AGRICULTURALLY CONSISTENT MAPPING OF SMALLHOLDER FARMING SYSTEMS USING REMOTE SENSING AND SPATIO-TEMPORAL MODELLING

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Complex agricultural landscape, fragmented

Small plots (< pixel High Spatial Resolution (HSR))

Diversity of practices (e.g. intercropping) and crop calendars

High cloud cover

Difficulties of remote sensing for the characterization of complex systems (e.g. smallholder farming)

[Inglada et al. 2015, Lebourgeois et al. 2017]
Objective

Develop a new approach to **process satellite time series** based on a **modelling platform** integrating **constraints** related to **human-environment interaction** to improve the characterization of smallholder agriculture areas.
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Develop a new approach to **process satellite time series** based on a **modelling platform integrating constraints related to human-environment interaction** to improve the characterization of smallholder agriculture areas.

- How can **spatio-temporal modelling help to transform remote sensing** data into more reliable thematic products?
- How can **remote sensing help to objectify the functioning of processes** as expressed by formalized knowledge in models?

Investigate the complementarity of Remote Sensing and Spatio-Temporal Modelling approaches.
VHSR:
Structure

SPOT6/7 (1.5m), Pléiades (0.5m)
Data

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**Time series:** Functioning

Sentinel 2 (10m), Landsat 8 (30m)
Data

**VHSR:**
- Structure

**Time series:**
- Functioning

**Formalized knowledge:**
- Spatio-temporal constraints

**Strategies and agricultural practices**
- Road
- Path
- Stream
- Hamlet
- Market

**Data sources:**
- SPOT6/7 (1.5m), Pléiades (0.5m)
- Sentinel 2 (10m), Landsat 8 (30m)
Land use data & surveys on ag. strategies
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GPS land use surveys

Build a ground truth database for learning and validation
Land use data & surveys on ag. strategies

- GPS land use surveys
- Interviews with rural development experts, farmers, scientists + literature

Build a ground truth database for learning and validation

Formalization into spatio-temporal rules expressing farmers’ strategies
Method > Spatio-Temporal rules
Selection of rules:
- Representative of the whole study area
- Recurrent in interviews
- Realistic (in agronomic terms)
- Applicable
Method > Spatio-Temporal rules

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![Market gardening](image)

- R1: Good connection to markets
- R2: Irrigated or near stream
- R3: Distant to village < 300 m
- R4: ...
Selection of rules:
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Market gardening

R1: Good connection to markets
R2: Irrigated or near stream
R3: Distant to village < 300 m
R4: ...

Irrigated rice

R1: Irrigated lowlands
R2: < 150 m from a stream
R3: Growth 12/15-04/15
R4: ...
Method

Remote Sensing

Spatio-Temporal Modelling

Land use characterization
| Remote Sensing | Spatio-Temporal Modelling |
Remote Sensing

OBIA

VHSR segmentation

(SPOT6 – 1.5m)

Spatio-Temporal Modelling
Remote Sensing

1. OBIA
2. VHSR segmentation (SPOT6 – 1.5m)

Spatio-Temporal Modelling

1. Feature extraction
2. from time series
3. to build a learning database
4. Based on training samples
Remote Sensing

1. OBIA
   VHSR segmentation
   (SPOT6 – 1.5m)

2. Feature extraction
   from time series
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3. Classification
   + class membership probabilities
   with Random Forest algorithm

CMP1 [0.30; 0.40; 0.20; 0.10]
Method > Spatio-Temporal Modelling

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Spatio-Temporal Modelling

Definition of spatio-temporal rules

Market Gardening

R1: ...
R2: ...

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Market Gardening

Implementation
Map of probability
Method > Spatio-Temporal Modelling

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Map of probability

Redefinition of class membership probabilities

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Method > Spatio-Temporal Modelling

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Spatio-Temporal Modelling

Definition of spatio-temporal rules

Market Gardening

R1: ...
R2: ...

Implementation
Map of probability

Redefinition of class membership probabilities

CMP2: [0.15; 0.20; 0.65; 0.00]
Class membership from Random Forest

Legend
- River network
- National roads
- Tracks
- Main markets
- Villages / towns

Probability of market gardening:
- 0.0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1

Class membership from spatio-temporal rules

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- River network
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- Tracks
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Probability of market gardening:
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- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1
Combination: Test of various fusion methods (mean, fuzzy logic, rules ponderation, etc.)
Class membership from Random Forest

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- 0.9 - 1

Disagreement map

Class membership from spatio-temporal rules

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- River network
- National roads
- Tracks
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RS & ST Modelling
Class membership from Random Forest

Obtaining disagreement areas

Class membership from spatio-temporal rules

Disagreement map
Validation with field experts
Relevance of the approach

→ Original approach combining remote sensing and modelling with knowledge from the human and social sciences, providing more agriculturally consistent maps.

→ Helps to improve the understanding of processes and the characterization of a complex system.

→ Generic framework which could be adapted to other thematic applications (e.g. biodiversity).
Conclusion

Relevance of the approach

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→ Helps to improve the understanding of processes and the characterization of a complex system.

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What’s next?

→ Test of the approach on a more complete ground and satellite dataset + statistic validation of the classification from GT.

→ Sensitivity analysis of our model to spatiotemporal rules.

Thank you for listening

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