DAKIS - Digital Agricultural Knowledge and Information System

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

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.
Identification of biomass potentials at subfield level at the Dahmsdorf site.
Identification of potential to reduce soil erosion and erosion hotspots at subfield level for four landscape windows (5x5 km) in Brandenburg and Bavaria.
Monitoring floristic biodiversity and identifying high nature value farmland and effects of management

Deepak Basavegowda (ATB), Inga Schleip (HNEE)
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)

Markos Krull (ZALF)

Villanueva-Rivera et al., 2011
Bobryk et al., 2016
A toolbox to build agroecosystem models based on SimComponents ➔ Application of model solutions from subfield to regional scale

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

Weather/Climate
- Temperature
- Radiation
- CO2
- Water
Crop
- Transpiration
- Phenology
- Growth
- Nutrient Uptake
Soil
- Roots
- Nutrients
- Water
- Temperature

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

Biomass at harvest (g m$^{-2}$)
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)

Data Collection
Monitoring Sensors

Scenarios
(climate, technologies, policies, markets)

Simulations, Forecasts
Land use options

DAKIS Front-end

Propose options

Farmer decides on production plan
Reconsider or adapt operation during season

Continued monitoring

GUI allows to
• view/modify input data
• execute GAMS jobs
• Results directly visualised
• Sensitivity analysis
• Scenario comparison

Mathematical programming module
• Policies
• Biogas plants
• Livestock activities
• Feeding / substrate use
• Plant production activities
• Manure management
• Investments and Cash Flow
• Environmental Accounting

S. Zachäus

Ali Hosseini Yekani
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

\[
\begin{align*}
\text{Max}_{X} \quad GM &= \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} (1 + r)^{-t} gm_{t,j} X_{t,f,j} \\
\sum_{f=1}^{F} \sum_{j=1}^{J} a_{t,i,f,j} X_{t,f,j} &\leq b_{t,i} \quad \text{for } t = 1, 2, \ldots, T \text{ and } i = 1, 2, \ldots, I \\
\sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} &\leq ess_{t,s} \quad \text{for } t = 1, 2, \ldots, T \text{ and } s = 1, 2, \ldots, S \\
\sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} &\geq esd_{t,d} \quad \text{for } t = 1, 2, \ldots, T \text{ and } d = 1, 2, \ldots, D \\
X_{t,f,j} &\geq 0
\end{align*}
\]

*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*  
*esd*_{t,d}: Total society’s demand of ESs *d* in year *t*
Simplified form of whole farm mathematical model within DAKIS

\[
\begin{align*}
\text{Max } & \quad GM = \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} (1 + r)^{-t} g_{m_{t,j}} X_{t,f,j} \\
\sum_{f=1}^{F} \sum_{j=1}^{J} a_{t,i,f,j} X_{t,f,j} & \leq b_{t,i} \quad \text{for } t = 1, 2, \ldots \\
\sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} & \leq ess_{t,s} \quad \text{for } t = 1, 2, \ldots \\
\sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} & \geq esd_{t,d} \quad \text{for } t = 1, 2, \ldots \\
X_{t,f,j} & \geq 0
\end{align*}
\]

GM: Maximized net present value of farmer’s total gross margin during time horizon
r: Discount rate
\(g_{m_{t,j}}\): 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 \(j\)
\(b_{t,i}\): 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 \(f\)
\(ess_{t,s}\): 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 \(f\)
\(esd_{t,d}\): Total society’s demand of ESs \(d\) in year \(t\)
Simplified form of whole farm mathematical model within DAKIS

\[ GM = \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} \left( a_{t,i,f,j} X_{t,f,j} \right) = X \]

\[ \sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} \leq ess_{t,s} \quad \text{for } t = 1,2, \ldots \]

\[ \sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} \geq esd_{t,d} \quad \text{for } t = 1,2, \ldots \]

\[ X_{t,f,j} \geq 0 \]

\( GM \): Maximized net present value of farmer’s total gross margin
d\( r \): Discount rate
g\( m_{t,j} \): 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
\( b_{t,i} \): 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 \( f \)
es\( ss_{t,s} \): Total society’s supply of ESs \( s \) in year \( t \)
es\( sd_{t,d} \): Total society’s demand of ESs \( d \) in year \( t \)

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
Simplified form of whole farm mathematical model within DAKIS

\[
\text{Max } \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} g_m t,j X_{t,f,j} (1 + r)^{-t}
\]

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} a_{t,i,f,j} X_{t,f,j} \leq b_{t,i} \quad \text{for } t = 1,2,\ldots
\]

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j} X_{t,f,j} \leq e_{s,t,s} \quad \text{for } t = 1,2,\ldots
\]

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,d,f,j} X_{t,f,j} \geq e_{s,t,d} \quad \text{for } t = 1,2,\ldots
\]

\[X_{t,f,j} \geq 0\]

\(GM\): Maximized net present value
\(T, F, J\): Number of years, fields, and crops
\(r\): Discount rate
\(g_m t,j\): Gross margin of one unit of crop \(j\) in year \(t\)
\(a_{t,i,f,j}\): Technical coefficient of constraint \(i\) for producing one unit
\(b_{t,i}\): Total available amount of constraint \(i\) in year \(t\)
\(c_{t,s,f,j}\): Consumption of ESs \(s\) for producing one unit of crop \(j\) in field \(f\)
\(e_{s,t,s}\): 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 \(j\) in field \(f\)
\(e_{s,t,d}\): Total society’s demand of ESs \(d\) in year \(t\)
New model: Determination of optimal consumption and provision of ESS by introduction of the shadow prices of consumed and produced ESS

\[
\text{Max}_{x_{t}, ESS^c, ESS^p} \quad \text{SGM} = \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} \sum_{s=1}^{S} \sum_{d=1}^{D} (1 + r)^{-t} [g_{m_{t,j}}X_{t,f,j}]
\]

Explicit private return of farmer

Implicit public cost (Social cost) of consumption of ESSs

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} a_{t,i,f,j}X_{t,f,j} \leq b_{t,i} \quad \text{for } t = 1, 2, ..., T \text{ and } i = 1, 2, ..., I
\]

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,s,f,j}X_{t,f,j} = ESS^c_{t,s} \quad \text{for } t = 1, 2, ..., T \text{ and } s = 1, 2, ..., S
\]

\[
\sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,d,f,j}X_{t,f,j} = ESS^p_{t,d} \quad \text{for } t = 1, 2, ..., T \text{ and } d = 1, 2, ..., D
\]

\[
ESS^c_{t,s} \leq ess_{t,s} \quad \text{for } t = 1, 2, ..., T \text{ and } s = 1, 2, ..., S
\]

\[
ESS^p_{t,d} \geq esd_{t,d} \quad \text{for } t = 1, 2, ..., T \text{ and } d = 1, 2, ..., D
\]

\[
X_{t,f,j} \geq 0, ESS^c_{t,s} \geq 0 \text{ and } ESS^p_{t,d} \geq 0
\]

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

**ESS^c_{t,s}**: Optimal amount of consumption of ESSs \(s\) in year \(t\)

**ESS^p_{t,d}**: Optimal amount of provision of ESSs \(d\) in year \(t\)

**SC**: Shadow cost, related to the consumed ESSs

**SR**: Shadow revenue, related to the produced ESSs
New model: Determination of optimal consumption and provision of ESS by introduction of the shadow prices of consumed and produced ESS.

Max \( X_{t,f}X_{t,f,j} \) \( SGM = \sum_{t=1}^{T} \sum_{f=1}^{F} \sum_{j=1}^{J} \sum_{s=1}^{S} \sum_{d=1}^{D} \frac{1}{(1+r)^t} \left[ g_{t,j}X_{t,f,j} \right] \)

Implicit public cost (Social cost) of consumption of ESS

\[ \sum_{f=1}^{F} \sum_{j=1}^{J} a_{t,f,j}X_{t,f,j} \leq b_{t,i} \quad \text{for } t = 1,2, \ldots, T \text{ and } i = 1,2, \ldots, I \]

\[ \sum_{f=1}^{F} \sum_{j=1}^{J} c_{t,f,j}X_{t,f,j} = ESS^c_{t,s} \quad \text{for } t = 1,2, \ldots, T \text{ and } s = 1,2, \ldots, S \]

Explicit private return of farmer

\[ \sum_{f=1}^{F} \sum_{j=1}^{J} p_{t,f,j}X_{t,f,j} = ESS^p_{t,d} \quad \text{for } t = 1,2, \ldots, T \text{ and } d = 1,2, \ldots, D \]

Implicit public income (Social income) of provision of ESS by farmer

\[ ESS^c_{t,s} \leq ess_{t,s} \quad \text{for } t = 1,2, \ldots, T \text{ and } s = 1,2, \ldots, S \]

\[ ESS^p_{t,d} \geq esd_{t,d} \quad \text{for } t = 1,2, \ldots, T \text{ and } d = 1,2, \ldots, D \]

\[ X_{t,f,j} \geq 0, ESS^c_{t,s} \geq 0 \text{ and } ESS^p_{t,d} \geq 0 \]

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

\( ESS^c_{t,s} \): Optimal amount of consumption of ESSs \( s \) in year \( t \)

\( ESS^p_{t,d} \): Optimal amount of provision of ESSs \( d \) in year \( t \)

\( SC \) - shadow cost, related to the consumed ESS

\( SR \) - shadow revenue, related to the produced ESS

Payments for Ecosystem Services (PES)
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 Centre for Agricultural Landscape Research (ZALF)
6. Key references


If related to a project provide website address:

https://adz-dakis.com/en/
**Normative Model**

- Farm level model based on economic rationality
- Porter value chain
- Network Flow framework
- Result: Economic optimum of farm level production taking input and output markets into account

**Positive Model**

- Regional level
- Industry value chain
- Network Flow + Multi Criteria Decision Making framework
- Result: Socially optimal regional production pattern, taking into account the whole value chain from raw material to endusers (incl. required Ecosystem services)

**DAHBSIM-Farm value chain model (1)**

- Positive version of DAHBSIM-Value chain model
- Calibrated based on DAHBSIM-Farm value chain model
- Result: Identify the policies that reach the social optimum from (2) based on the economic behaviour of farmers as in (1)

**DAHBSIM-Value chain model (2)**

- Calibrated DAHBSIM-Value chain model

**Co-leading the task 3.4**

**Leading the task 6.4**

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

**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)
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, MAIC, 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: MAIC; 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, MAIC, IAV, SPI, ENAM, UICN, GRDR, UoC, CREAD, OSS, ENSA, RIAM, UoS, TENMIYA, UoP)

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