UAV & satellite synergies for Ecology : a review.

ABSTRACT: *Complementarities between unmanned aerial vehicle (UAV) and satellite remote sensing (RS) reveal a great potential of synergy. This is seen as essential to fill the lack of observational data and knowledge on ecosystems. Of the three main synergies approaches identified in the scientific literature, only one is exploited in Ecology. The contribution of each of these major approaches is shown with a study of biodiversity monitoring in a wet grassland.*

ABOUT US

ALVAREZ-VANHARD EMILIEN. *Phd student at LETG-Rennes, UMR 6554 CNRS, Rennes, FRANCE. mail : emilien.alvarez-vanhard@univ-rennes2.fr*

HOUET THOMAS. *Director of research at LETG-Rennes, UMR 6554 CNRS, Rennes, FRANCE. mail : houet.thomas@univ-rennes2.fr*

CORPETTI THOMAS. *Director of research at LETG-Rennes, UMR 6554 CNRS, Rennes, FRANCE. mail : corpetti.thomas@univ-rennes2.fr*

A great potential of synergy

MASSIVE PRODUCTION OF RS DATA

- Significant increase of satellites.
- Democratization of UAVs.

➡ Fully exploiting these data sources requires the development of synergy approaches.

SATELLITE AND UAV COMPLEMENTARITIES

RESOLUTIONS

	Tempo.	Spatio.	Spectro.	Swath
UAV	High	High	Middle	Low
Nano-satellite	Middle	Middle	Low	High
Civilian satellite	Low	Middle	Low	Middle
Environmental satellite	Middle	Low	Middle	High
Global weather satellite	High	Low	Middle	High

High / Middle / Low

CHARACTERISTICS

	UAV	Satellite
Flexibility	**High**	Low
Meteo.	Wind / rain	Coud
Pre-process	Important	**Analysis ready**
Operator	Yes	**No**
Data volume	High	**Cloud**
VHSR cost	**Low**	High
Pay load	**Switchable**	Fixed
Legislation	Restrictive	**None**

Our contributions :

- A categorization of the main synergy approaches.
- Focus on ecological application.
- Application outlooks in biodiversity monitoring.

Identifying synergies

SELECTION OF PAPERS

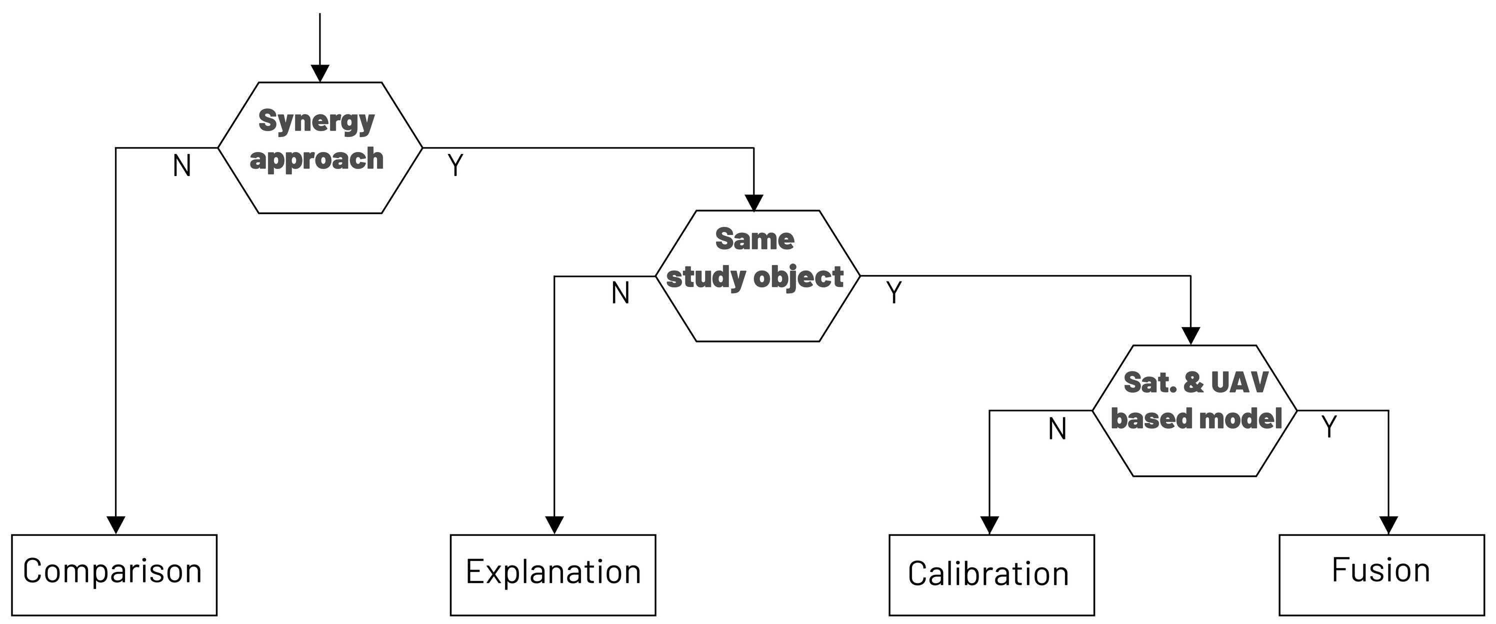
- Query « UAV AND Satellite » on academic databases.
- Filter optical data + terrestrial surface.

➡ **139 peer-reviewed papers**

SYNERGY APPROACHES CATEGORIZATION

Four approaches have been identified via the following criteria :

CATEGORISATION'S CRITERIA



COMPARISON : *Benefits and disadvantages of each data.*

EXPLANATION / MULTISCALE ANALYSIS : *Exploit complementary information of each data.*

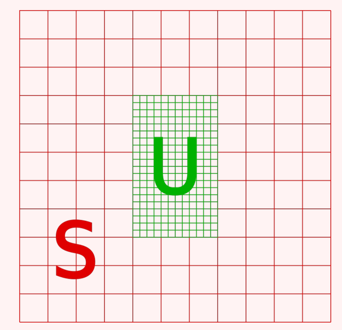
SATELLITE-BASED MODEL CALIBRATION : *UAV data are used to calibrate algorithms on satellite data (ground truth, label, ...). Two sub-categories are identified : qualitative and quantitative calibration.*

DATA FUSION : *Creation of new data to improve resolutions.*

Outlooks for EBVs

This synergy can contribute to the Essential Biodiversity Variables initiative [3]. We give here examples of each approachs applied to biodiversity monitoring in a hotspot : the wet grassland.

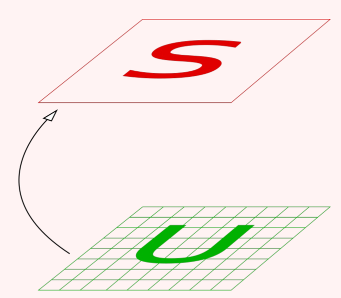
MULTISCALE ANALYSIS



- Temporal features on large area from satellite are related to phenological traits or other temporal dynamics of the ecosystem.
- Spatial features from UAV are related to plant communities patterns and landscape structure.

➡ These features are potential proxies of **community composition** such as **taxonomic** and **functional diversity**.

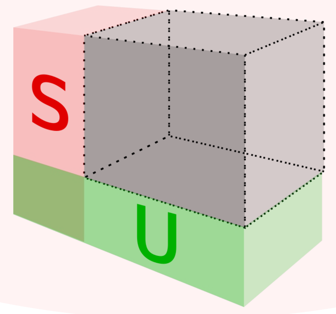
MODEL CALIBRATION



- RS **habitat mapping** is often limited by satellite coarse resolution.
- Satellite mixed pixels can be unmixed thanks to the UAV's VHSR [4].
- Use of UAV data improves the estimation of the most heterogeneous plant communities and helps to better understand **ecosystem structure**.

DATA FUSION

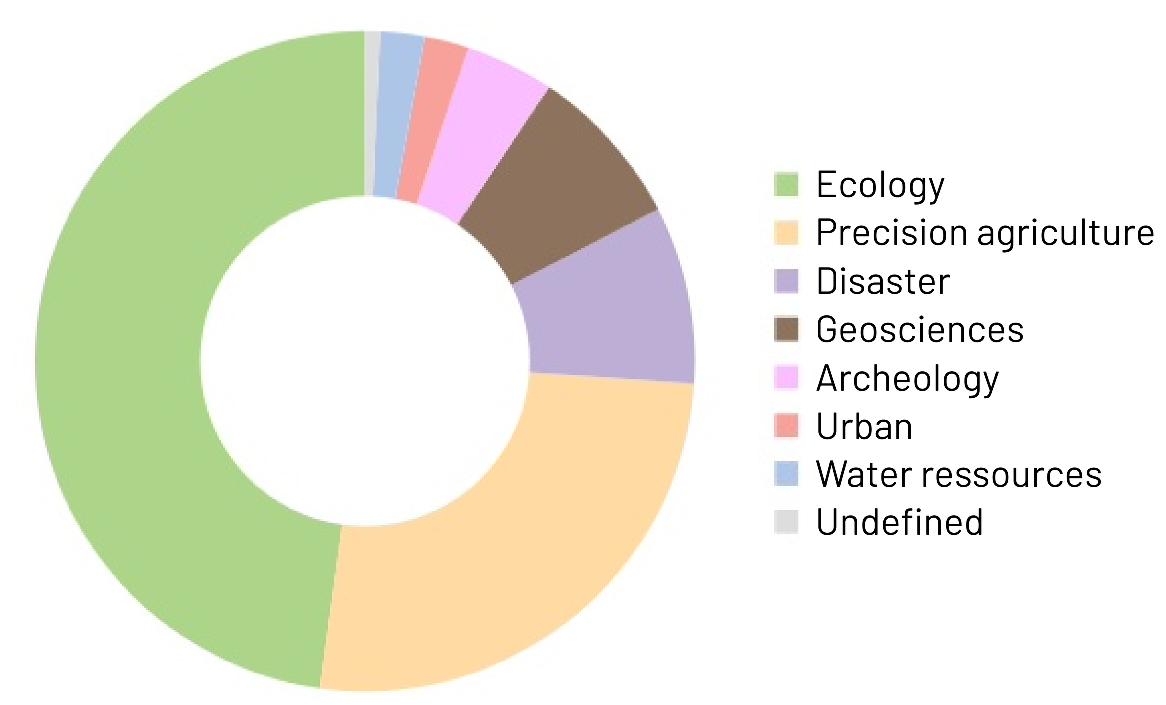
- Finely characterize **hydroperiods** on a small study site such as a wet grassland requires spatially explicit data with high temporal and spatial resolution.
- Spatio-temporal fusion of UAV and satellite data allow to generate an artificial data cube with combined resolutions allowing a fine characterization of this **biodiversity driver**.



Focus on Ecology

MAIN AREA OF APPLICATION

DISTRIBUTION OF PAPERS IN APPLICATION



- **But limited to a single approach** ➡ model calibration.
- Qualitative models : UAV information is used to label satellite pixels. These models can then be used to map land cover and land use for a better understanding of landscape structure and habitat distribution [1].
- Quantitative models : UAV provides raw reflectance, biophysical parameters (e.g. Fraction Vegetation Cover) or land cover rates. Inferrence models with satellite data allow extrapolation of the measure on larger area [2].

UAV VS IN-SITU DATA

- UAV is mainly used with satellite and in-situ data using nested inference models.
- UAV can **replace field observations** in some cases (33% studies calibrate models without in-situ data).
- UAV is cheaper and quicker.

Conclusion

COMPLEMENTARITY...

- **UAV fills the gap** between satellite and in-situ data.
- **A lowcost solution** more accessible than hyperspectral or LiDAR.
- The synergy makes sense for biodiversity monitoring of hot spot.

... & INTEROPERABILITY

- Differences in spatial and spectral resolutions lead to **reflectance differences** related to the optical properties of surfaces.
- Intercalibration ➡ geometric & radiometric .
- **Development of facilities** for multisource data processing, such as Earth observation data cubes.

REFERENCES

[1] Z. Szantoi, S.E. Smith, G. Strona, L.P. Koh, S.A. Wich, Int. J. Remote Sens. 38 (2017) 2231–2245.

[2] D. Solazzo, J.B. Sankey, T.Ts. Sankey, S.M. Munson, Geomorphology 319 (2018) 174–185.

[3] P. Vihervaara, A.-P. Auvinen, L. Mononen, M. Törmä, P. Ahlroth, S. Anttila, K. Böttcher, M. Forsius, J. Heino, J. Heliölä, M. Koskelainen, M. Kuussaari, K. Meissner, O. Ojala, S. Tuominen, M. Viitasalo, R. Virkkala, Glob. Ecol. Conserv. 10 (2017) 43–59.

[4] E. Alvarez-Vanhard, T. Houet, C. Mony, L. Lecoq, T. Corpetti, Remote Sens. Environ. 243 (2020) 111780.