From Paper to Pixels

The Evolution of Pesticide Labels for a Digital Future

Sarah Hovinga

Global Regulatory Policy Manager,
Digital Farming

Bayer Crop Science

March 31st, 2026

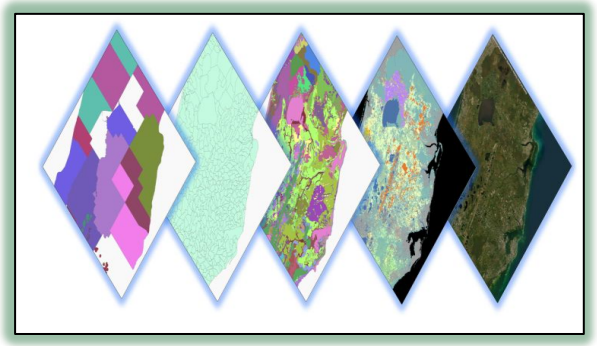
Pesticide product labels and labeling are legal requirements governing safe & effective use and must be compliant with all relevant regulatory and legal pesticide requirements

- Instructions for mixing, applying, storing, disposing
- Represents a pesticide manufacturer's License to Sell after receiving required regulatory approvals
- It is the culmination of all the effort of Research and Development to develop and launch a product (on average, 12.3 years and $301 million)

https://croplife.org/our-work/ensuring-regulatory-integrity/regulatory-integrity-in-crop-protection/

Digital tools and technologies enable safe, effective, and environmentally responsible pesticide applications in an increasingly complex regulatory environment

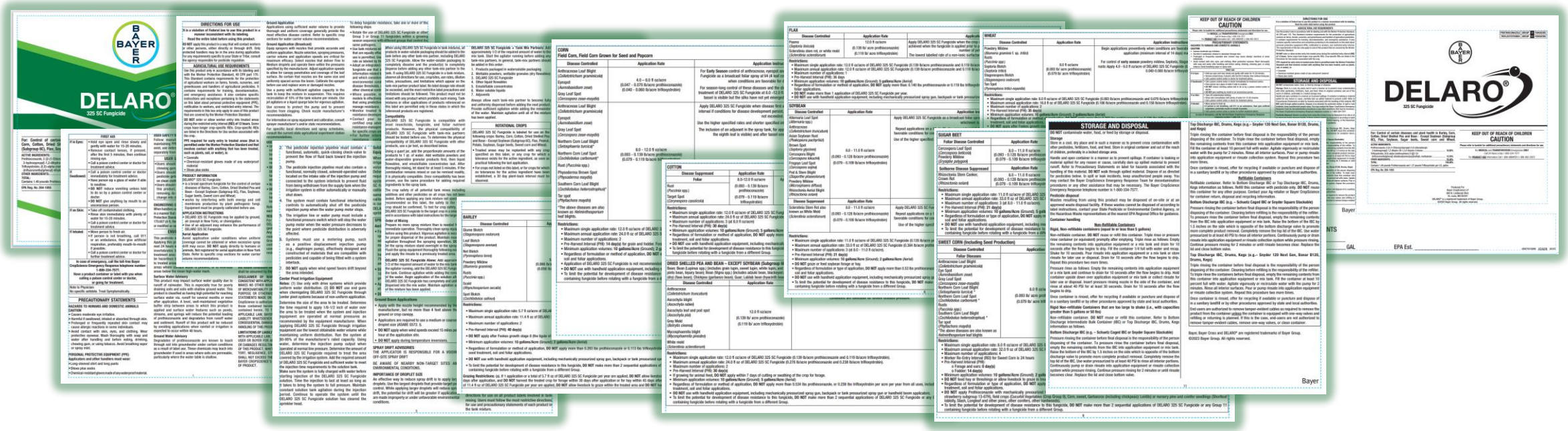
- Agricultural technologies (i.e., equipment, sensors, models, etc.) have advanced and give an idea of real-world conditions (i.e., applied inputs, wind direction, run-off, etc.) rather than worst-case scenarios
- This enables mitigation measures and updated risk assessments to more accurately evaluate site-specific pesticide risks, targeted/precision application, which will reduce regulatory complexity and enable farmer decision making
- Digitizing this data is necessary to enable future-readiness and interoperability of agricultural information and systems, including pesticide label data in machine/software-readable/actionable formats



Desbourdes, C., Perriot, B., Douzals, J., Chapple, A., Lauck Birkel, S., Legue, C., Bravidor, J., & Dietz, F. (2025). "DriftRadar® concept: towards the automatic management of spray drift". In *Precision agriculture '25*. Leiden, The Netherlands: Wageningen Academic. https://doi.org/10.1163/9789004725232_048

Digital tools and agtech are outpacing paper era labels

- Farmers and applicators still rely on Paper/PDF labels
- Paper/PDF labels are complex, static, and hard to interpret and keep up to date
- Not fully integrated with modern digital tools
- The move from document-centric to data-centric labels requires agreed-upon **data elements, data structures, standard phrases, controlled vocabularies, reference data, validation rules & dependencies, data models, governance, and maintenance** plans



What is a Digital Label Infrastructure (DLI)?

- A Digital Label Instance (DLI) supports the full label lifecycle, from creation and approval to on-farm use and documentation
- A DLI provides key information for field-specific risk assessment, such as crop, use rates, targets, and mitigation measures
- DLI information can be combined with equipment data and field conditions (e.g., weather, slope, surroundings) to enable tailored applications
- Machine-readable labels allow algorithms and Rules-as-Code logic to assess risk and recommend use patterns and mitigation measures directly to farmers

Potential benefits for stakeholder groups for a streamlined Digital Label process

From submission, to approval, and during implementation

- **Input Manufacturer** – efficient and consistent approvals, better application recommendations for improved product performance (Right product, Right place, Right amount, Right time)
- **Regulator** – increased accuracy, quality, consistency, and efficiency during reviews, improved/less complex mitigation and risk assessment possibilities
- **Applicator** – easier label comprehension with less human errors, improved accessibility for all communities
- **Grower** – reduced complexity for timely and up-to-date product information, and in the future, tailored to their field, equipment, and site-specific conditions
- **Food chain** – potential for validation for future programs (carbon credits, sustainability criteria, etc.)
- **Society** – better quality jobs, robust, efficient, and transparent food supply, increased sustainability impact

Electronic PDFs ≠ Digital Labels or Digitized Pesticide Label Information

- Electronically-available PDFs are
  - Static documents, not structured digital information
  - For human reading, not for machine logic
    - Limited support for automation, validation, or integration with other systems
- Digital labels and Digitized Pesticide label information
  - Designed to be machine/software readable/actionable, enabling rule engines, checks, and integration with equipment and farm software
  - Can feed digital platforms that provide up to date, tailored label information for specific fields, equipment, and conditions
- Importance of the difference of digitized structured pesticide label information and a PDF label rendered on this information

Structured Content

- Structured Labels: **A necessary first step, but not the final destination**
  - Structured labels organize data elements (e.g., product name, use sites, rates, buffer requirements, personal protective equipment, ESA conditions), and highlight controlled vocabulary & standard phrase opportunities to improve consistency and readability
  - This structured content is *critical input* to digital labels and AI, but by itself does **not yet enable** automation, rules engines, or full integration with application equipment
  - Reference data improves searchability and AI performance
  - Essential for interoperability across systems
  - Simplify conversion and reduce errors
  - Structured approach enables subject-matter expert participation

Data models and reference data are the skeleton of digital labels

Provide architecture for machine-readable labels

- // Enable consistency, interoperability, automation
- // Foundation for digital exchange platforms
- // Foundational elements that inform data models include: data elements, structures, standard phrases, controlled vocabularies, reference data, validation rules & dependencies

AI-Ready Label Information

- Context will increase the accuracy and effectiveness of AI
  - Unambiguous data elements, data structures, standard phrases, controlled vocabularies, reference data, validation rules & dependencies, data models, governance, and maintenance
- Examples of opportunities for digitized pesticide label information and AI
  - Pesticide Label Submission: AI can help automate routine checks while experts retain oversight
    - E.g., Reduced review time with utilizing AI to augment human reviews, supported by “Rules-as-Code” for machine/software readable regulatory logic
  - Support label comprehension for applicators via digital interpretation
    - E.g., Digital systems can customize label information by state, use site, method, pest, and location, and narrow-in on the information, helping users navigate complexity

Key Principles for the Use of AI in Regulatory Analyses and Evaluations

CropLife INTERNATIONAL

Brussels, 13th October 2025

Subject: Principles for use of AI[i] in regulatory analyses and evaluations

This document is intended to describe the CLI position on the use of AI[i] for regulatory analyses and evaluation purposes, it does not apply to the use of AI in Data generation and compilation within individual companies

1. **Transparency**
   - Clarity of Processes: The use of AI algorithms and their decision-making processes should be well-documented, allowing both applicants, regulatory agencies, other stakeholders and interested parties to understand how conclusions were reached.
   - Data Provenance: Clear documentation of data sources used in AI models to enhance trust and reproducibility of results.
   - Versioning: documentation of the version of the AI model that has been used, as well as modification that have been built on the base model.
   - The results of any analysis/evaluation performed by AI must be fully reproducible considering that used model and data relied upon remain unchanged

2. **Explainability**
   - Understanding AI Decision-Making: Ensuring that AI models can provide clear explanations for their predictions and decisions is essential for regulatory agencies and stakeholders to understand the rationale behind the findings, facilitating informed evaluations.

3. **Responsible Use of Proprietary Data**
   - Intellectual Property Rights: It is essential to respect and protect the intellectual property rights associated with proprietary data, ensuring that data owners retain control over their information and data protection rights are secured.
   - Transparency in Data Sources: When proprietary data is used in AI models, transparency about the sources of this data and the methods of its collection enhances trust and credibility in the findings, allowing regulatory agencies to assess the validity of the submissions more effectively.
   - Data Sharing Agreements: Establishing clear protocols regarding the use and sharing of proprietary data needed for evaluation.
   - Respect of confidentiality: protection of personal data and CBI must be always respected.

4. **Fit for Purpose - Robustness and Validation**
   - Reliability of Results: AI models must be validated against established benchmarks to ensure that they produce reliable and accurate results for regulatory submissions and evaluations.
   - Sensitivity Analysis: to identify how changes in input data affect outcomes, ensuring that the models can handle variability of different cases.
   - Continuous Improvement: Regular updates and re-validation of AI systems based on new data and regulatory changes maintain the relevance and accuracy of the models.

CropLife International | Avenue Louise 326, Box 35 | B-1050 Brussels, Belgium

Transparency

- AI models, data sources, and model versions must be clearly documented to ensure traceability, trust, and full reproducibility of results.

Explainability

- AI systems should provide clear, understandable explanations of their outputs so regulators and stakeholders can assess the rationale behind conclusions.

Responsible Use of Proprietary Data

- Intellectual property, confidentiality, and data protection must be respected, with clear data-sharing agreements and transparency on data sources.

Fit for Purpose, Robustness & Validation

- AI models must be validated against benchmarks, assessed for sensitivity to input changes, and regularly updated to remain accurate and relevant.

Human-in-the-Loop

- Regulatory experts retain accountability, with mandatory human review of AI-generated outputs before decisions are finalized.

Independent Governance

- An independent body should provide guidance, define SOPs, and act as a referee in case of disputes involving AI-supported evaluations.

Progress Towards Digital Labels Requires Global Communication and Collaboration Between Many Stakeholders

- PMRA leading the 2025/2026 OECD DL CoP PMRA actively running "IT Modernization Project
- Funded & authored OECD EGEEPD 2021 Label Data Element Report

- Entry Into Force of Digital Labels: 1st Jan 2028
- CropLife Europe AgriGuide Project – central platform for machine and software-readable digital labels
- EU e-submission tool available (IUCLID)

- Organization for Economic Cooperation and Development (OECD) 2024/2025 activities revitalized this effort with the creation of a Digital Label "Community of Practice" (OECD DL CoP - Feb 2025) which serves as a platform for regulator exchange and stakeholder input (CLI/BIAC)
- Past efforts: OECD Expert Group on the Electronic Exchange of Pesticide Data (OECD EGEEPD - inactive as of 2022). → Key needs highlighted: interoperability of IT systems, harmonization of label data elements, sharing data between authorities

- CLI: Digital Regulatory Data team to align on digital label needs and OECD DL CoP & IT Expert Coordination

- ISO/TC 347 Data-driven Agrifood Systems, implementing recommendations from ISO Strategic Advisory Group on Smart Farming report 2023

- EPA
  - EPA actively working on Digital Label projects: 2023 White Paper, Workshops, MyPest, AI Pilot, etc.
  - Pesticide Programs Dialogue Committee (PPDC) Label Reform Working Group (LRWG) officially formed 2023-2025 (follow-up from PPDC Emerging Technologies WG). *Recommendations are to continue this work to best support EPA.*
- States
  - AAPCO interest in annual meetings 2024/2025/2026
  - CDPR CalPEST electronic submission portal launched 2024
  - ALSTAR/NPRIS/CERIS engagement
- Industry
  - CLA Digital Label Task Force established mid-2023
  - HCPA adopting structured labels (voluntarily) mid-2024
- Academia
  - Weed Science Society of America work on structured label

- IT Infrastructure work on-going, was an active participant of OECD EGEEPD, including an advanced thought-starter on digital labels

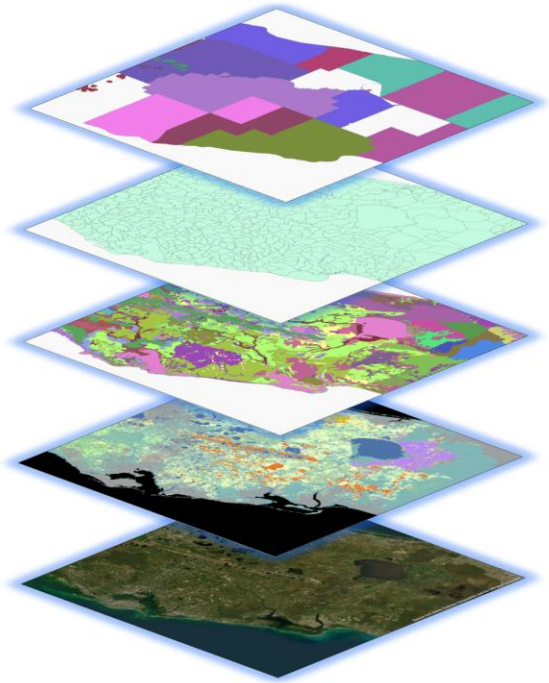
National Work

Global Work

Dynamic environment; list not exhaustive

Databases and information could link together to show a fully enabled digital path, from Product Label to Equipment Application

Data Layers



- Digitized label
- Site-specific Data (e.g., slope, soil type, groundwater/watershed restrictions, proximity to waterways, etc.)
- Temporal data (e.g., season, date, etc.)
- Real-time Weather Data (e.g., wind, rain, inversions, etc.)
- Regulatory requirements (e.g., Local restrictions, Language needs)
- Product-specific websites
- Machine interface and tracking (if required)

Thank you!

AgScienceMom

LinkedIn

Sarah Hovinga

Sarah.Hovinga@bayer.com

Email