Planning Agricultural Core Road Networks based on a Digital Twin of the Cultivated Landscape

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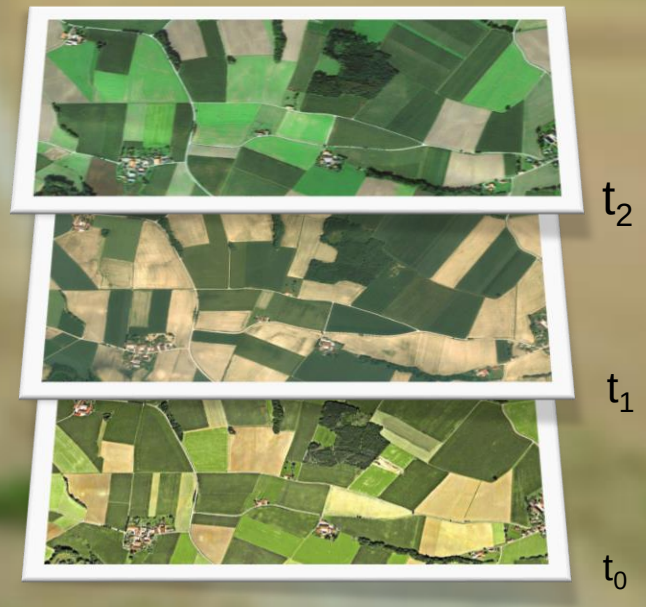


Foto: J. Eisentraut, 2018

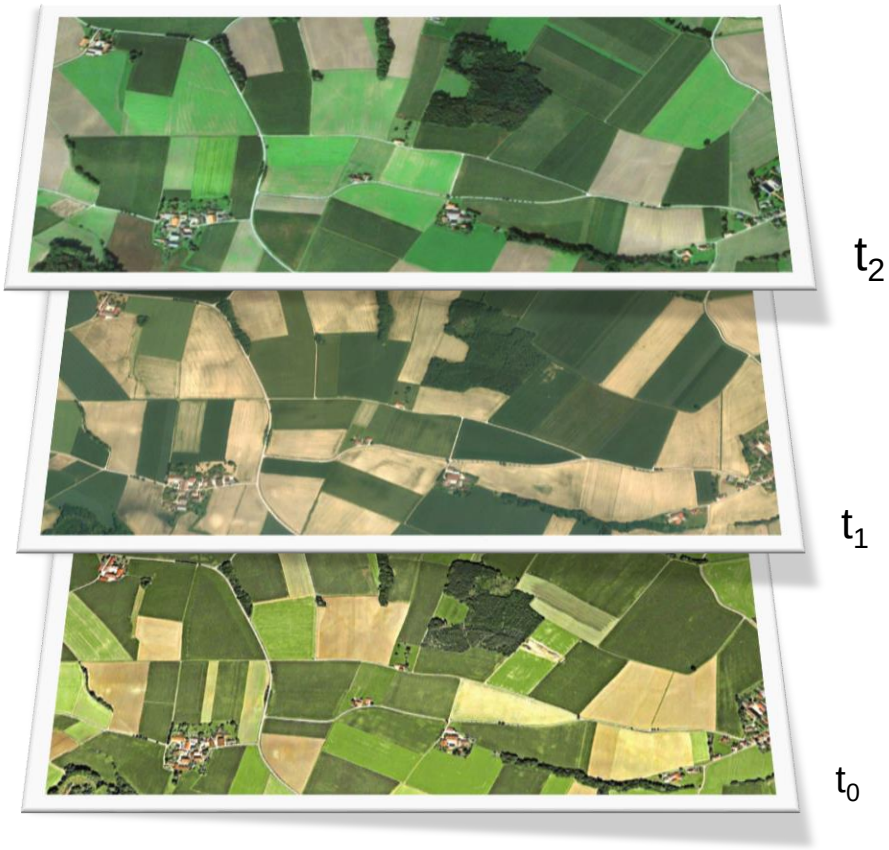
The concept of the Digital Twin (DT)

- Mainly used in the context of industry 4.0
- DT = digital representation of a physical or non-physical object representing the state and behavior of an object
- DT is kept up to date throughout the entire life cycle of its physical counterpart
- Digital Twin concept promises to optimize the development, operation and maintenance of products

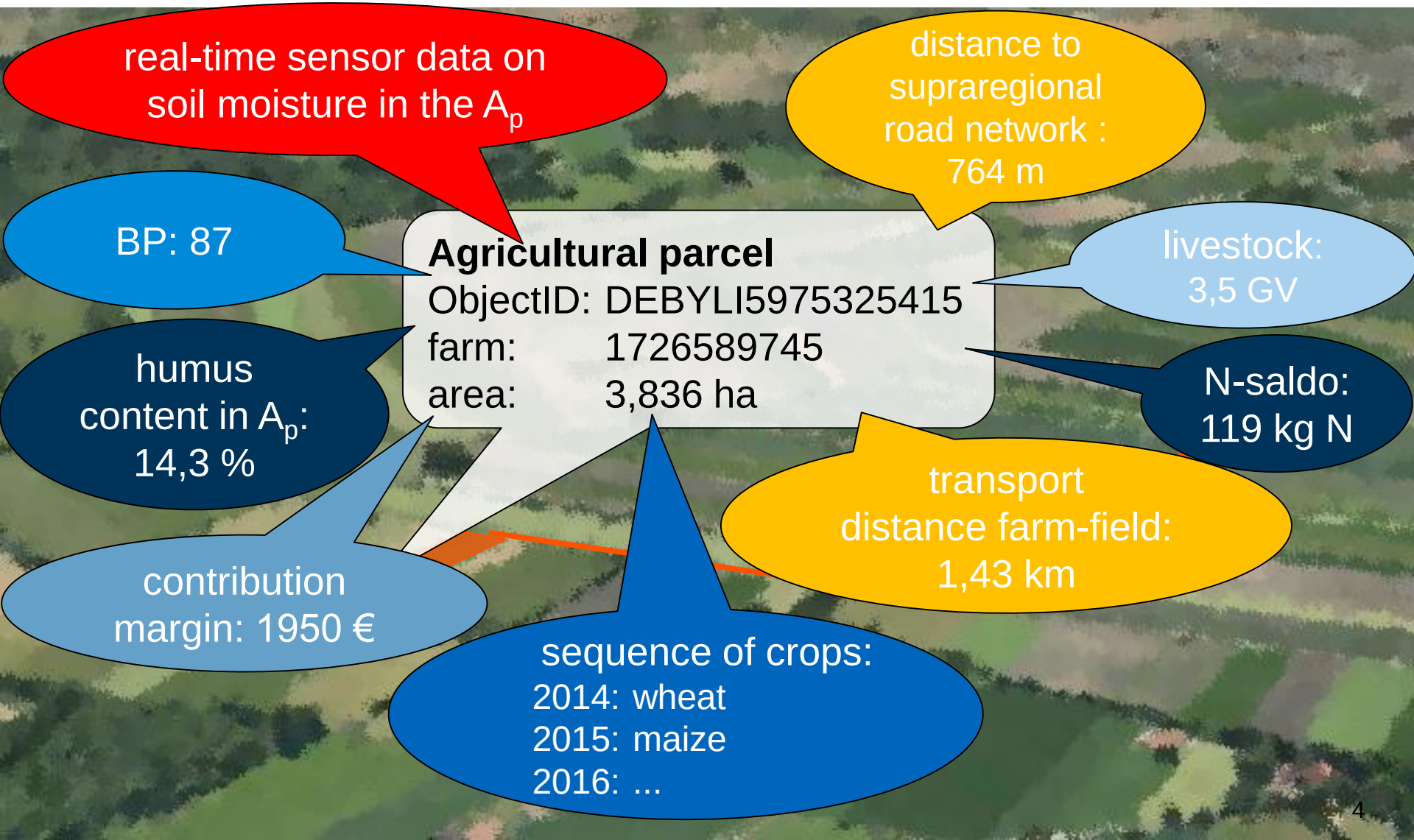
Towards a Digital Twin (DT) of the cultivated landscape

- The scope and information content of the DT of the cultivated landscape goes beyond traditional Digital Landscape Models:
  - Modeling of the evolution of objects
  - Temporal relations between objects
  - Semantic extension of the model
  - ...
- In contrast to industry information about real world objects of the cultivated landscape is heterogenous and distributed across several organizations and stakeholders

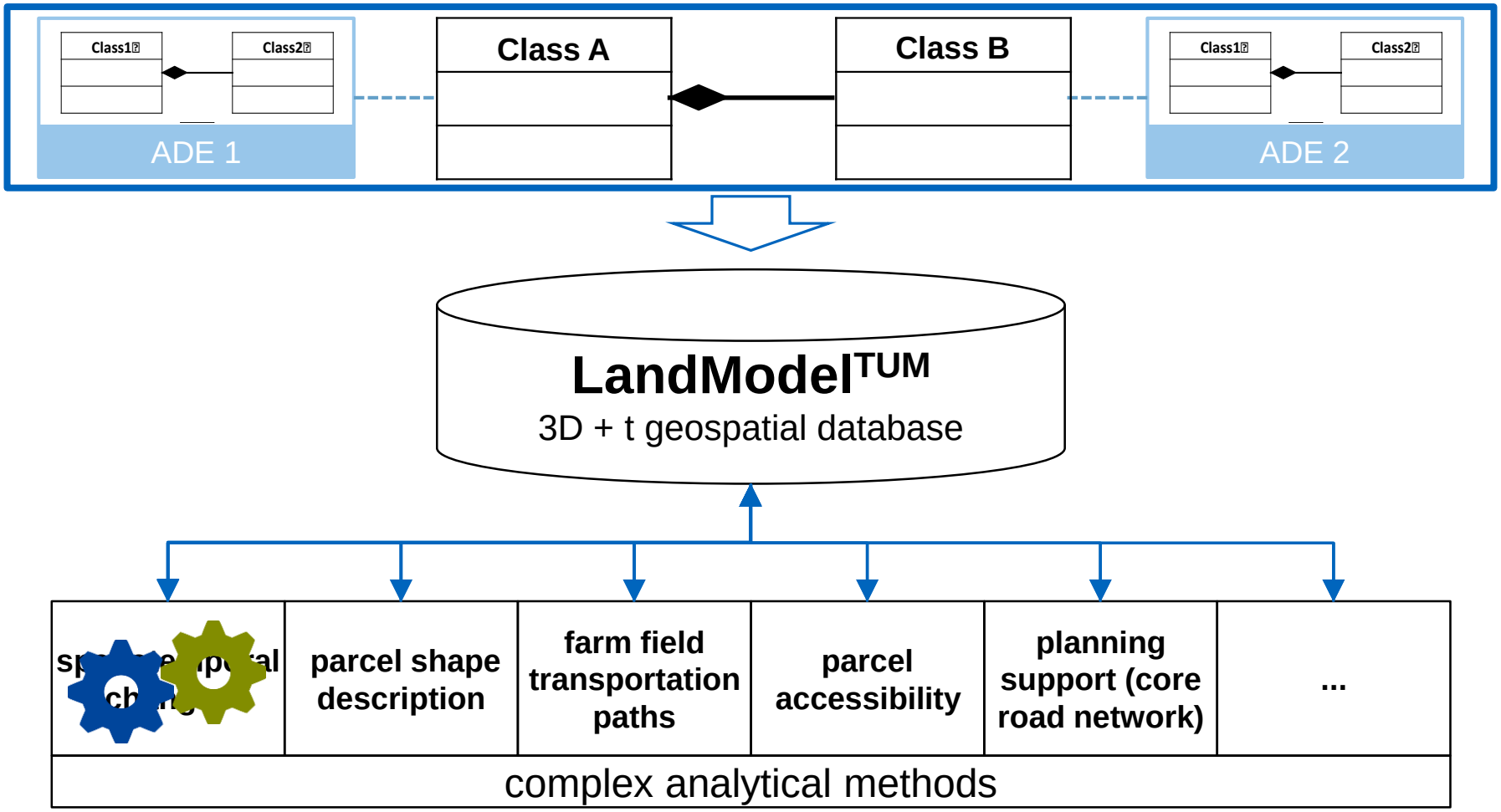
  ➔ information integration



Vision: smart rural areas



Core concept: coupling of the information model and complex analytical methods



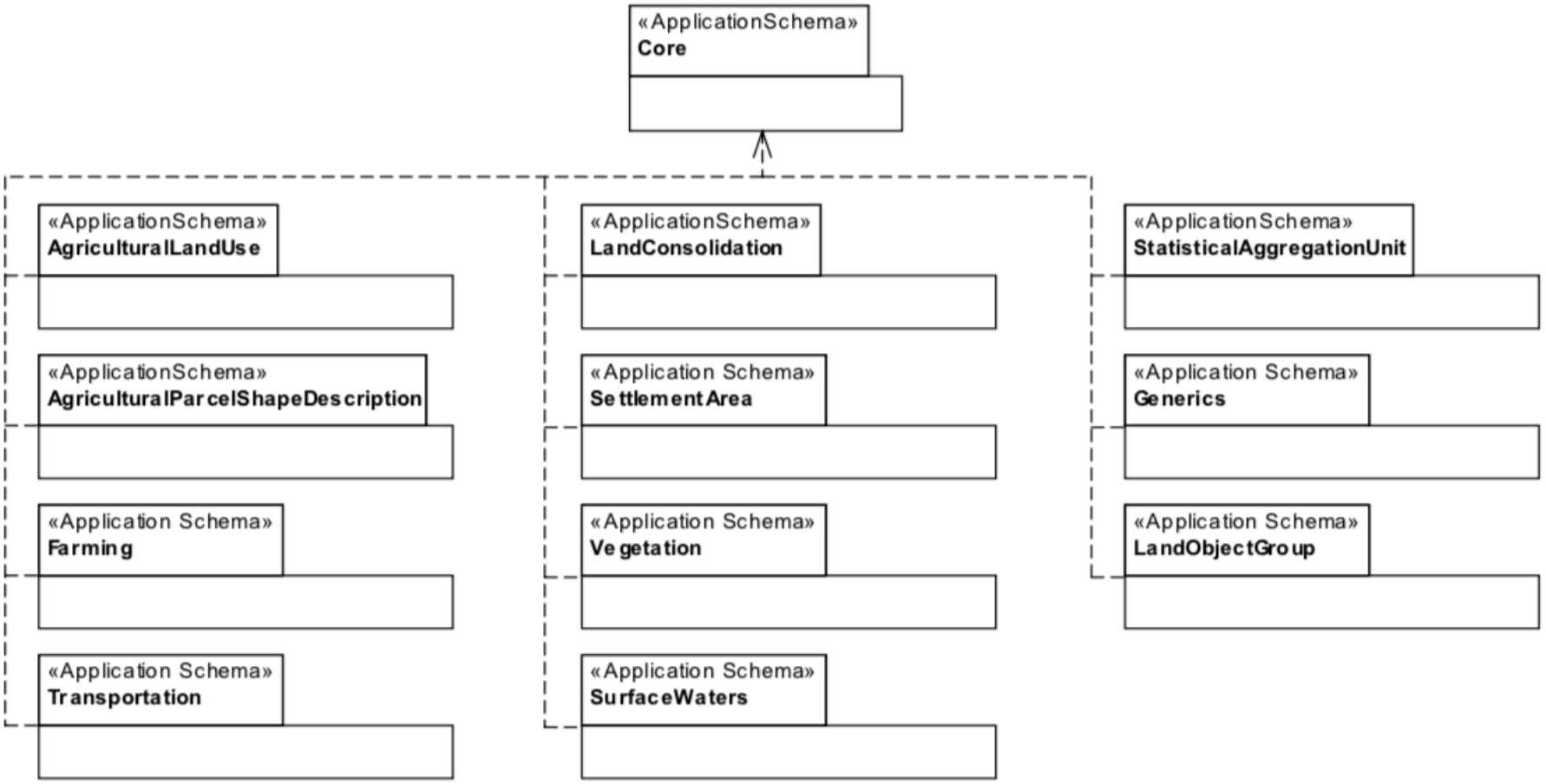
Basic requirements

- Modeling of relevant object types, attributes, and relationships
- Comprehensive modelling of temporal aspects:
  - lifetime of objects
  - changes of state
  - temporal validity of relationships between objects
  - temporal transitions between objects over time
- Conformance to international standards of the ISO 19100 series (especially ISO 19107, ISO 19108, ISO 19109)
- Concept of semantic enrichment

Key research questions

- How to design an information model in order to use it as an application-independent spatiotemporal Digital Twin of the cultivated landscape?
- What concepts are needed to use the Digital Twin for the fusion of interdisciplinary information?
- How can the developed concepts for the monitoring of the current state also be used to evaluate possible states of the future (e.g. in the context of planning processes)?

Packages of the LandModel^{TUM}



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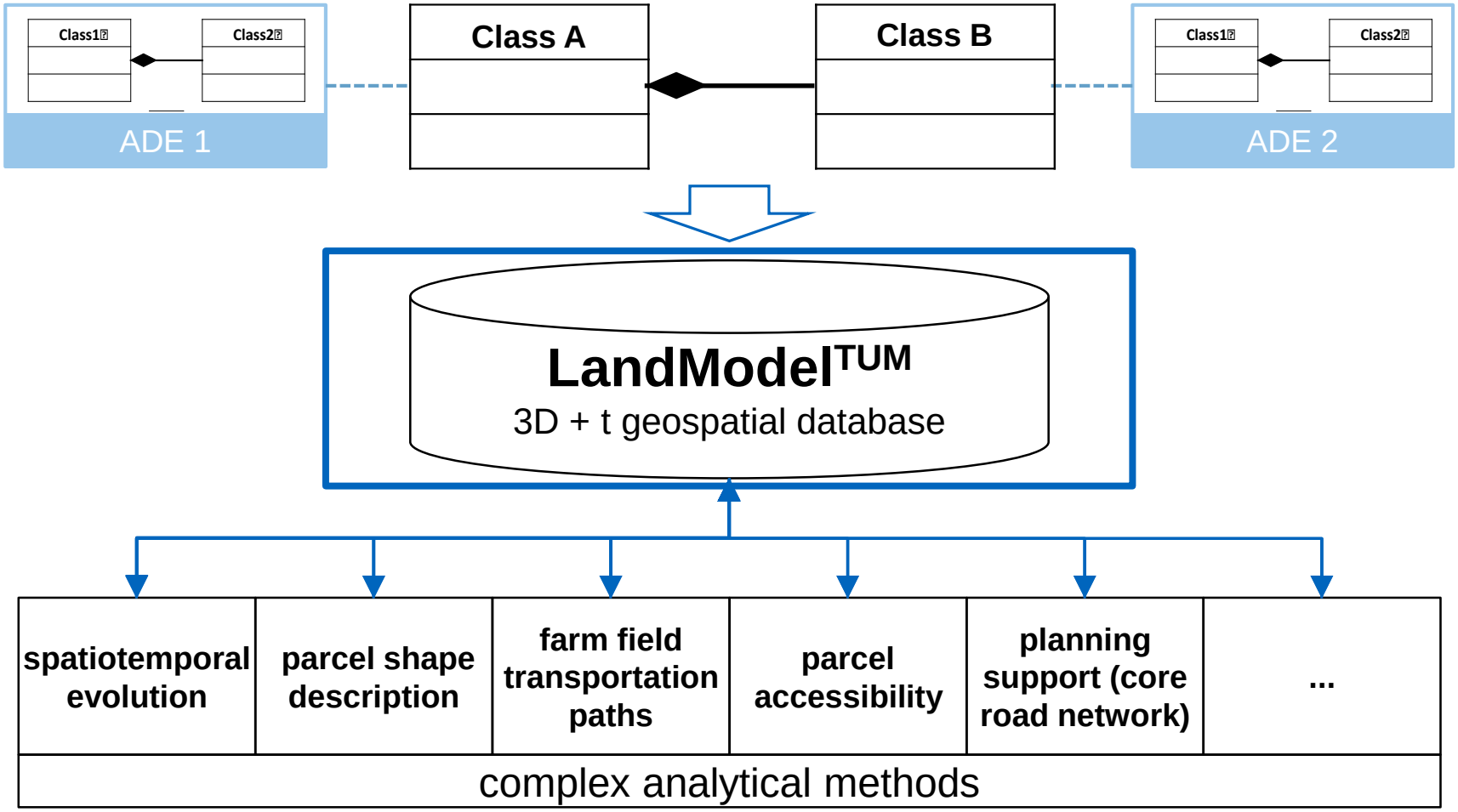
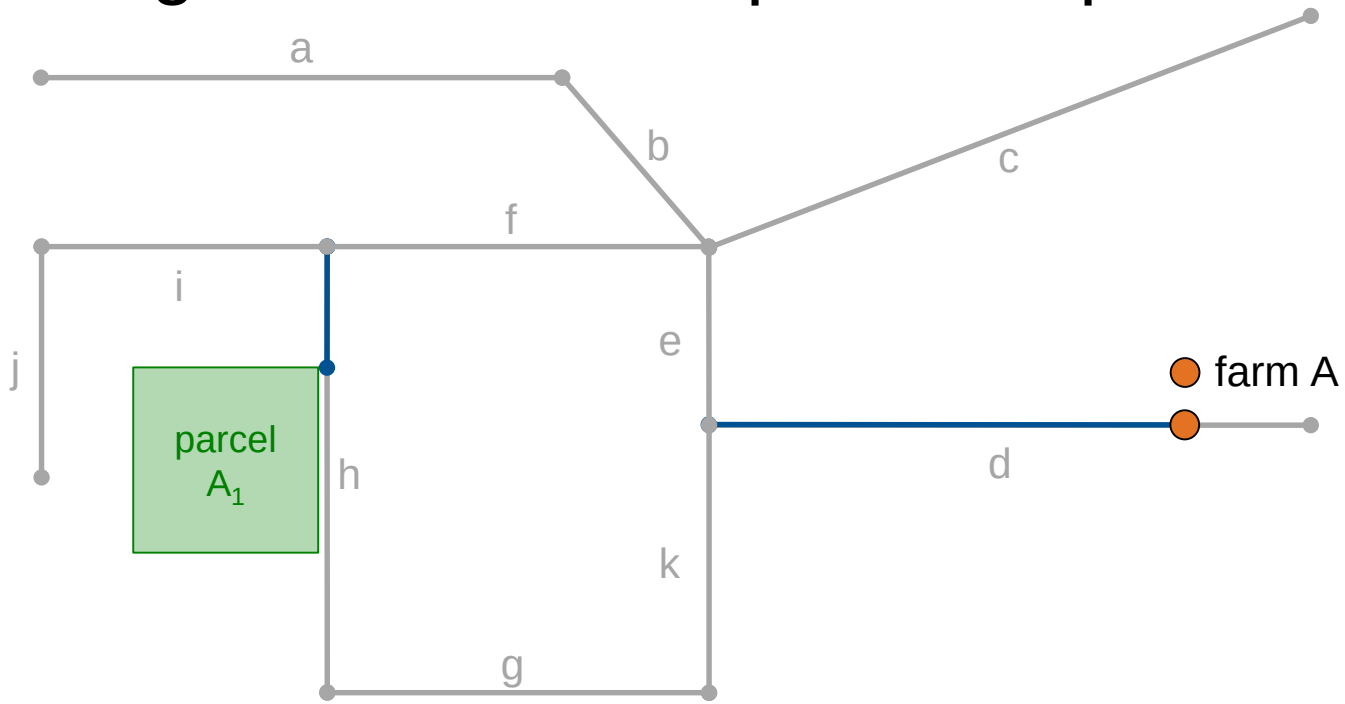


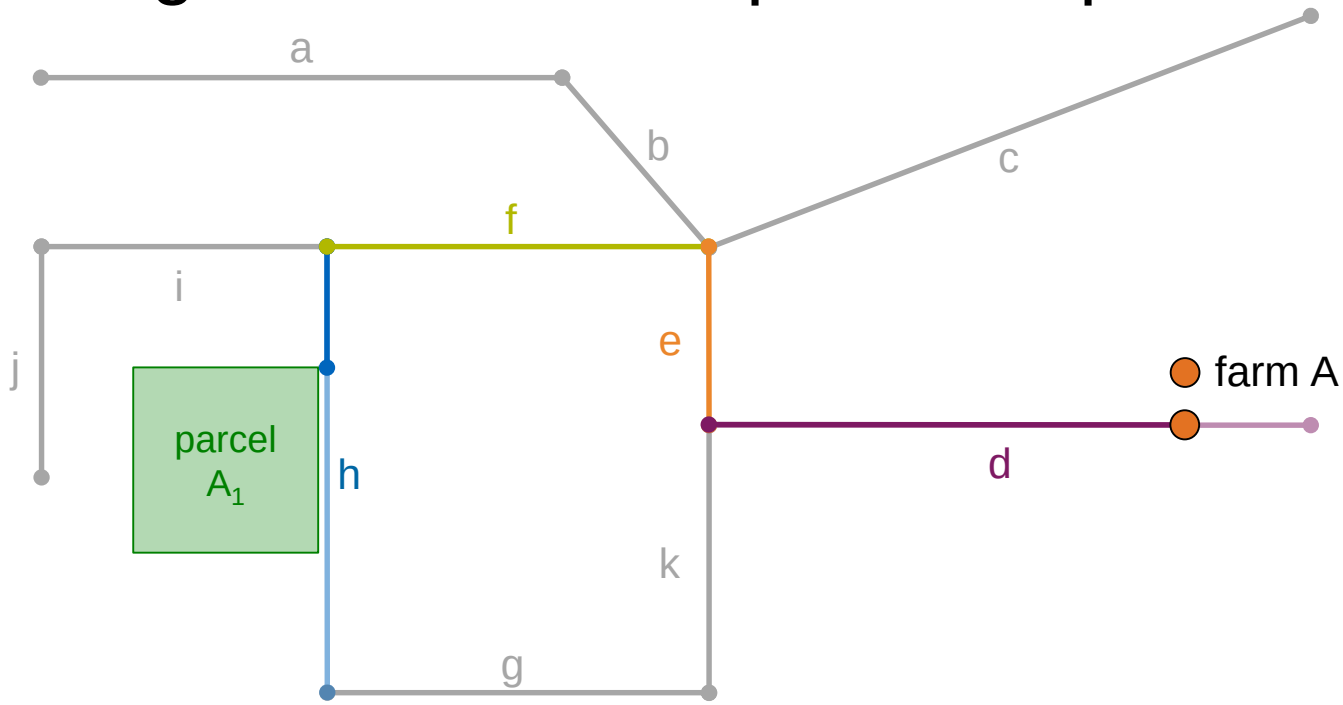
Key research questions

- How can algorithms be used to derive realistic farm-field transportation paths taking into account the existing transport network, the location of farms, and their agricultural parcels?
- How can the traffic significance of individual path segments within the agricultural road system be quantified?
- How can the developed concepts for the monitoring of the current state also be used to evaluate possible states of the future in order support a geodesign process?

Estimating farm field transportation paths

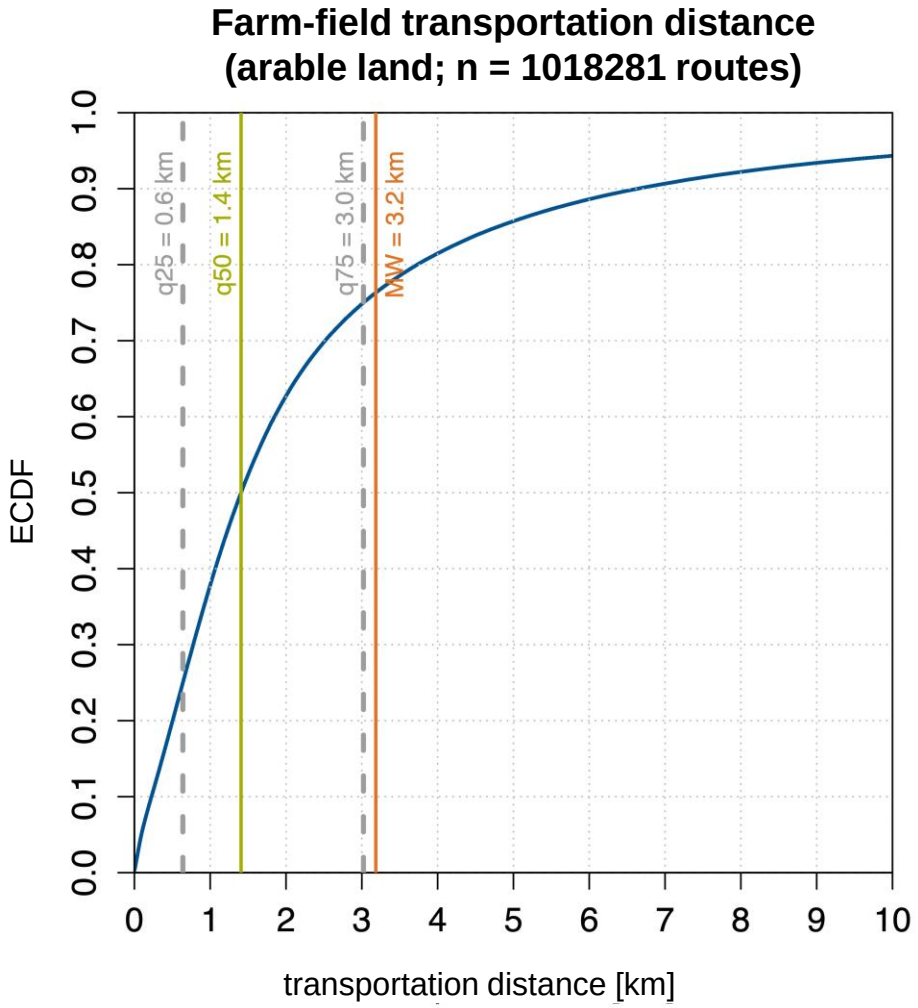


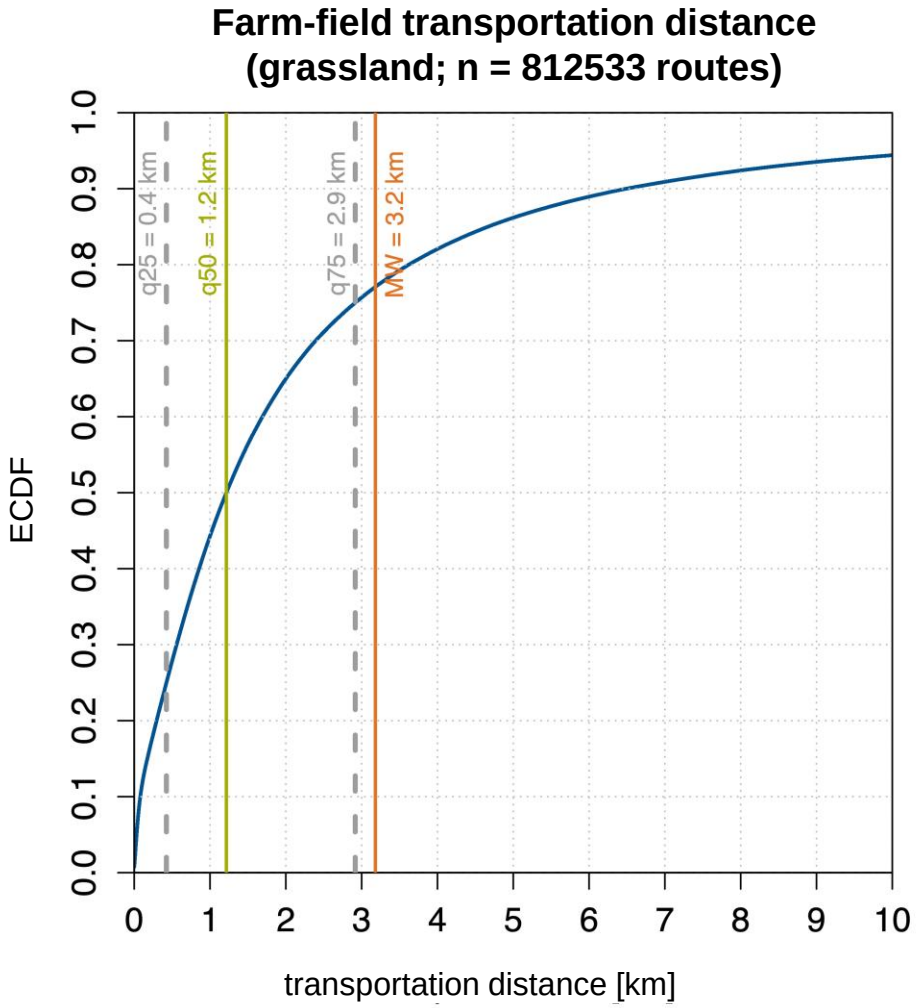
Estimating farm field transportation paths



farm	parcel	index	idSegment	from	to
A	A_1	0	h	0,8	1,0
A	A_1	1	f	0,0	1,0
A	A_1	2	e	1,0	0,0
A	A_1	3	d	1,0	0,1

Farm-field transportation distance in Bavaria



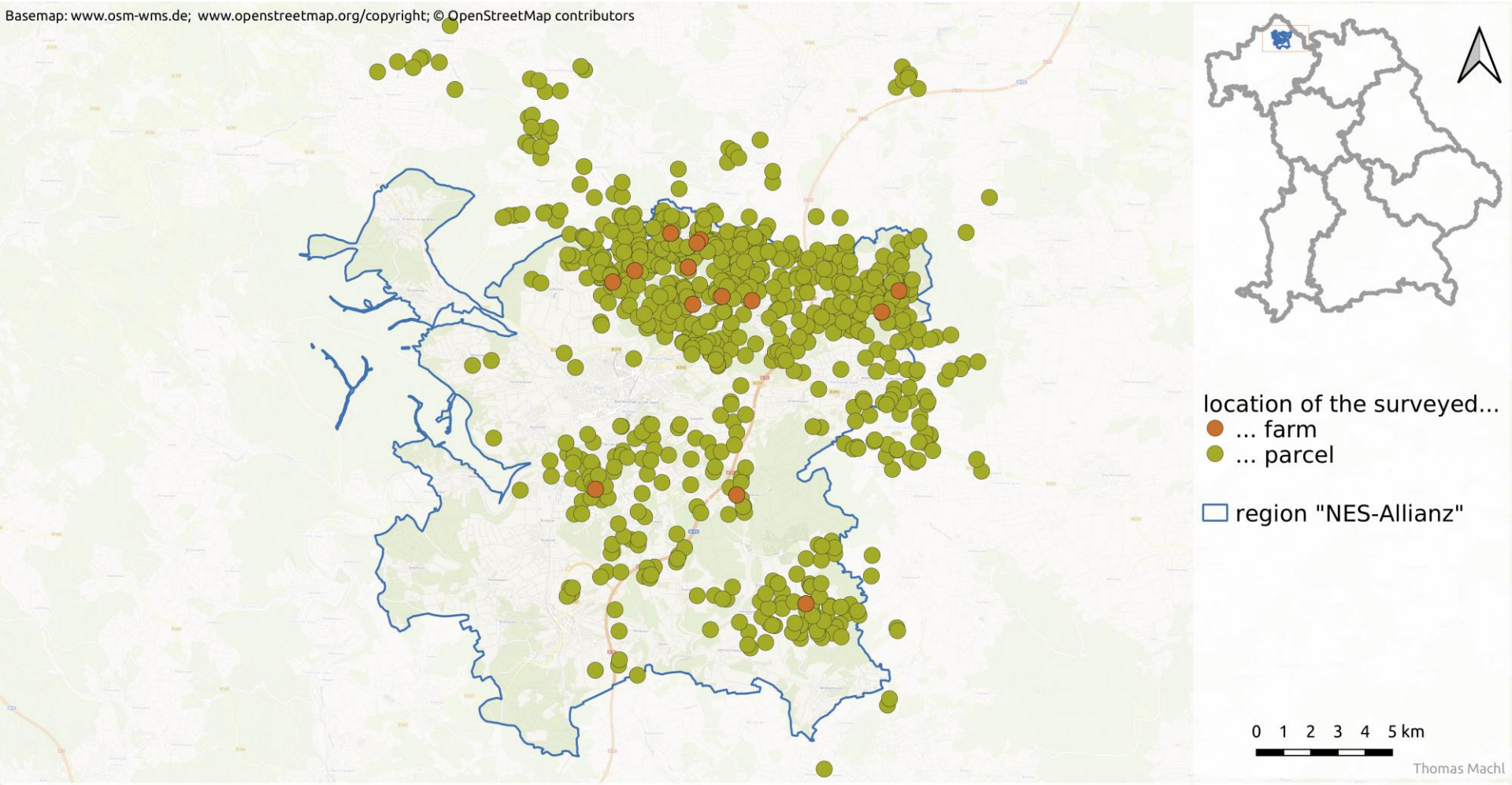


Evaluation of the developed approach

- Survey of 13 farms and 1 biogas plant operator
- Farm size: 20 to > 1000 ha (q_{25}: 78 ha; q_{50} 122 ha; q_{75} 181 ha)
- Comparison of approx. 800 farm-field transport paths (> 80 % FS)

Image: Astner, 2017

Location of the surveyed farms and parcels



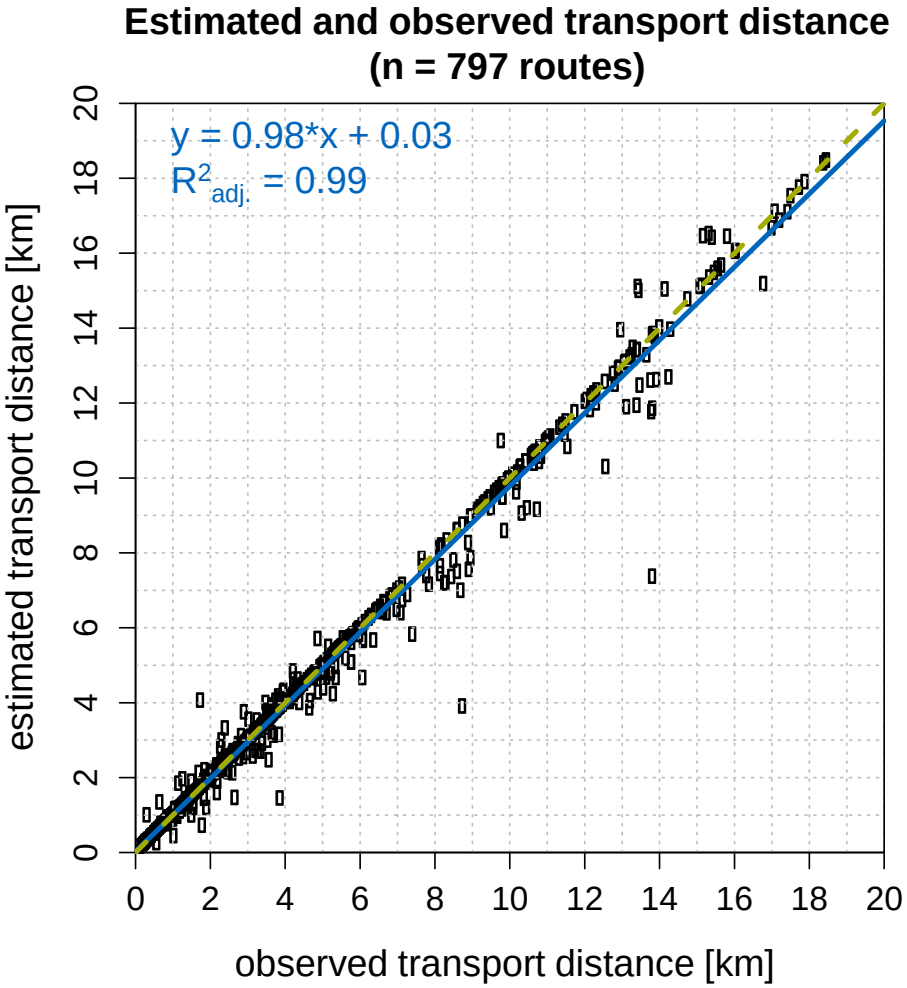
Location of agricultural parcels and farms
for the evaluation of the calculated farm-field transport paths

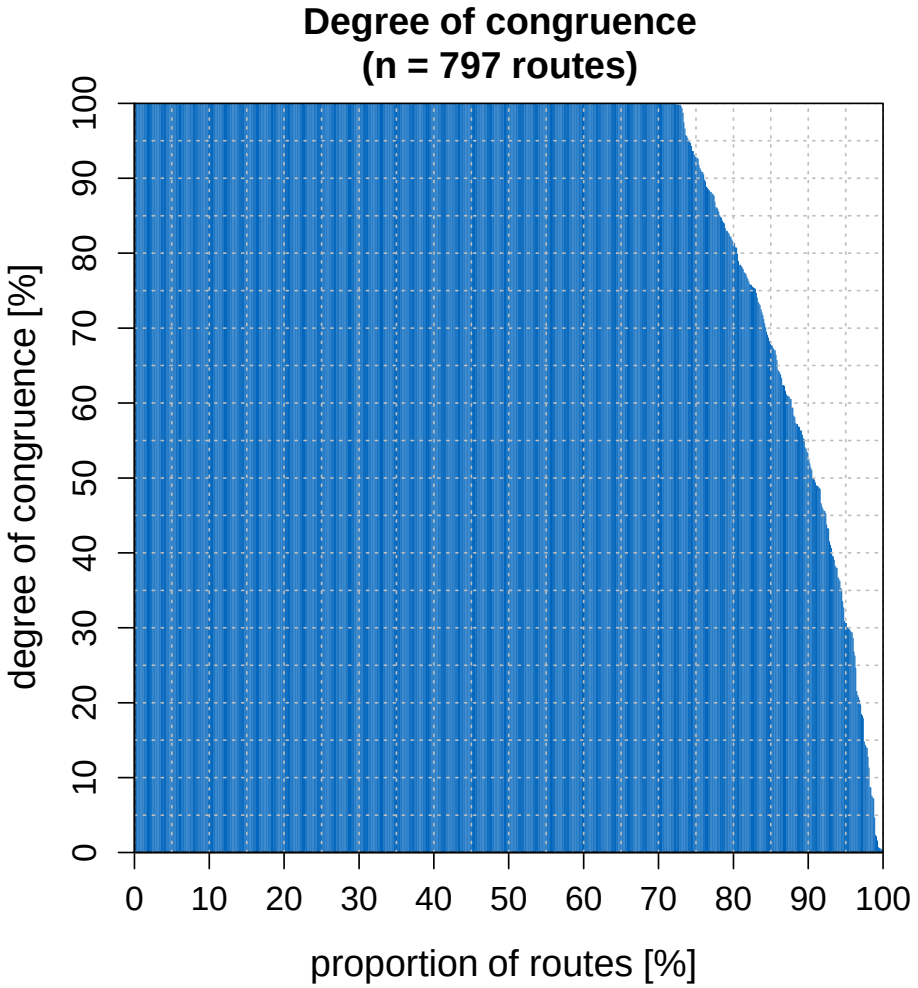
Evaluation of the estimation accuracy

$$DOC = \frac{length_{congruentPath}}{Length_{estimatedPath}}$$

actual route
estimated route
congruent part of theroute
Deviating part of the route

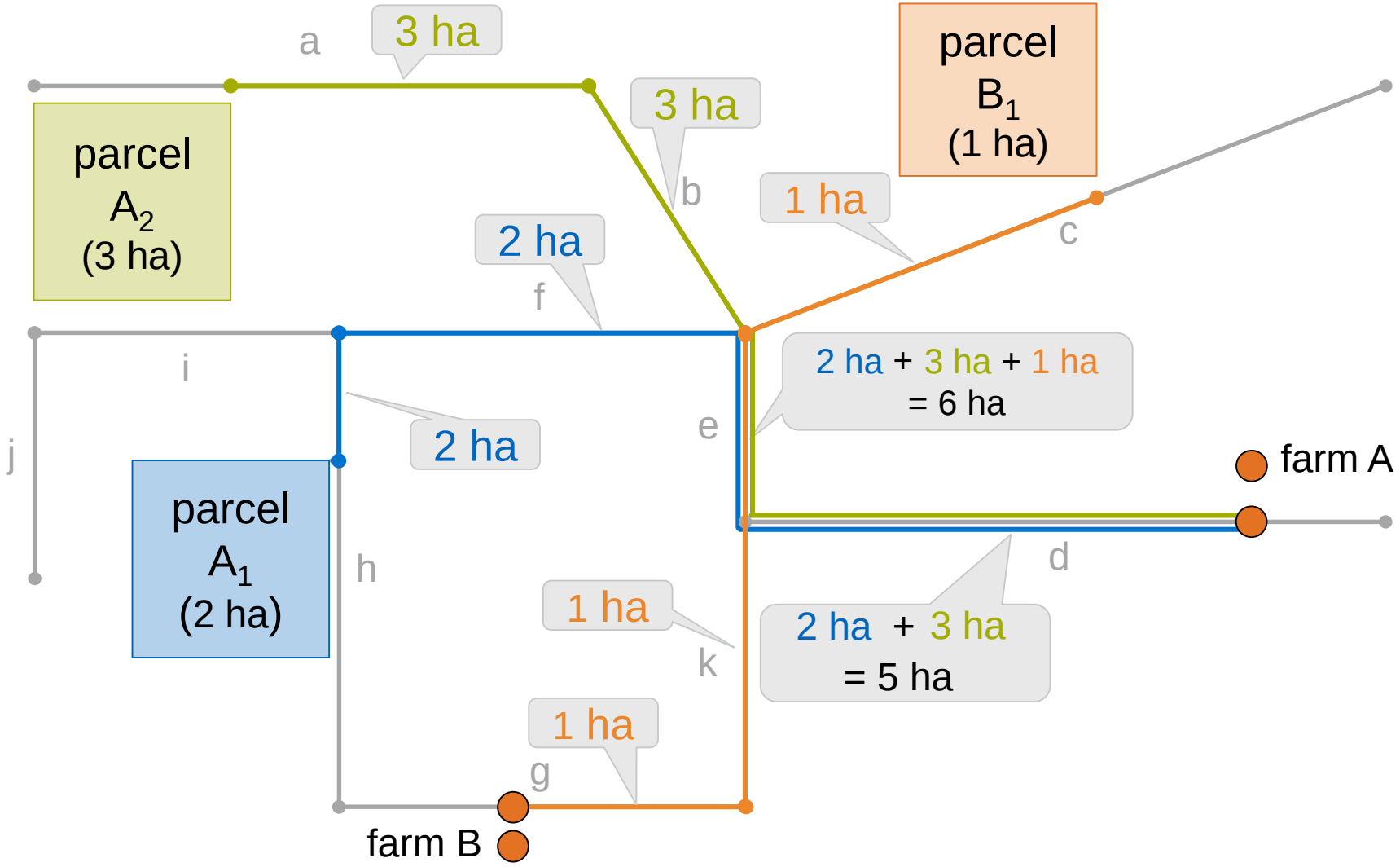
Evaluation of the estimation accuracy



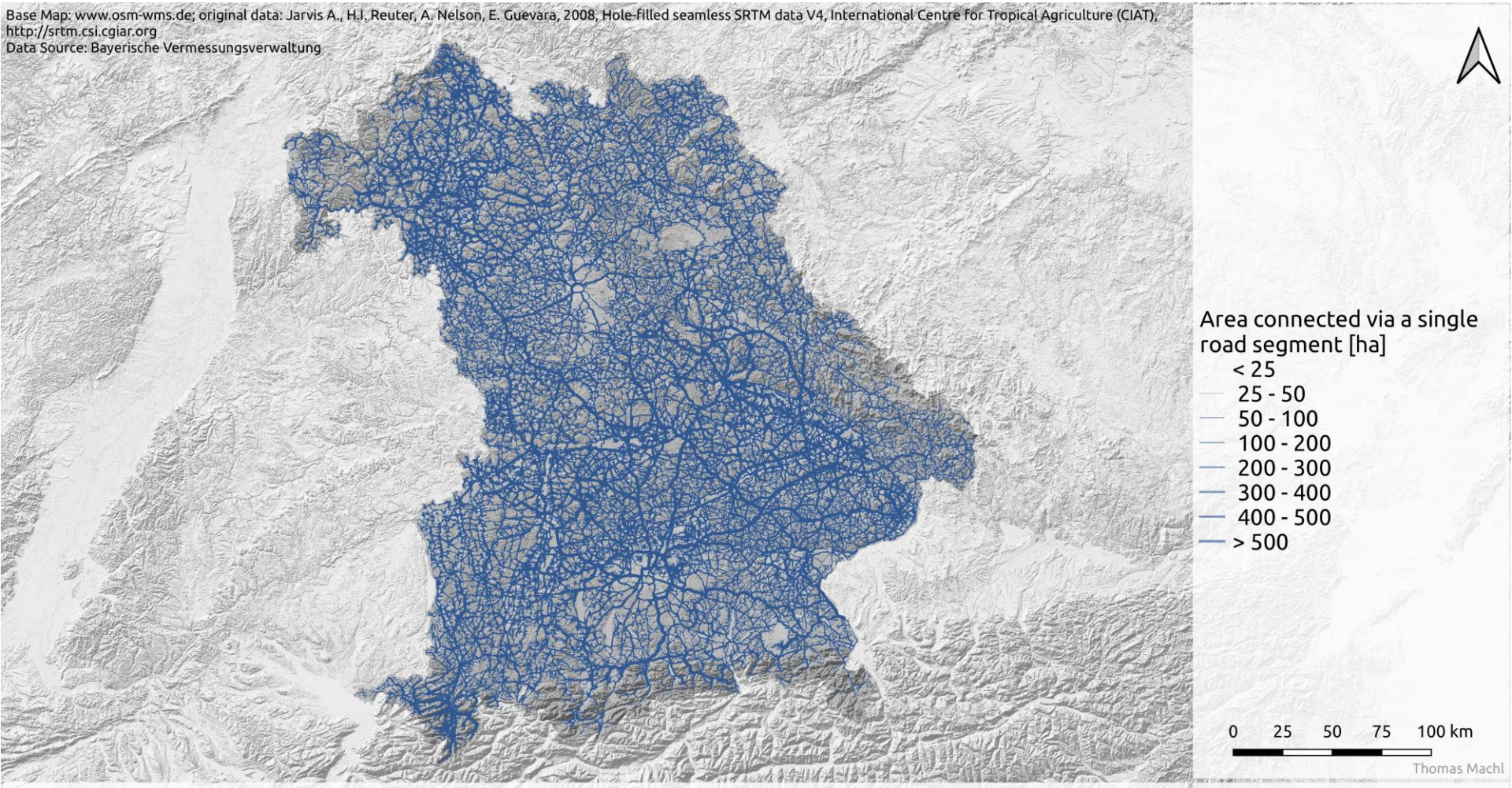


Data source: Astner, 2017

... vom Einzelpfad zur Erschließungsfläche



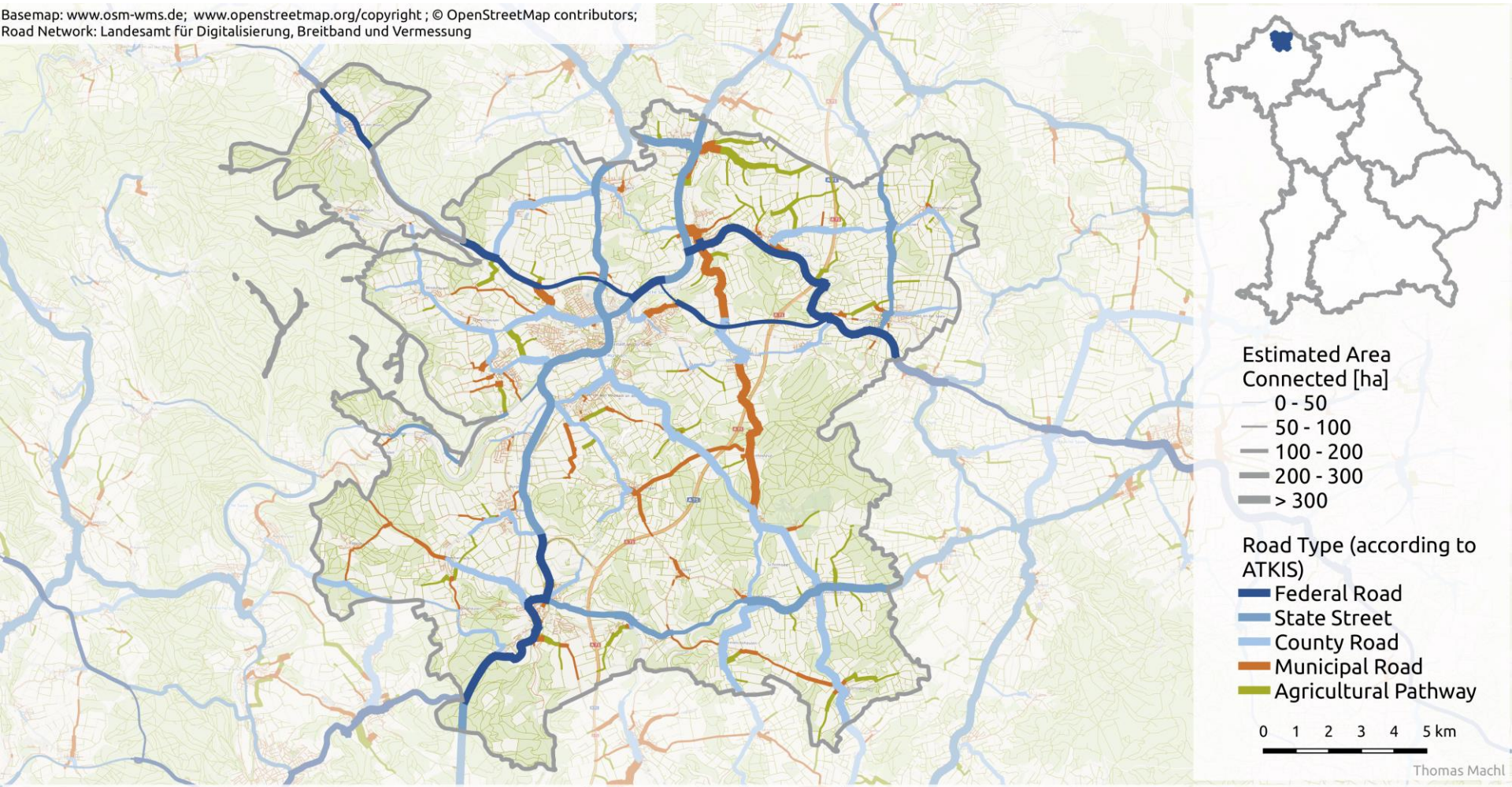
Erschließungsfläche einzelner Wegsegmente



Estimated Area Connected Via Individual Road Segments of the Bavarian Transportation Network Based On Farm-Field Transportation Paths (2018)

50 years of development in agricultural engineering...

Use of analysis results for planning



Estimated Area Connected Via A Single Road Segment
NES-Alliance

Outlook: from monitoring to geodesign

Aim: Close coupling of design and impact analysis

Road network planning:

- Estimation of construction costs and effects on transport distances
- Assessment of effects on land consumption, water runoff, etc.