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Diagnostic tool that INtegrates Optical, infrared and SAR data

Sugar cane monitoring in the Cauca valley, Colombia

DINOSAR project

Geospatial World Forum, Agriculture Seminar

April 30, 2026

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Project information

- Start January 2024 – Finish December 2026
- Funded by the European Union: Horizon Europe programme
- Project partners from Colombia, Spain, France and the Netherlands

eleaf SPACE FOR GROWTH | Universitat d'Alacant Universidad de Alicante | agroAP AGRITECH SUPPORT | SAR VISION | euronovia | HCP international

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The Problem

- Agricultural systems contribute to land degradation, which leads to decreasing production and possibly deforestation
- Over-use of agricultural inputs, applied in an attempt to increase yield, has the opposite effect if not managed well
- In areas with substantial cloud cover the effectiveness of optical EO-tools for crop monitoring is limited

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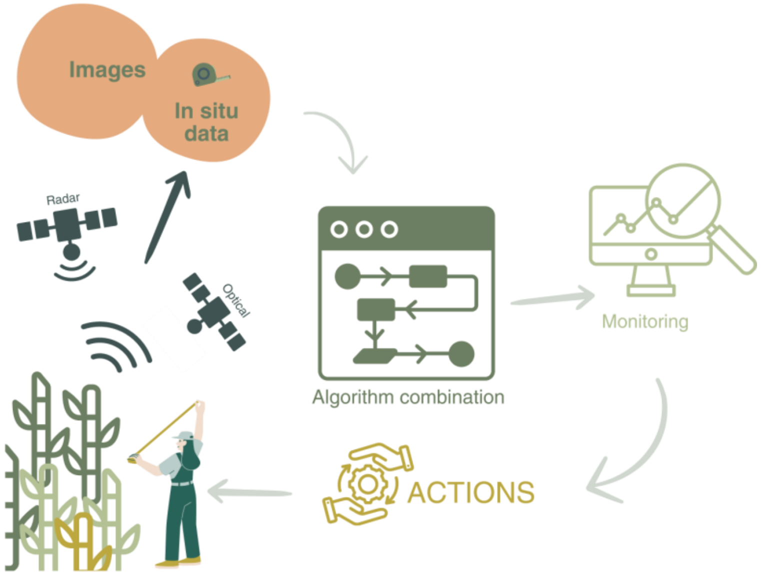
The Solution

- Develop Copernicus based algorithms to support smart farming applications that can be used worldwide, clouds or no clouds
- Support farmers to match agricultural inputs (fertilisers, pesticides, water) to what the crop needs
- Decrease the environmental footprint
- Start with one specific case-study: sugar cane in Colombia



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Recommendations

- Use of in situ data for development of a crop monitoring algorithm with S1 and S2
- Have the complete chain in a project: from university, service providers, precision agriculture company and the user group
- Involve user groups in product development: farm managers, harvest managers, mill managers, farmers, farmer associations, technical associations
- No vendor lock-in to a portal: every client can connect to services in their own portal

Needs of Agricultural Professionals, Managers and Farmers

- Monitor sugar cane closely during the first critical three months of growth
- Conduct regular (weekly) assessments of sugar cane development
- Detect potential anomalies and suggest solutions and improvements
- Provide quantitative of sugar cane variables (such as biomass): transitioning from dimensionless vegetation indices to real values

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dinosar Methodology

- **D**iagnostic Tool that **IN**tegrates **O**ptical, Infrared and **SAR** data: scientific project funded by the European Union with the goal of improving continuous sugar cane monitoring with Earth observation data
- A new methodology that integrates (combines) optical and SAR images (as well as any source of auxiliary information) is being developed
- The methodology is based on State Space techniques (Dynamical Systems Theory) as they allow to:
  - Exploit in-situ measurements (to tune and improve the modelling)
  - Use agronomical and physical crop models
  - Include satellite observations to produce final predictions
  - The whole methodology is evaluated for sugar cane monitoring in the Cauca Valley (Colombia)

Field campaign (1)

- Selected study area located in the Cauca Valley (northeast of Cali, Colombia)
- A one-year long field campaign carried out in 34 fields (with a total of 70 points) spread over the area
- Fields are visited on a weekly basis and multiple sugar cane variables are manually measured (e.g., biomass, cane height).

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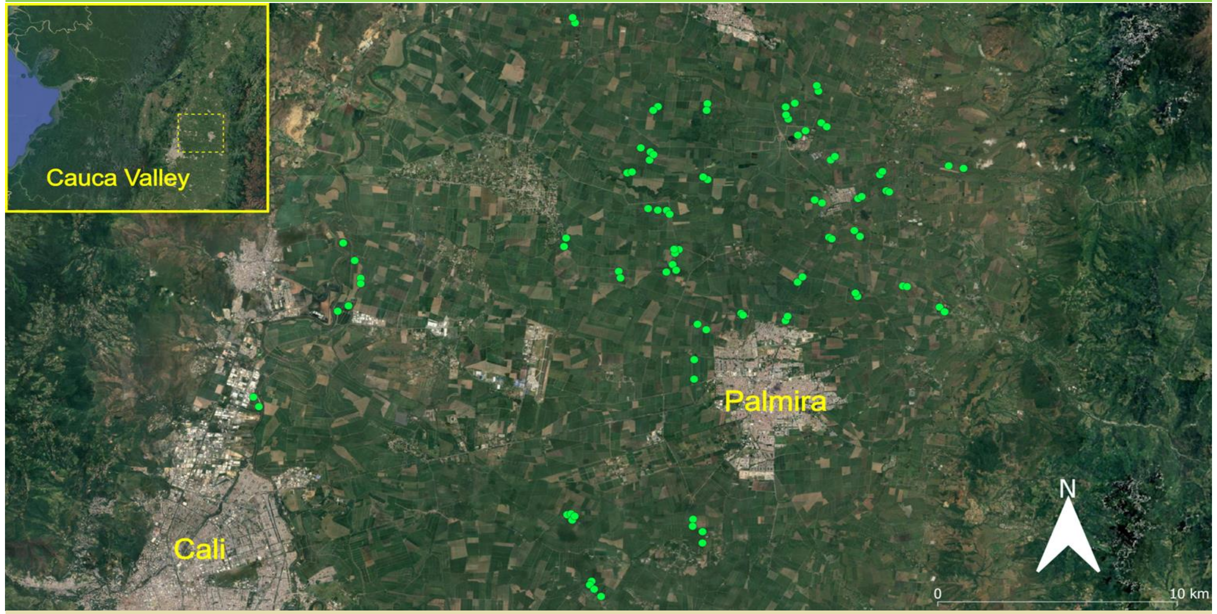
In-situ data locations



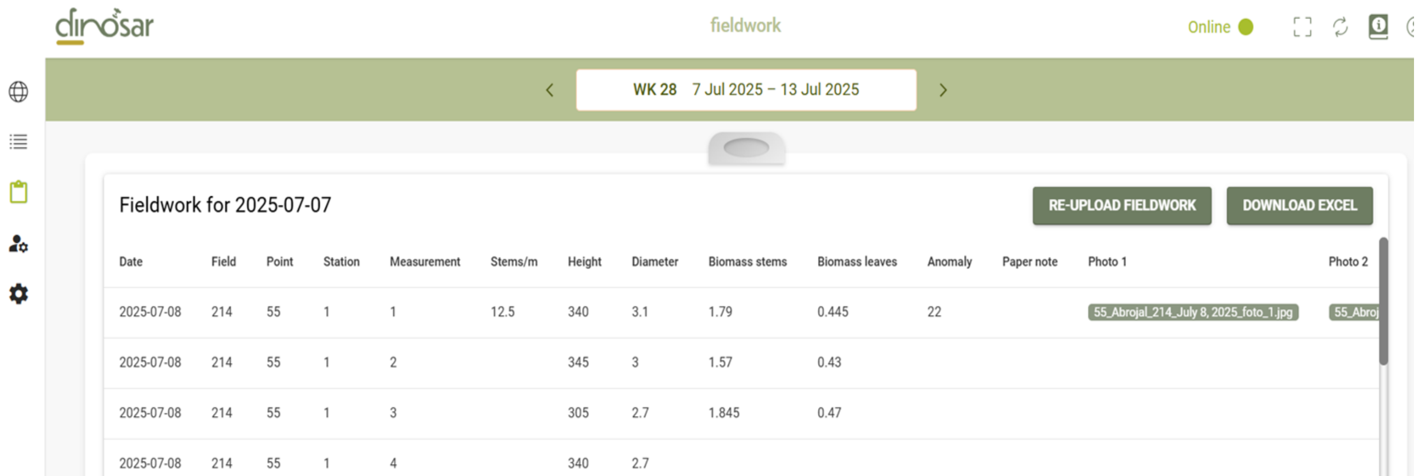
Field validation is essential for developing accurate models and avoiding speculative estimates that might mislead end users

Farm "La Paz"

Field campaign (2)

- A quality check is applied to ensure consistency and to eventually detect potential anomalies
- All field measurements are then uploaded to the project's platform (FieldLook) for visualization and further analysis

Field Collection Data → Checking Quality of Data → Convert Fulcrum File to DINOSAR File → Upload File to DINOSAR Platform



Date	Field	Point	Station	Measurement	Stems/m	Height	Diameter	Biomass stems	Biomass leaves	Anomaly	Paper note	Photo 1	Photo 2
2025-07-08	214	55	1	1	12.5	340	3.1	1.79	0.445	22		55_Abrojal_214_July 8, 2025_foto_1.jpg	55_Abroj
2025-07-08	214	55	1	2		345	3	1.57	0.43				
2025-07-08	214	55	1	3		305	2.7	1.845	0.47				
2025-07-08	214	55	1	4		340	2.7						

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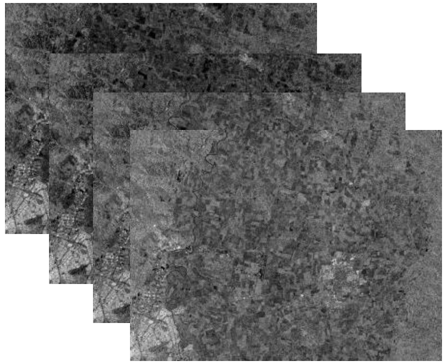
Satellite observations

- Time-series of Copernicus Sentinel-1 and Sentinel-2 images acquired over the analyzed area are preprocessed to generate the set of satellite observations



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Sentinel-1 preprocessing

Burst and sub-swath selection

↓

Radiometric calibration

↓

Coregistration

↓

Speckle filtering

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Geocoding (10x10 m)

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SAR products

Sentinel-2 preprocessing

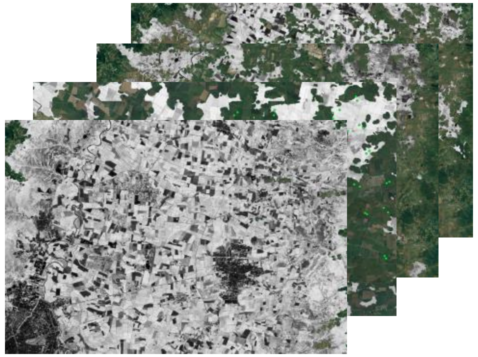
Geometrical and atmospheric correction (10 x 10 m.)

↓

Cloud masking

↓

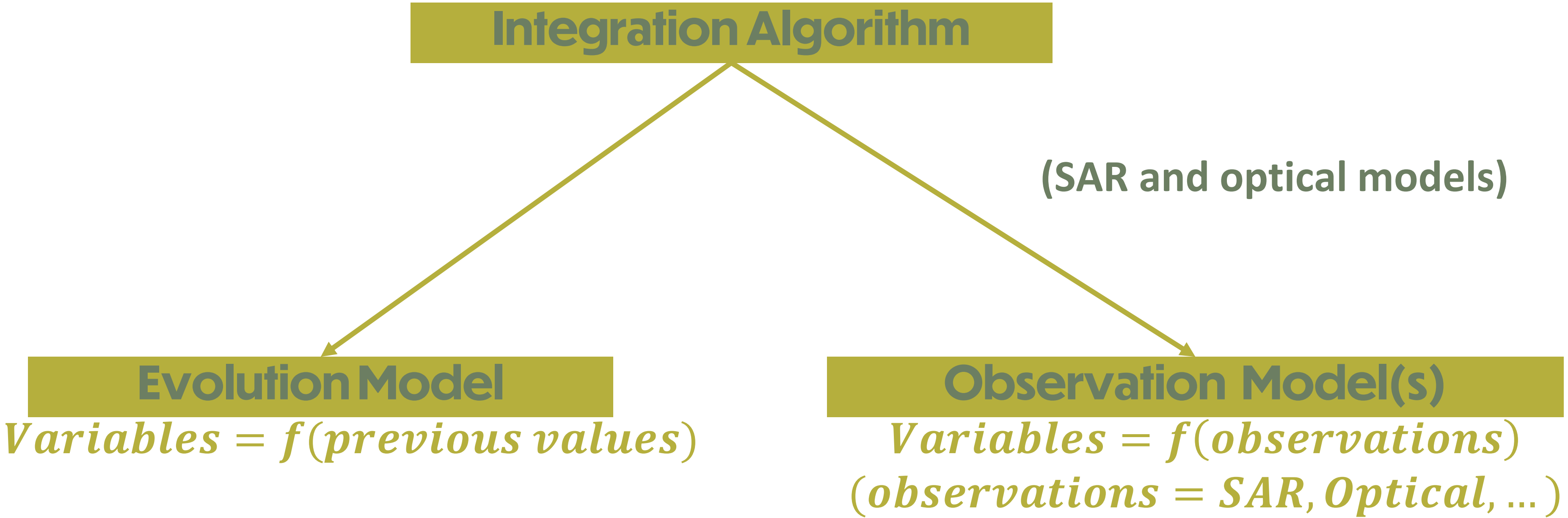
Optical products



Integration model (1)

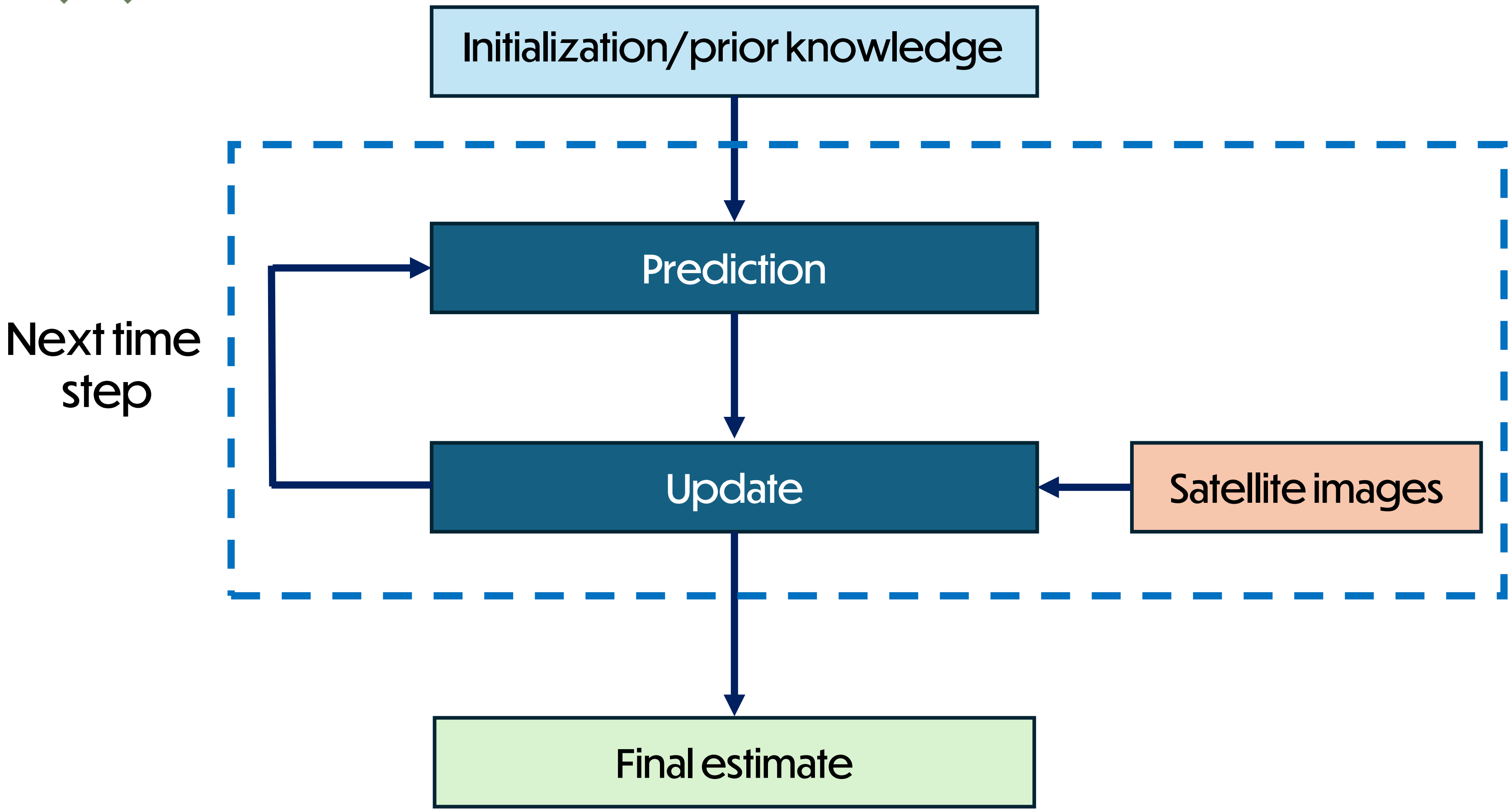
The integration algorithm (or integrated model) is composed of two different parts:

- Evolution model: provides estimates of the crop physical variables as a function their previous values and their expected evolution
- Observation model: provides estimates of the crop physical variables as a function of the available observations (satellite images)



Integration model (2)

These two models (evolution and observation) are integrated into a single framework that allows to produce optimum estimates by means of the well-known Kalman Filter



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Integration algorithm – Operational workflow

Previous State

$\hat{x}_k$

next time step

Predicted State
(evolution model)

No observation available

$\hat{x}_{k+1}$

Prediction Only

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Update (using satellite observations): 3 cases

SAR only	Optical only	SAR and Optical
$\hat{x}_{k+1}$	$\hat{x}_{k+1}$	$\hat{x}_{k+1}$
Sentinel-1 image available	**Sentinel-2 image available**	**Sentinel-1 and Sentinel-2 images available**

Prediction + Update

Results

Global accuracy metrics
(after 100 iterations with randomly-selected points)

Prediction Method	Average RMSE [kg]	Average MAE [kg]
Observation only (SAR)	0.29	0.21
Observation only (optical)	0.20	0.14
Prediction only	0.22	0.16
Prediction + Update - Optical only	0.18	0.13
Prediction + Update - SAR only	0.13	0.08
Prediction + Update - SAR and optical	**0.10**	**0.06**

no integration **partial integration** **complete integration**

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Conclusions

- A novel methodology for sugar cane monitoring established, integrating SAR and optical imagery into a quantitative biomass estimation model
- The comprehensive and well-structured field campaign provided strong support for the development and validation of the method
- Experimental results demonstrate that the proposed data fusion approach (integration method) offers superior accuracy compared to other strategies:
  - No integration: using only modeling or machine learning techniques for biomass prediction yields lower performance
  - Partial integration:
    - Optical-only: accuracy is significantly affected by data gaps caused by cloud cover
    - SAR-only: while more robust than considering only optical data for prediction, the overall accuracy remains suboptimal

Future work:

- Replace the current machine learning–based observation models with refined, physically-based SAR and optical models
- This upgrade aims to deliver higher accuracy and better generalization

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Thank you!

To be continued...

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