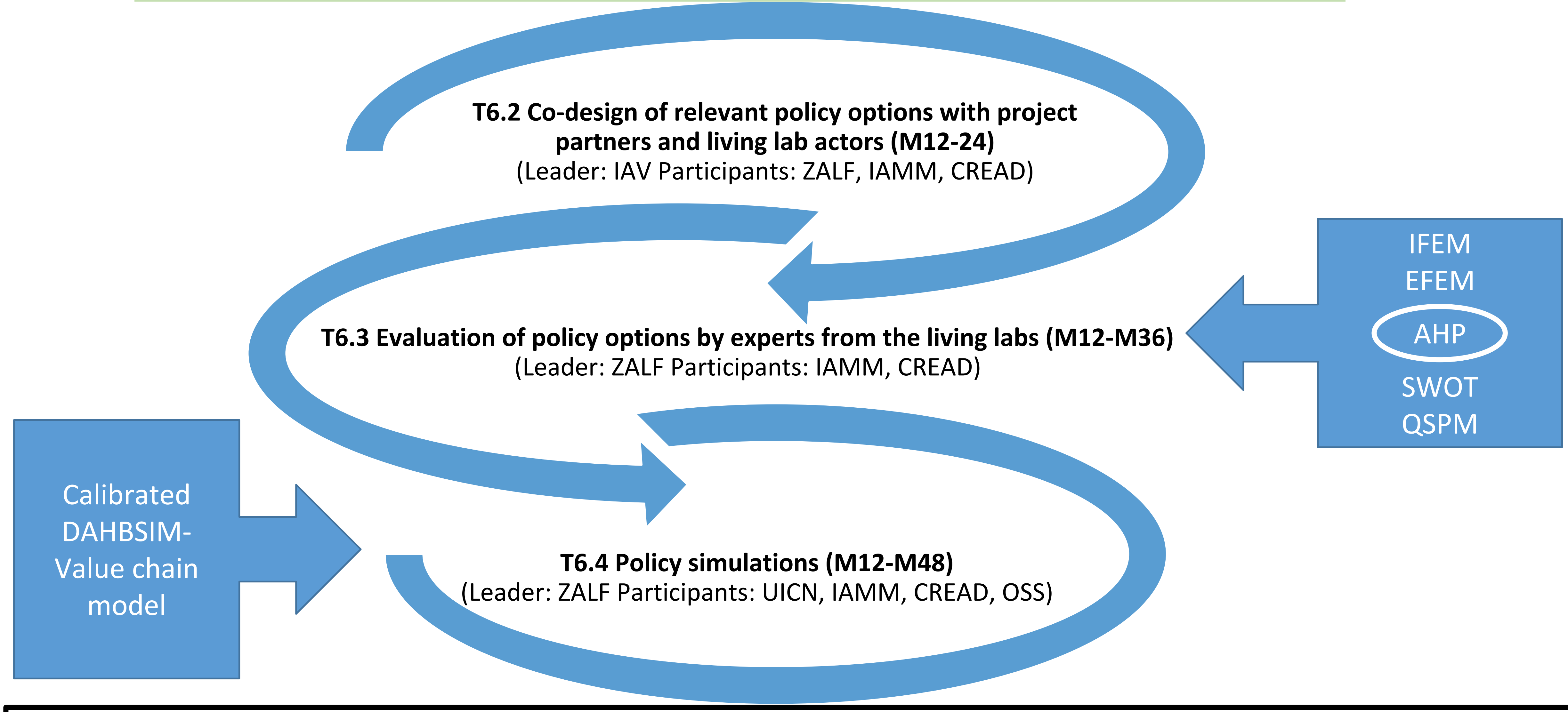
T2.4 Achieve scalability (M24-M48)
(Lead: WUR; Participants: IAMM, ZALF, LL and RL Leaders)

T3.4 Value Chain Impact Assessment (M18-M30)
(Lead: UTH, Co-lead: ZALF; Participants: IAMM, IAMB, IAV, CREAD, All LL Leaders)

T6.4 Policy simulations (M12-M48)
(Leader: ZALF Participants: UICN, IAMM, CREAD, OSS)

D2.2: Trade-offs analysis of current & foresight scenarios tested at LL and RL levels (M48; lead: ZALF)

WP6: EU-compliant policies to foster AE transition in North African countries (Leader: ZALF)



D6.3 Policy simulation report, including (i) a list of relevant existing and novel policy options in each participating NA country; (ii) expert evaluation of policy options in each country; (iii) simulation results of implementing the high-ranked policy options (M40, ZALF)

D6.4 Policy paper on Agro-ecology in North African countries: Opportunities and Recommendations in line with EU-Africa strategy, Paris Agreement and SDGs, based on review & simulation findings (M48, CARI, ZALF)

Participating in three tasks of WP1: Multidimensional and multiscale AEP strategy evaluation framework

- T1.2 Building a multidimensional, multiscale evaluation framework on AEP performances in NA (M3-M7)
  (Lead: IAMB; Co-lead: IAMM ; Participants: INAT, UTH, CARI, ZALF, WUR, MAICh, IAV, ENAM, UICN, GRDR, UoC, CREAD, OSS, ENSA, RIAM, UoS, TENMIYA, UoP)

- T1.3 Identifying criteria and potential areas for scaling-up and extrapolation (M6-M24)
  (Lead: MAICh; Participants: IAMM, IAMB, ZALF, CREAD with review from INAT, UoC, IAV)

- T1.4 Scientific reflexivity on the project evaluation methodology (M29-M48)
  (Lead: IAMB; Co-lead : IAMM ; Participants: INAT, UTH, CARI, ZALF, WUR, MAICh, IAV, SPI, ENAM, UICN, GRDR, UoC, CREAD, OSS, ENSA, RIAM, UoS, TENMIYA, UoP)

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Participating in T8.3: Open science strategy, ethics, intellectual property and DMP (M01-M06)
(Task leader: IAMM; Participants: IAMM, WUR, ENSA, UTH, ZALF)