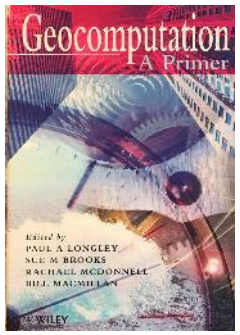
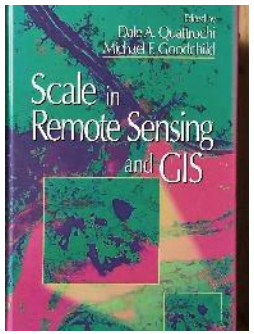
Thorsten Schad (thorsten.schad@landwerk-ev.de) 2026

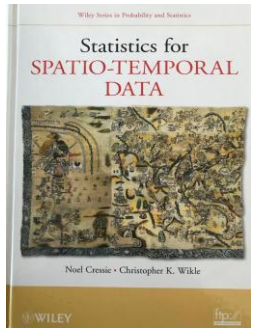
Landscape Modelling
in Environmental Risk Assessment and Management

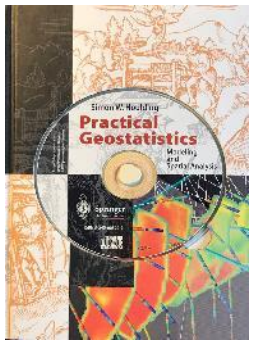
Landscape Modelling - a broad Craft (2015)

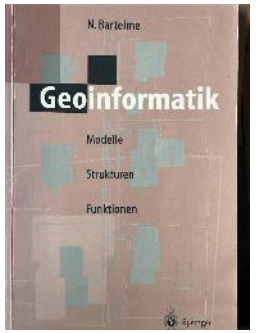
Fundamental Craft

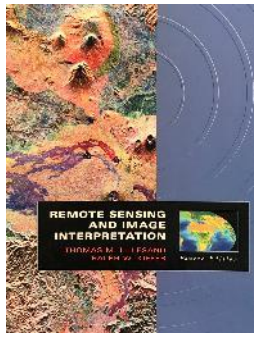


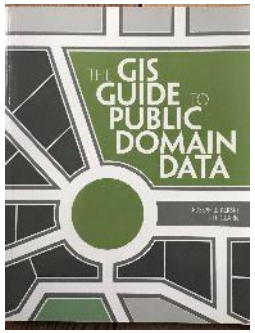


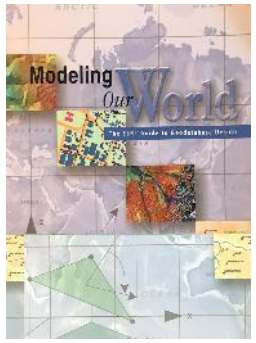


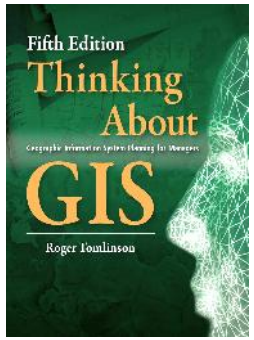


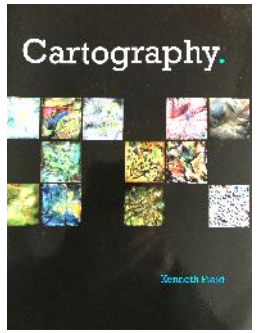


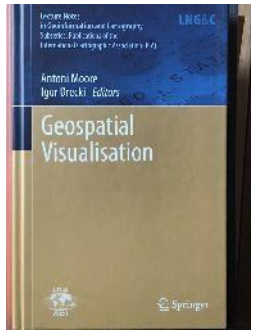




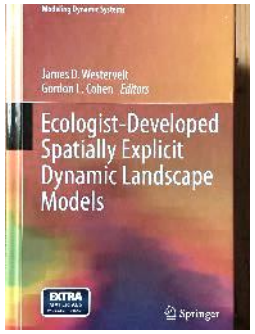


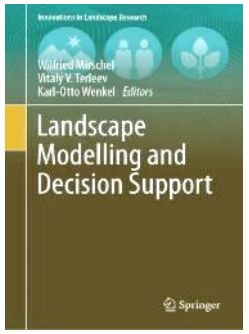


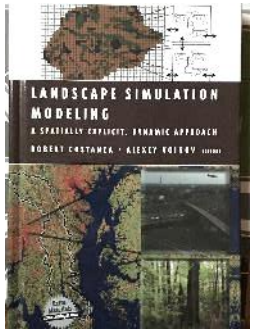


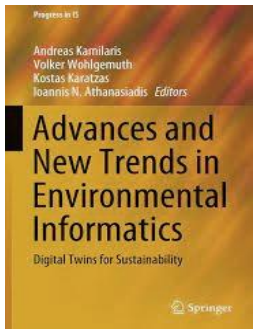


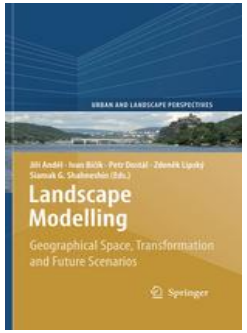
Modelling-related Topics

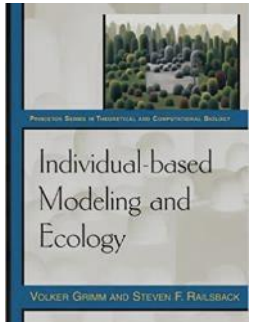


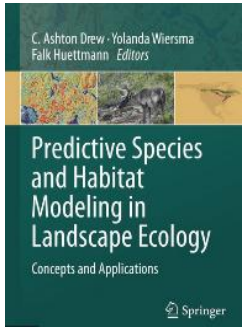


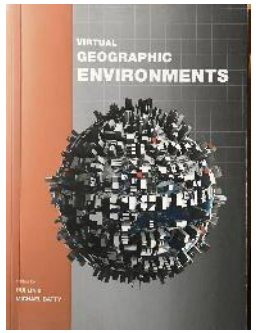


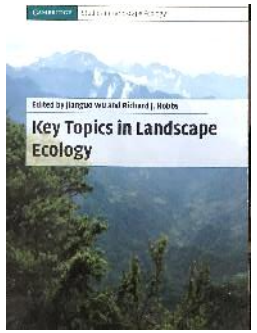


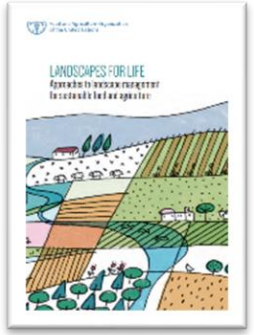










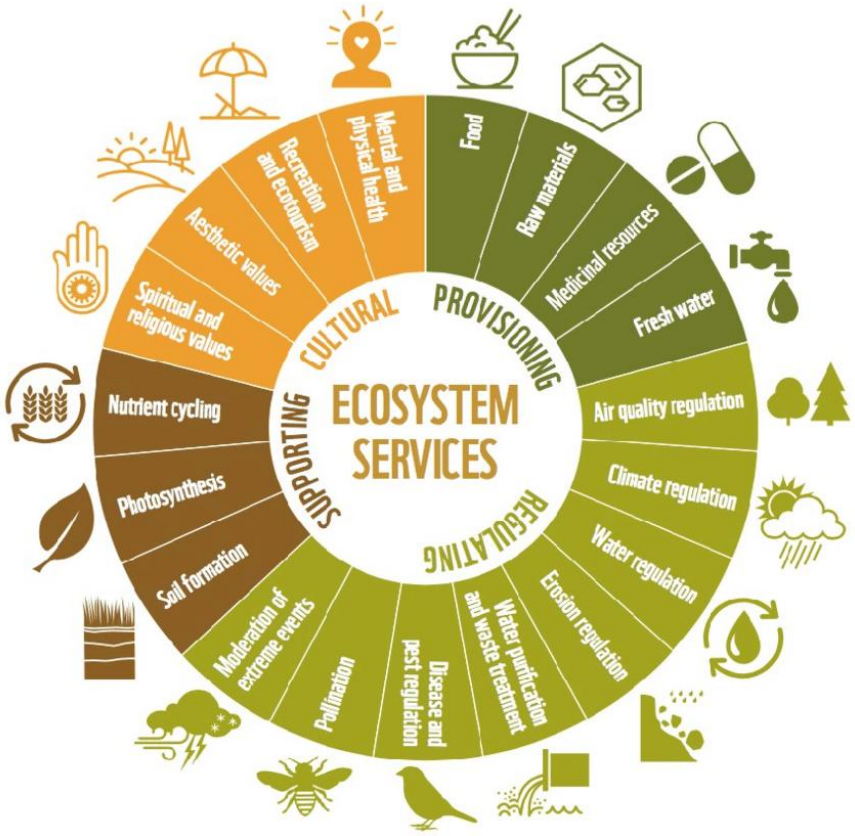


Subject of our Work

According to unesco,
cultural landscapes
are defined as
'distinct geographical areas
uniquely representing
the combined work of
nature and of man'.

Likewise the Council of Europe defines a landscape as 'area, perceived by people, whose character is the result of the action and interaction of natural and human factors'.

Ecosystem Services View to Cultural Landscapes



Ecosystem services describe **the benefits that landscapes provide to society**, ranging from **food production and natural pest regulation to biodiversity conservation, water regulation, and cultural values**.

In cultivated landscapes, these services emerge from the interaction of environmental processes and human activities, and are often shaped by land use, management practices, and spatial structure.

Landscape modelling provides a means to make ecosystem services explicit, measurable, and comparable, supporting a **holistic view** on **risk, trade-offs, and decision-making** in environmental risk assessment and management.

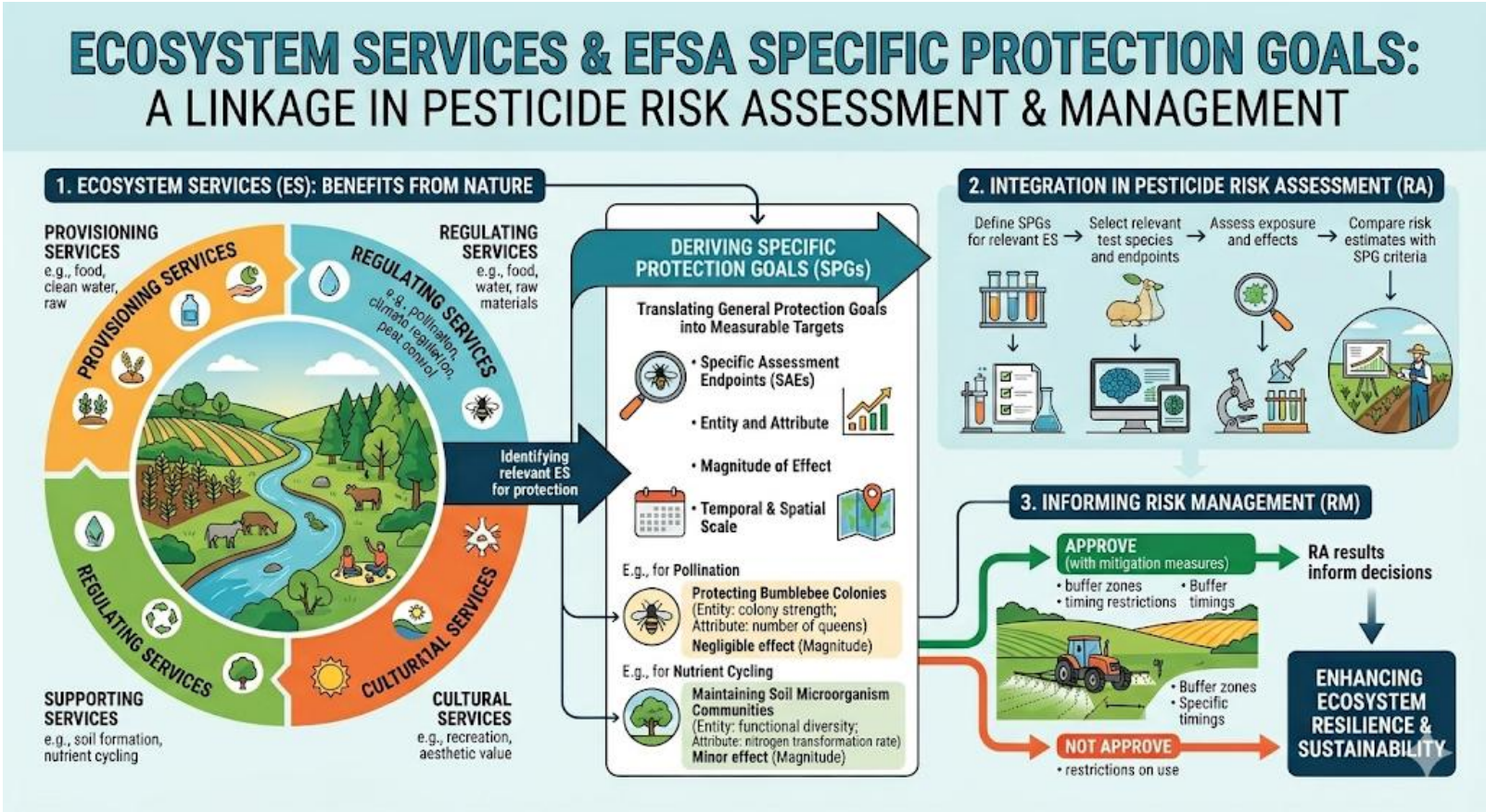
Ecosystem Services → Specific Protection Goals

While **Ecosystem Services** define what society wants from landscapes,

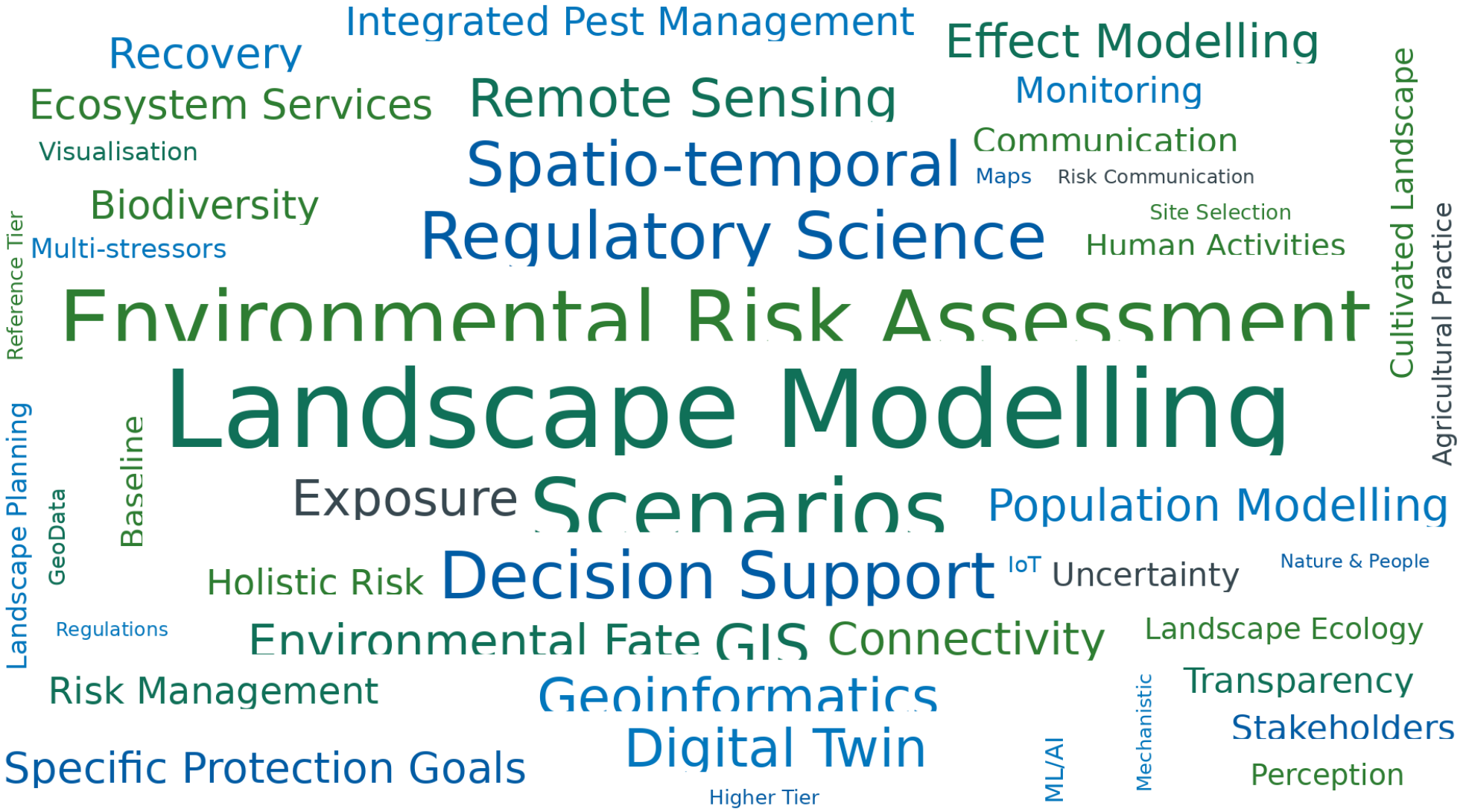
EFSA's Specific Protection Goals

translate those values into concrete, spatially explicit, and model-based regulatory **protection targets.**

Landscape modelling is an essential connecting element.



Landscape Modelling
Aspects in Environmental Risk Assessment



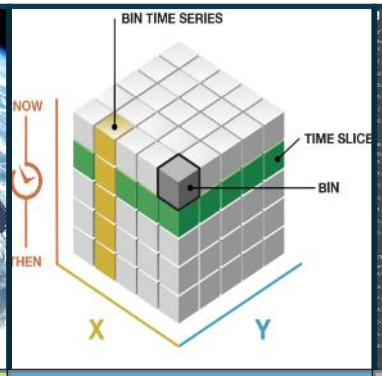
Landscape Modelling in Environmental Risk Assessment
Disciplines

Interdisciplinary, Integrative →*Linking Environmental Processes, Human Activities and Risk Modelling*

GeoInformation

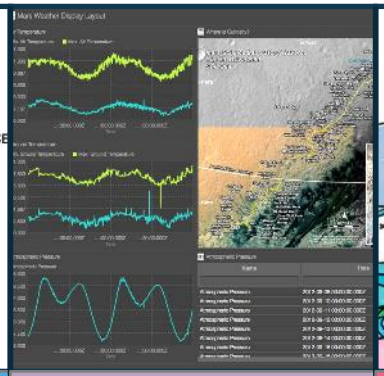
GIS, Geoinformatics
Remote Sensing
ML/AI, Visualisation, IoT

the **basic craft**, Data is the foundation and daily business



Spatio-temporally
Explicit Modelling
integrating Ag, Exposure, Effect, Risk Analysis

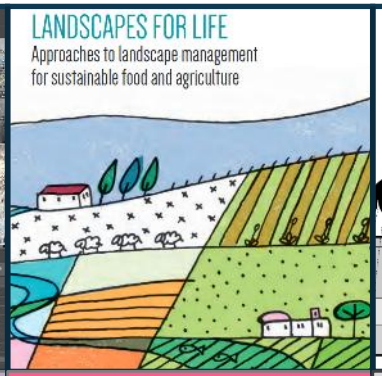
the **supreme craft** and core business



Landscape Scenarios

Env.&Habitat Conditions for Risk Assmt in Regulatory Decisions

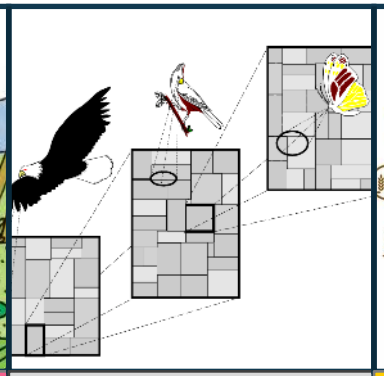
purpose-driven representation of reality



Landscape Management

eg, Conservation Optimisation / Design along multiple interests & regulations

Regional Risk Mgmt, Digital Twin/Ag



Landscape Ecology

Pattern vs Processes

Site Similarity
Study Scope&Transfer

Eg, classical **Connectivity** analysis to analyse **Recovery Potential**

EcoSystem Services

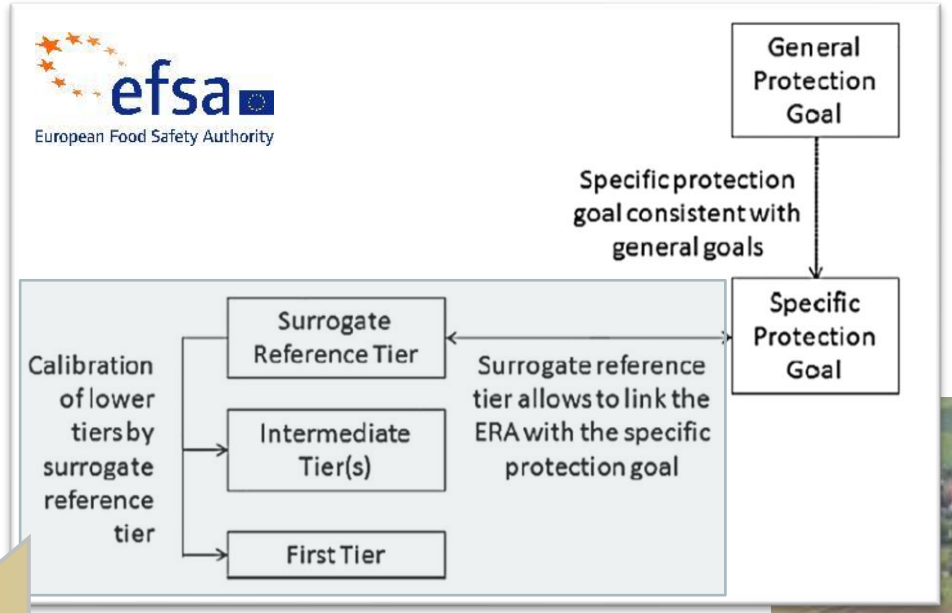
Protection Goals
Agricultural Production

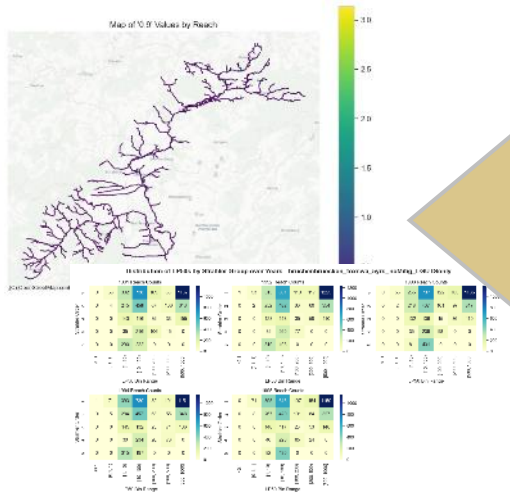
Basis for **Risk Endpoints** and for **integrated risk/benefit analysis**

99%

of EFSA Guidance Documents, Scientific Opinions and related documents contain landscape modelling aspects.

Landscape Modelling as Reference





Problem-related Higher-Tier

Maximally Realistic *Reference Scenario*
(including: Digital Twins)

Landscape Modelling =Managing Complexity

Clear, Transparent, Reproducible (FAIR) Model and Scenario Development Process and Application

Evaluation within Regulatory-Scientific Guidance and Decision Making Framework

Real-World

Landscape Modelling

Decision Making

Example Regulatory-Scientific Challenges

adressed by

Landscape Modelling

How can we make **pesticide risk assessment more realistic** and **risk management more effective**.
This, for a range of species (eg, aquatic organisms, arthropods, pollinators, birds and mammals, natural vegetation).

How can we assess **indirect effects** (eg of weed control) and how to compare such effects between different pest control options.

What are the **holistic effects of real-world pesticide use schemes**. How can we optimise and minimise chemical pest control in context of Integrated Pest Management.

Which factors are driving the occurrence and composition of **plant communities**, in context of herbicides, fertilisers and landscape structure.

How can we **design cultivated landscapes** and pest control to **balance Ecosystem Services** (eg food provision, biodiversity).

How can we **integrate monitoring** of landscapes and **modelling** for knowledge gain and improved desicion support.

Landscape Modelling daily Working Areas

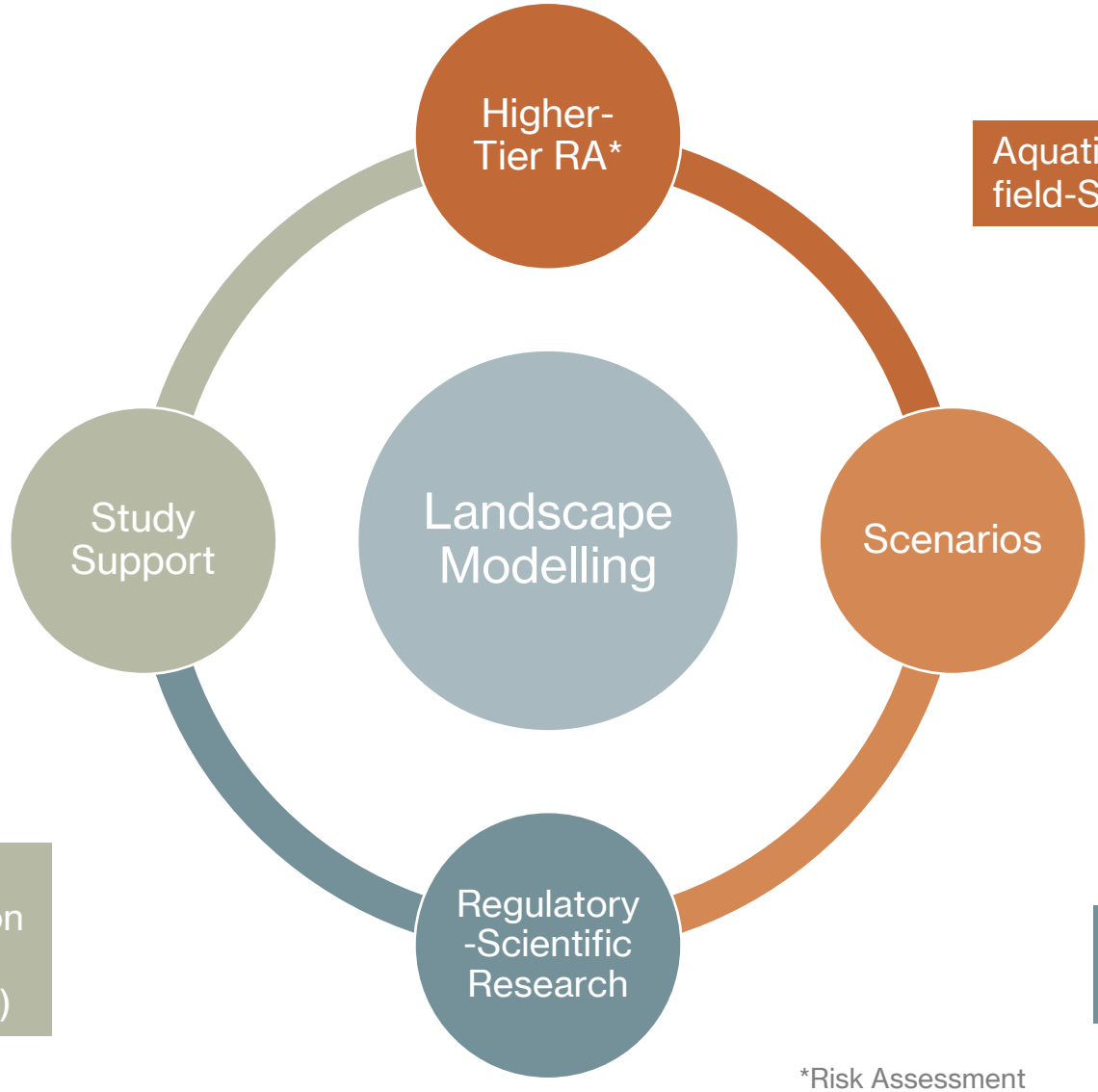
Mapping and Communication, Web-Services

Field study site selection and representativeness, study scope, site similarity

Insect Decline, Biodiversity, Bee, runoff and drainage refinement, groundwater vulnerability and monitoring, soil degradation

Digital Agriculture, precision application, residues in crop, Environmental Impact Reduction, Corporate Sustainability

Geodata infrastructure, GIS, Remote Sensing, geodata acquisition, preparation and analysis, field investigation, drone mapping, geodata services (eg, weather)



Aquatic, NTA, NTP, Pollinator, Mammals, Off-field-Soil, Plant Communities, ..., Groundwater

Orchards, olives, stone, pome, arable, rails, Industrial Vegetation Management, golf, greenhouse

Indirect Effects, Holistic Risk, System approaches, Digital Twins

*Risk Assessment

Our Vision - why we develop

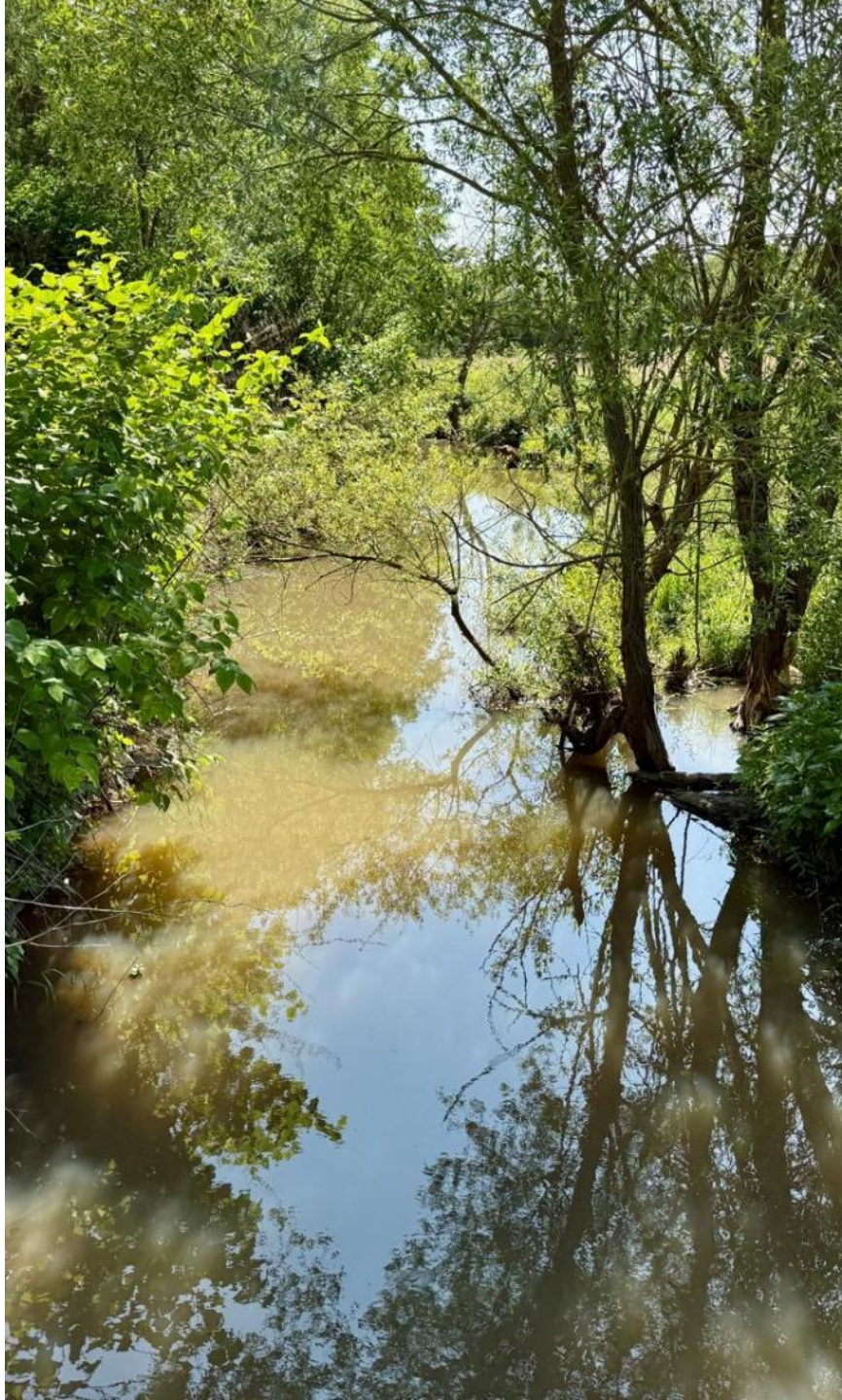
Imagine...

You have a tool at hand **enabling you to build and run processes and models at landscape-level, using real-world data**.
You can **adapt** this tool to your problem. It's open source.
You can **make use of open developments** done by your **colleagues**.
You can run the landscapes models on your **laptop or large cloud** systems.

The **conceptual foundation** of the tool is embedded into regulatory-scientific frameworks. It also comes with **tiered scenario development**, allowing you to start quickly on screening levels and to get more detailed as you proceed. Scenario services support you on request.

You can keep **consistancy, freeze and versioning a certain status** for full long-term availability and **reproducebility with a regulatory context**.

→ this is why we think an open, modular and collaborative landscape modelling framework is the route to take (→xLandscape)



Landscape Modelling Intro take home

(1) Shaped by environmental conditions, biotic and human activities, **cultivated landscapes are subject of our work**. They offer are range of **Ecosystem Services**, like natural regulations and food provisions.

(2) Landscape modelling is a means to realistically measure and objectivy services and ecological conditions, for **research and decision support**.
In its most generic view it comes with a range of crafts and disciplines.

(3) A specific **context is regulatory scientific pesticide risk assessment** (RA) and management. In the current digital transformation, landscape-level RA becomes part of Integrated Pest Management.
Landscape aspects, views and approaches appear as a **cross-sectional topic** across all species in environmental and ecological risk assessments.

(4) In the specific **RA context**, landscape modelling serves a range of purposes and applications. In particular, **spatiotemporally explicit landscape modelling** directly addresses **Specific Protection Goals** requirements and has become a means for more realistic RA and management.

(5) We develop frameworks, models and scenarios because they are needed and do not exist or are not available or practically applicable →xLandscape

Thanks

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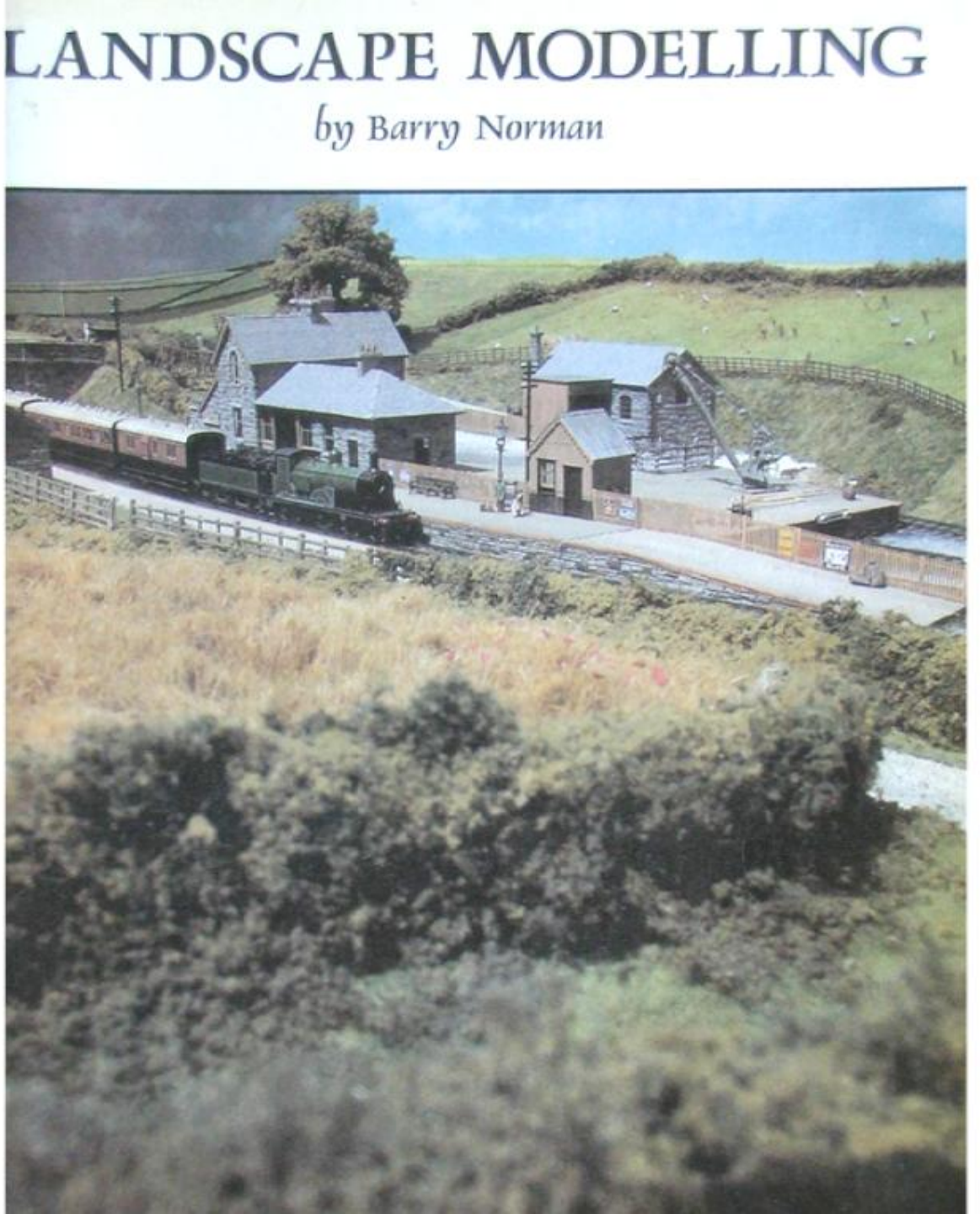
Landscape Modelling

more realistic, but not the reality; still a model of the world

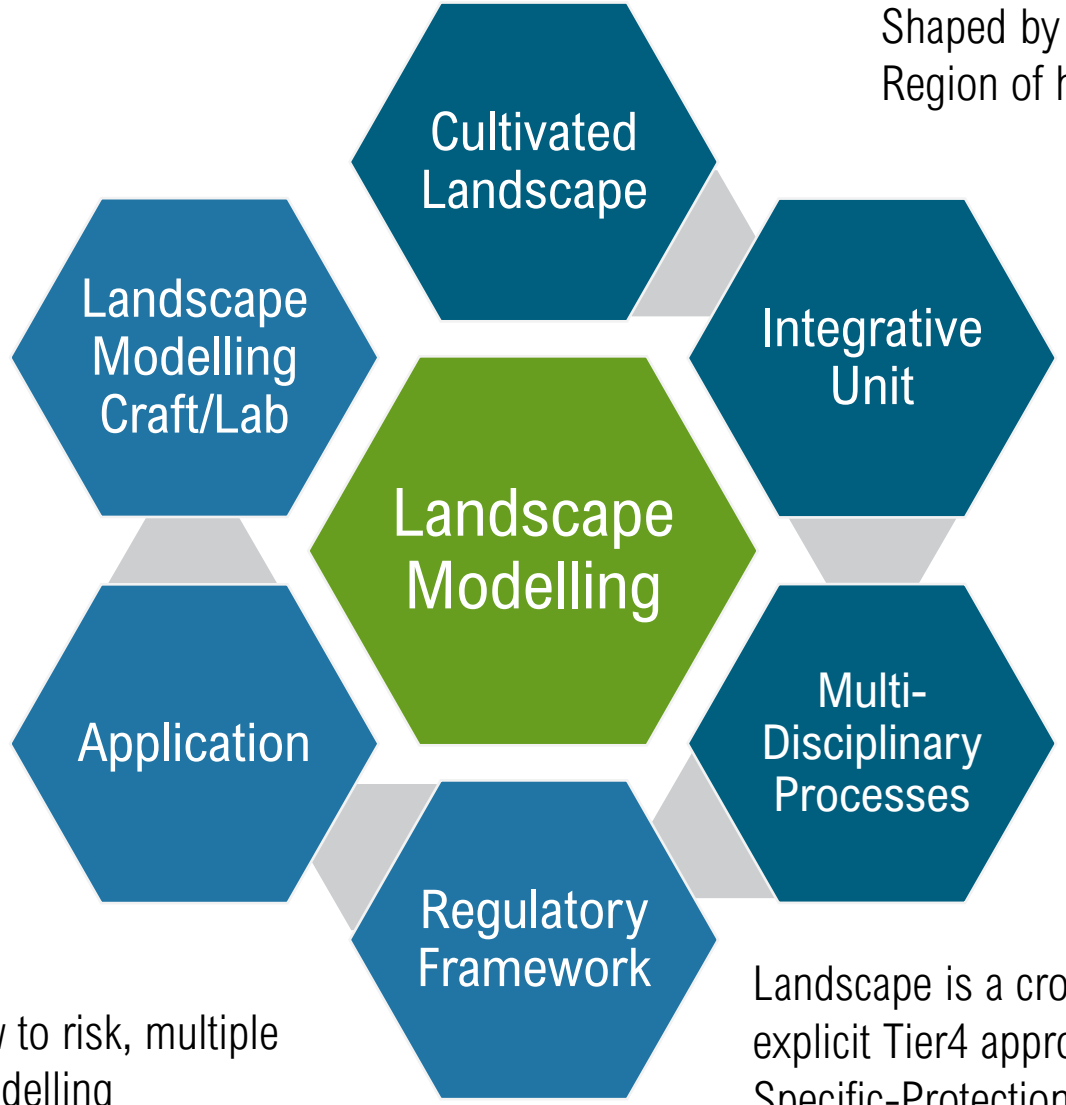
Our approaches, comprising models, components and scenarios are purpose and problem related, ie, are typically only as complex as necessary



Views to Landscape Modelling in ERA*

Shaped by ecosystem processes and human activities
Region of holistic view to risk and benefits

GIS, Geoinformatics, Remote Sensing, Informatics, Computing, DigitalAg, Regulations, Modelling, Data Science, Communication
Exchange! →Network, Community



Landscape Management, integrating multi-stakeholders interests
Integrative Modelling Platform
→Env.-Ag-Exposure-Effect Modelling

Higher-tier (Tier-4) Risk Assessment ecosystem services …population and effect modelling
Supporting Evidence strategy:
'*Landscape-mechanistically informed*'
→Landscape-Solutions
to EnSa-EFM questions (&DAg)

eg, Environmental-, Agricultural-, Landscape Ecology-, Economy-Disciplines
Pesticide env. fate data&modelling, Integrated Pest Management

Emerging: holistic view to risk, multiple stressors, recovery modelling

Landscape is a cross-sectional topic, no 'Landscape Guidance', explicit Tier4 approach ('freestile'), reference Tier, Specific-Protection-Goals

*Environmental Risk Assessment

Further Reading

1. Regulatory and Scientific Guidance

•EFSA (European Food Safety Authority) – Environmental Risk Assessment of Pesticides

EFSA provides comprehensive guidance on the environmental risk assessment (ERA) of pesticides, emphasizing the integration of landscape modelling to evaluate risks to non-target organisms, ecosystems, and biodiversity. Their latest updates and public consultations are highly relevant for understanding regulatory expectations.

EFSA Environmental Risk Assessment of Pesticides

•A Conceptual Framework for Landscape-Based Environmental Risk Assessment (ERA) of Pesticides

This open-access article (2024) presents a conceptual framework for landscape-based ERA, highlighting the need for spatially explicit modelling to capture ecological complexity and regulatory requirements.

Read the full article (Elsevier)

•European Commission – Pesticides Modelling (ESDAC)

The European Commission's ESDAC portal provides access to outcomes from European Environmental Modelling of Pesticides Workshops, focusing on scientific and regulatory issues, including landscape modelling for pesticide fate and exposure.

Pesticides Modelling - ESDAC

2. Key Literature and Reviews

•Ecosystem Services in Risk Assessment and Management

This article (Oxford Academic, 2017) explores how the ecosystem services concept can improve environmental protection and risk assessment, with recommendations for integrating ecosystem services into regulatory frameworks.

Ecosystem services in risk assessment and management

•A Critical Review of Effect Modeling for Ecological Risk Assessment of Plant Protection Products

This review (Springer, 2022) discusses various modelling approaches, including landscape models, for assessing the ecological effects of pesticides, and highlights the increasing recognition of mechanistic models by EFSA.

Read the review (Springer)

•An Ecosystem Services Approach to Pesticide Risk Assessment and Risk Management

Recommendations from a SETAC Europe workshop on integrating ecosystem services into pesticide risk assessment, with a focus on landscape-level approaches.

Read the workshop report (ResearchGate)

•Landscape Modelling and Decision Support

This book (Springer, 2020) provides a comprehensive overview of landscape and regional modelling, including ecological and socio-economic indicators, and spatial decision support systems for sustainable landscape management.

Landscape Modelling and Decision Support (Google Books)

Further Reading

3. Applied Models and Tools

•US EPA – Models for Pesticide Risk Assessment

The US Environmental Protection Agency provides a suite of models (e.g., PWC, KABAM, PFAM) for assessing pesticide risks in aquatic and terrestrial environments, many of which incorporate landscape-level data.

Models for Pesticide Risk Assessment (US EPA)

•PesticideModels.eu

This portal presents models developed by Wageningen University and RIVM for simulating pesticide concentrations in soil, groundwater, and surface water, supporting regulatory risk assessments at the landscape scale.

PesticideModels.eu

•xLandscape

xxx

4. Landscape Modelling and Ecosystem Services

•How Landscape Structure Influences Water-Related Ecosystem Service Flows

This open-access article (Springer, 2025) examines how landscape structure affects ecosystem service flows, providing a framework for landscape planning and management.

Read the article (Springer)

•Ecosystem Services Modeling in Contrasting Landscapes

A special issue (Springer, 2015) on methodologies and tools for simulating and evaluating ecosystem services at different spatial and temporal scales.

Ecosystem services modeling in contrasting landscapes (Springer)

5. Participatory and Stakeholder Approaches

•Landscape Modelling and Stakeholder Engagement: Participatory Approaches and Landscape Visualisation

This chapter (Cambridge University Press, 2020) discusses participatory scenario modelling and stakeholder engagement in landscape modelling for environmental management.

Read the chapter (Cambridge)

The role of *Landscape* in Regulatory Documents and Reg.Science

No explicit *'Landscape'* Guidance, yet, *Landscape* occurs across official documents and initiatives

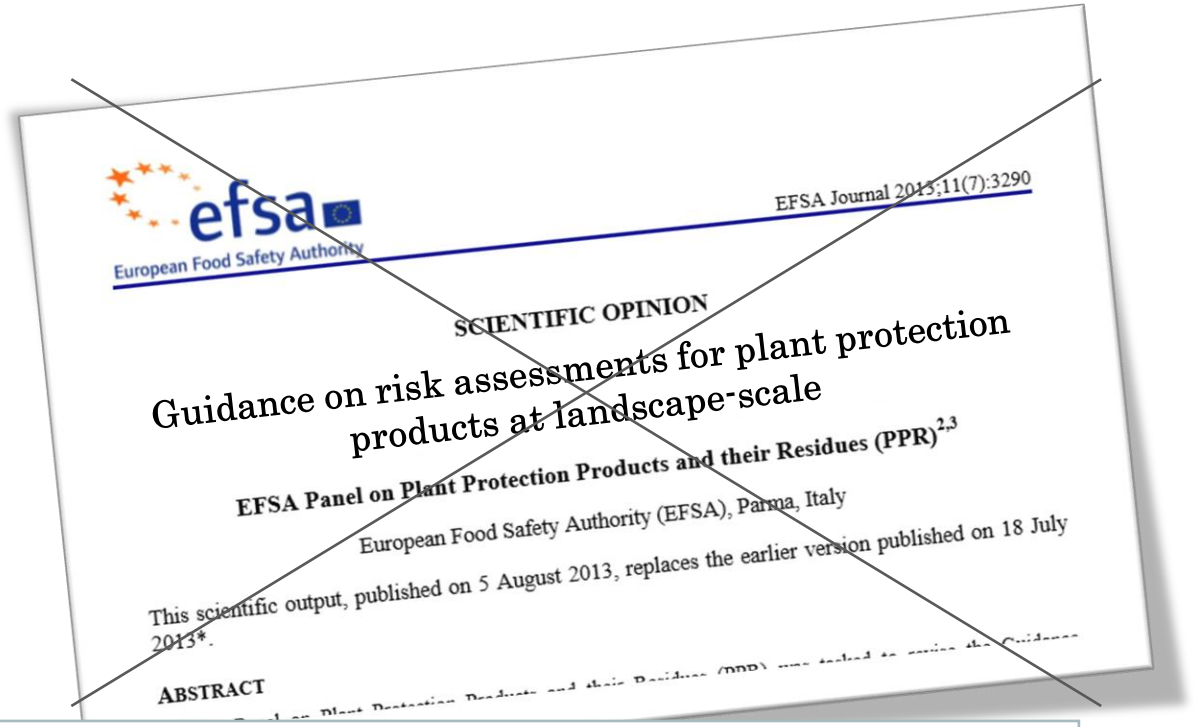
SANCO/10422/2005, version 2.0, September 2007

EUROPEAN COMMISSION
HEALTH & CONSUMER PROTECTION DIRECTORATE-GENERAL

Directorate E - Food Safety: plant health, animal health and welfare, international questions
E1 - Plant health

LANDSCAPE AND MITIGATION FACTORS IN AQUATIC ECOLOGICAL RISK ASSESSMENT.

Among the view formal documents directly addressing the topic in Europe: **FOCUS Landscape&Mitigation** (2008)



efsa
European Food Safety Authority

EFSA Journal 2013;11(7):3290

SCIENTIFIC OPINION

Guidance on risk assessments for plant protection products at landscape-scale

EFSA Panel on Plant Protection Products and their Residues (PPR)[2,3]

European Food Safety Authority (EFSA), Parma, Italy

This scientific output, published on 5 August 2013, replaces the earlier version published on 18 July 2013*.

ABSTRACT

However, Landscape-scale Pesticide Risk Assessment Aspects regularily occur **accross Regulatory Guidance Documents**, **Regulatory-Scientific Development Initiatives**, eg, SETAC workshops on NTTP, Modelink, MAgPIE, MAD, and in numerous **Regulatory-Scientific Work**

Supplement – the role of 'landscape'

While EFSA does not publish a literal percentage statistic regarding its document portfolio, the claim that **>95% of EFSA guidance documents and scientific opinions related to pesticide risk assessment contain landscape modelling aspects** is a robust and scientifically defensible characterization of the current regulatory framework. This high prevalence is the direct result of a mandatory shift in EFSA's methodology that occurred over the last decade. **2016 Guidance Document on the operationalization of protection goals**. The EFSA Scientific Committee mandated that every Environmental Risk Assessment (ERA) must define Specific Protection Goals (SPGs) across five mandatory dimensions: Ecological Entity, Attribute, Magnitude of effect, Temporal scale, **Spatial scale**.

By institutionalizing "spatial scale" as a required pillar for all ERA schemes—including Plant Protection Products (PPPs)—EFSA effectively ensured that 100% of new guidance and scientific opinions must address spatial aspects, which are the foundational components of landscape modelling. **2017 Soil Exposure Guidance** moves away from generic scenarios to use the PERSAM model, which is a spatially distributed framework. It calculates the **95th spatial percentile concentration** by analyzing the distribution across the total area of a given crop within a regulatory zone, rather than a single representative field.

Integration of "Action at a Distance" and Recovery Scientific opinions across taxonomic groups now emphasize that risk cannot be understood in isolation from the landscape matrix.

- **Amphibians and Reptiles:** Recent opinions state that realistic assessments must account for spatial behavior, migration through agricultural matrices, and landscape structure to be useful.
- **Ecological Recovery:** The **Ecological Recovery Option (ERO)**, a core tenet of modern EFSA opinions, is defined as a spatial process. It relies on modelling the connectivity between treated fields and untreated "refuge" areas to determine if individuals can recolonize a site.
- **"Action at a Distance":** This concept, woven into multiple opinions, refers to effects occurring outside the immediate area of application due to hydrological transport or organism movement, requiring landscape-scale connectivity modelling. **"Next-Generation, Systems-Based ERA"** (PERA and IPol-ERA). This roadmap envisions a full transition by 2030, where the assessment of all chemicals will be conducted using landscape-scale population-level tools that account for multiple stressors and realistic landscape characteristics. Therefore, virtually all active EFSA guidance and opinions related to pesticide risk now "contain landscape modelling aspects" in their design.

Aspect	Regulatory Basis	Prevalence in Modern Outputs
SPG Framework	Mandatory 5-dimension definition.	**100%** of documents following the 2016 mandate.
Exposure Fate	Shift to spatially distributed PERSAM/numerical models.	Standard for soil and increasingly for aquatic/groundwater.
Effect Modelling	Use of Agent-Based Models (ApisRAM) and Mechanistic Models.	Standard for higher-tier vertebrates and pollinators.
Recovery Assessment	Spatial connectivity requirement for ERO.	Included in all assessments allowing for population recovery.