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The EcoDynamics Diagnostic Engine: A Satellite- and GIS-based Method for Assessing and Diagnosing Ecosystem Condition

> Nature-related disclosure now requires a measure of ecosystem condition that the current toolkit cannot deliver. The EcoDynamics Diagnostic Engine is a systems-based answer. It extends the peer-reviewed, field-based Ecological Health Index (EHI) from a single annual field score into a weekly time series running back to 2018, computed from public satellite- and GIS-data for every pixel, parcel/field, farm and portfolio, at low cost and with no site visit. This paper describes the method, its applications and its foundational science.

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Abstract

Nature-related disclosure now requires a measure of ecosystem condition that current methods do not deliver. The EcoDynamics Diagnostic Engine (EDDE) is a systems-based answer. From satellite and geographic-information-system (GIS) data, with no site visit and at low cost, it assesses the four primary ecosystem processes on any parcel/field as a weekly time series running back to 2018. That series is the EcoDynamic Index (EDX), and the engine reports each year's peak week as that year's Land Health Score, on a scale of 1 to 9. It extends the peer-reviewed, field-based Ecological Health Index (EHI) (Xu et al., 2019) from a single annual field score to that continuous series. In doing so it turns an analogue, static field method into a dynamic, digital diagnostic, built with artificial intelligence, and open about how that AI is used. Calibrated against 92 parcel-year observations across a diverse range of land states, the method recovers relative variation well, ordering a benchmark property's fields as trained in-field assessors do; the ordering replicates on a second, more diverse property of 44 fields (leave-one-out rank agreement r of about 0.77) once anchored to its own ground truth assessment. On the one property with a four-year record it calls the two-year direction of change correctly on eleven of 12 fields, catching every declining field, against a majority-class expectation of eight. It has been applied across three jurisdictions and four contrasting ecoregions, from oceanic British pasture to African savanna, where the assessment and diagnosis have held up and surfaced ground phenomena that had been hard to explain. Future calibration efforts will improve absolute, cross-site scale. From the same assessment the EDDE diagnoses the limiting ecosystem process for root-cause phenomena, prescribes actions based on these, organises measurements for nature-disclosure frameworks including TNFD and ESRS, and issues a portable, checkable nature-related credential; carbon and local cooling effects are reported as secondary outcomes. The coefficients and scoring engine are proprietary; the method is published here.

Keywords: ecosystem condition, ecosystem function, remote sensing, satellite Earth observation, GIS, Ecological Health Index, EHI, EcoDynamic Index, EDX, EcoDynamics Diagnostic Engine, EDDE, Land Health Score, ecosystem processes, land health, brittleness, time-series monitor-

ing, change detection, Ecological Outcome Verification, nature-related disclosure, TNFD, ESRS, carbon sequestration, climate cooling, artificial intelligence

Note on proprietary materials and status of outputs

This publication withholds details regarding the scoring engine and its coefficients used in the EcoDynamics Diagnostic Engine. These are proprietary. For the avoidance of doubt, any outputs from EcoDynamics Diagnostic Engine and EcoIntel are decision support, labelled indicative throughout, and do not constitute an audited assurance or verification opinion. This is an organisational status choice rather than a methodological issue. Where available and/or possible, EcoDynamics Diagnostic Engine and EcoIntel reference and cross-check outputs against authoritative datasets to demonstrate scientific validity.

Definition of terms

- **The EcoIntel platform** is the commercial product, available at ecointel.io.
- **The EcoDynamics Diagnostic Engine** is the computational model inside ecointel.io.
- **The EcoDynamic Index (EDX)** and **the Land Health Score** are the EDDE's core outputs, defined in full under From EHI to EDX and the Land Health Score below.
- **Parcel/field** is the basic unit of assessed land, an individual field or land parcel; the two words are used interchangeably in this paper.

Introduction

A systemic gap in ecosystem condition assessment

Three separate bodies of work have, in recent years, quietly converged, without apparent overlap between them, and together they reveal a systemic gap in the understanding of ecosystem condition:

1. Global nature-related disclosure frameworks (notably TNFD, 2023), and legislation and regulations in some jurisdictions (notably the EU's ESRS (European Commission, 2023) and others) are converging on systems-based definitions of ecosystem health whilst other jurisdictions have put in place punitive measures to prevent scientifically unjustified nature-related claims (i.e., greenwashing claims pursued by the UK's Digital Markets, Competition and Consumers Act 2024 (DMCCA) at up to 10% of global turnover);
2. Field ecologists have developed a systems-based approach to understanding ecological health using phenological indicators; and,
3. Satellite- and geographic information system (GIS) datasets, GIS being the digital spatial layers such as terrain, hydrology, soils and land cover, give access to phenological observation of land-based ecosystems at a scale and level of detail not available before. Yet a systems-based assessment from remote sensing data has not yet been identified (Pettorelli et al., 2018).

Nature-related disclosure frameworks and legislation

In recent years, responsibility for nature-related claims has moved up through the C-suite, from sustainability and marketing to finance, general counsel and board level. In the EU, the law now demands disclosure of nature-related impact, and requires organisations at the top of the supply chains to adopt strategies to improve it. Smaller organisations carry only a voluntary burden. But because the organisations above them in the supply chain must meet mandatory reporting duties, those smaller organisations are increasingly pressured to understand and report on their own impact. In the UK, an organisation that makes nature-related claims not backed by scientific evidence can be fined for greenwashing by the DMCCA, at up to 10% of global turnover (Digital Markets, Competition and Consumers Act 2024).

Disclosure frameworks and legislation have settled on a range of terms, such as ecosystem condition and state of nature, terms that signal a move beyond a narrow focus on carbon towards a fuller account of nature. These terms originate in the definition offered by the United Nations' system of environmental-economic accounting, adopted by the UN Statistical Commission as an international statistical standard in 2021 (SEEA Ecosystem Accounting; United Nations, 2021). The standard articulates ecosystem condition as the quality of an ecosystem measured in terms of its abiotic and biotic characteristics, assessed with respect to its composition, structure and function. The author observes that this definition implicitly calls for a systems-based approach to assess and measure ecosystem condition.

The frameworks that now ask companies and governments to report on nature each lean on the SEEA's conception under varying terminology: the TNFD (2023) calls it the state of nature; the European standard ESRS E4 (European Commission, 2023) calls it the condition of ecosystems; GRI 101 (Global Reporting Initiative, 2024) places it inside a disclosure on the state of biodiversity; the Kunming-Montreal Global Biodiversity Framework (CBD, 2022) speaks of the integrity, connectivity and resilience of ecosystems; the EU Nature Restoration Regulation (Regulation (EU) 2024/1991), in force since 2024, obliges member states to bring habitats into good condition; the Science Based Targets Network (2023) and the Nature Positive Initiative (2024) both anchor their targets on the same idea. However, no metric or measurement has been identified that meets this definition. The TNFD is the most candid about why. It does not currently specify one metric, on the grounds that no single metric will capture all relevant dimensions of changes to the state of nature and a consensus is still developing (TNFD, 2023). That has been its position since 2023, and through 2026 it is still consulting on an appropriate condition metric (TNFD, GRI and SBTN, 2026).

The wider scientific literature reaches the same conclusion. Reviews of ecosystem condition accounts built under the SEEA framework find them inconsistent and not yet fit for standardised use (Maes et al., 2020), with no agreed basis for choosing among a large and growing pool of candidate indicators (Czucz et al., 2021), most of which capture structure rather than function (Nicholson Thomas et al., 2025). In the United Kingdom, the national statistics office reported that it could not calculate the SEEA Ecosystem Condition Index for all habitats because of data gaps (Office for National Statistics, 2022). Measuring the state of nature is now held to require several dimensions at once (area, integrity and the risk of collapse) with no single indicator having been identified so far that covers them all (Nicholson et al., 2021).

Systems-based assessment of land-based ecosystem health

In parallel yet entirely separately, over the last 20 years or so, field ecologists have developed a proxy-based systems approach to assess the four primary ecosystem processes that constitute land health: the water cycle, the mineral cycle, energy flow and the dynamics of the living community (used here in the ecological and not the human sense)† that drives them. Treating these particular four as one working set, assessed together at the land surface, comes from holistic management (Savory et al., 2019) and was carried into the peer-reviewed literature by the Ecological Health Index (Xu et al., 2019). Between them, the four ecosystem processes provide the services that land provides to people, including the food, water, fibre and climate regulation catalogued by the Millennium Ecosystem Assessment (2005). As soil scientist Professor Rattan Lal, director of the Carbon Management and Sequestration Center at the Ohio State University, summarises for the age of climate change, building on Sir Albert Howard's dictum‡: "The health of soil, plants, animals, people, environment and the planetary processes is one and indivisible" (Lal, 2019, 2024).

The ecosystem processes and their function cannot be measured directly at any sensible cost. They are linked to each other, they play out over a whole season and across a landscape, but as the USDA NRCS established already in 2006, pinning any one of the ecosystem processes down on the ground is not only slow but also expensive (USDA NRCS, 2006). But measuring them directly is not necessary. More accessible data can stand in as a proxy for how the processes function.

Field ecologists found a way to map the phenology of a land-based ecosystem onto the four ecosystem processes, and so to assess how well each is functioning. The principle at work is simple: patches of vegetation capture and hold water, sediment and nutrients, while bare ground sheds the same, and thus above ground surface indicators also track how the system is working below (Ludwig et al., 1997, 2005). The method uses a set of these so-called leading indicators, e.g., live canopy, bare soil, litter and dung decomposition, plant functional groups, soil capping and erosion (Xu et al., 2019), each a known stand-in for one or for several processes, and groups them by the process they belong to (Tongway and Hindley, 2004).

The concept of rangeland health, set out by the US National Research Council (1994), was made operational as three attributes: soil and site stability, hydrologic function and biotic integrity, scored through field indicators (Pyke et al., 2002; Herrick et al., 2005). Pellant and colleagues (2005) added to this the use of local reference sites: a nearby patch of land where the processes are clearly working, so a site is assessed by how far it differs from that local phenological expression. The Patagonian scorecard (Borrelli and Oliva, 2001) belongs to the same line of work, which over time led to the Ecological Health Index (EHI) (Xu et al., 2019): a systems-based method that assesses all four processes from above-ground indicators. These proxies have been tested against direct measurement and show that the grouped indices track soil behaviour closely, lining up with aggregate stability, water infiltration and respiration (Bartley et al., 2006). The method underpinning the latter is known as Landscape Function Analysis (LFA) and the correlations are strong: its stability, infiltration and nutrient-cycling indices line up with the soil properties they stand for at coefficients above 0.8, and above 0.9 for nutrient cycling against soil respiration (Tongway and Hindley, 2004; Bartley et al., 2006). The same method has since been used to assess soil processes directly on working farms following changes in grazing management (Read et al., 2016). This link between what shows at the surface and what is happening below ground allows below-ground function to be inferred from above-ground indicators.

The role of lagging and leading indicators in ecosystem assessment

Lagging indicators

Most assessment of ecosystem attributes today is based on so-called lagging indicators which include soil carbon, bioacoustics and eDNA. eDNA is the most powerful of them: from a cup of water or a pinch of soil, it can detect which species are present, with a sensitivity no field survey can match.

However, eDNA measures the presence of species, not the processes that sustain those species. It tells you nothing about the functional health of the water cycle, or the mineral and energy cycles, and also cannot serve as a diagnostic instrument to assess whether the land is being managed as well as it might. It is a snapshot of which species are present, not of what brings them and maintains their presence, and so it cannot show which way land health is heading, and it cannot run backwards in time. Like all field-based approaches, it is expensive and does not easily scale, making it hard to achieve a statistically meaningful density of samples in space and time. Continuous coverage across a land parcel, farm, supply base or a whole landscape is therefore slow and costly.

These limitations are well documented in the review literature, and they follow from the nature of eDNA. It tells you which taxa are present, which is a measure of composition, of which species are present. It does not directly measure how the ecosystem is functioning. Where function is reported from eDNA at all, it is not observed but inferred, once removed: each detected species is looked up in an external database of traits, and those traits are assumed to apply here (Cantera et al., 2025). A second limitation concerns abundance, meaning how much of a species is present rather than just whether it is present at all. In the controlled conditions of a laboratory, eDNA can estimate that quantity reasonably well. Out in the field, where nothing is controlled, that ability drops off sharply (Yates et al., 2019). A third concerns the detection itself, which several separate effects distort: bias in the primers used to amplify the DNA, gaps in the reference databases the sequences are matched against, and the way DNA is physically transported and decays between the organism that shed it and the sample that captures it (Beng and Corlett, 2020).

Soil carbon assessment shares these characteristics of eDNA: it is a slow “stock” that records the degree to which ecosystem processes have accumulated in the past but does not describe those processes themselves.

The weakness is well established. A change in soil organic carbon typically takes six to ten years to become statistically detectable (Smith, 2004), and soil science itself holds that no single measure captures soil health, with the biological and functional properties that matter most under-represented next to chemistry (Bunemann et al., 2018).

Leading indicators

Leading indicators, on the other hand, if available in sufficient variety and continuity in space and time, provide insight into the ecosystem processes themselves. They represent the structural working parts of the ecosystem processes or absence of them. Leading indicators shift ahead of the outcomes that lagging indicators record.

No single process tells you whether an ecosystem is healthy. Only taken together do the four processes show how a land-based ecosystem is functioning: whether water, energy, minerals and the living community are each working, how they are supporting or straining one another, and which of them is holding the rest back. Leading indicators, thus, enable a functional systemic view of ecosystem health.

Because it comes from signs of function that can be observed easily and continuously, it extends across wide areas and over time. Of course, the lagging indicators have their place: a targeted eDNA survey or a soil-carbon measurement confirms on the ground what leading indicators can only infer. A functional, leading indicator-based assessment can be confirmed by on the ground measurement, but not the other way around.

The EcoDynamics Diagnostic Engine bridges the systemic gap by using satellite- and GIS-data

A wicked problem to which a feasible solution is both urgently demanded and non-existent

Field-based approaches all have in common that they are slow, costly and come with gaps either in space and/or time, and thus do not scale easily. Of these, eDNA has a high reliability and consistency, whereas in-field leading-indicator assessment protocols rely on consistency of scoring across ecologists in the same season and even more so across seasons.

At the same time, the disclosure frameworks and regulations trace their definition of ecosystem condition back to the UN SEEA, and that definition, condition assessed through composition, structure and function, plainly invites a systems-based approach. Yet in practice the frameworks have reached for metrics that are difficult to assemble into a systems-based assessment of land health. They ask, in effect, for a set of separate measurements, an area here, a species count there, a soil-carbon stock somewhere else, rather than for a single assessment of whether the system as a whole is working. The space for a systems-based assessment is therefore open, but the metrics being adopted do not naturally respond to it.

In the EU, this has led to the extraordinary situation that the Nature Restoration Regulation (Regulation (EU) 2024/1991, in force since August 2024) requires member states to put restoration measures in place on at least 30% of the area of listed habitats not in good condition by 2030, rising to 60% by 2040 and 90% by 2050, whilst at the same time acknowledging that the condition of most habitats is not known in any meaningful metric terms, so much so that the same legal text allows the assessment of current habitat condition to run beyond 2030. It is clearly a wicked problem to which a feasible solution is both urgently demanded and non-existent.

A problem of seeing what we are looking at

The author argues that the gap is less about a shortage of data and more about ways of seeing, and so understanding, what we are looking at. Current instruments and their measures in common use today grew out of a reductive view of land that counts the parts in isolation and misses the working whole. A 2020 report co-authored by the author for the Food, Farming and Countryside Commission puts it plainly: the benefits of ecological farming are "systematically undervalued by conventional measures of agricultural productivity" (Greenham and Link, 2020), because those measures were built to see something else. Conventional soil tests are the clearest case, measuring the soil's chemistry and ignoring "the fact that 90% of the nutrient cycle is biological", so that they give "an incomplete picture of soil health" (Greenham and Link, 2020). That same report names what is needed: "a comprehensive, systematic, complexity-aware design, management and measurement system which can optimise economic and ecological outcomes simultaneously, and measure performance in both." The report calls it "the missing link" (Greenham and Link, 2020).

This is the opposite of a global standard, standard operating procedure, best practice or similar rule-based “farming by numbers” approach. The method assesses the management approach and its context together, and runs both through a diagnostic that reveals the functional potential of the system. As the rancher Don Campbell puts it, “To make small changes, you change the way you do things; to make major changes, you change the way you see things” (quoted in Brown, 2018).

What seemed to be lacking is a systems-based approach to state of nature and ecosystem condition assessment that is reliable, low cost, scalable and which offers a wide spatial and temporal coverage using existing data but looking at it differently.

How the EcoDynamics Diagnostic Engine (EDDE) offers a solution to this wicked problem

With regard to land-based habitats, the EDDE is able to assess the function and condition of land across different habitats and ecoregions from satellite and geographic data, at low cost and scale, requiring no site visits, using a systems-based leading-indicator methodology.

Satellite vegetation indices have measured plant productivity, phenology and ecological response for over 40 years (Tucker, 1979; Running et al., 2004; Pettorelli et al., 2005). The EDDE represents a remotely-sensed extension of the methodology articulated by the Ecological Health Index (EHI) (Xu et al., 2019). It assesses the same four ecosystem processes with the proxies arising from satellite- and GIS-data instead of in-field scorecard-based assessments. Thus, the EDDE, in effect, takes a costly and hard-to-scale kind of in-field proxy assessment and computes it instead from remote proxies, extending the field method across space and time at low cost.

Satellite remote sensing captures the cover, structure and productivity of vegetation well. Ecosystem function, the processes rather than the standing state, is harder to capture, and the scientific literature reviews frame the challenge as one of direct observation: which functional variables can a satellite measure from space? Function is regarded as one of the more achievable targets (Skidmore et al., 2021) but not yet reliably delivered (Pettorelli et al., 2018).

The EDDE overcomes this problem by following the route field ecologists use to assess ecosystem function from observable proxies. Function need not be observed directly to be assessed; it can be inferred from the coupled behaviour of its observable signs. The EDDE does exactly this. It treats vegetation cover, structure and productivity over time as a proxy for ecosystem function, grouping the leading indicators which satellites can monitor by ecosystem process, following them as a coupled system through time, and from that pattern infers the functional state, just as a field ecologist infers below-ground and overall systemic function from what shows at the surface. That inference, established by the surface-to-soil proxy relationships and Landscape Function Analysis (LFA) referenced above, is what turns an “immature” frontier (Pettorelli et al., 2018) into a working methodology.

Treating vegetation cover, structure and productivity over time as a proxy for ecosystem function is a case of a “difference in seeing what we are looking at” with regard to satellite data and thus represents what Thomas Kuhn referred to as a paradigm shift (Kuhn, 1962). Kuhn defined such a shift not as the arrival of new facts but as a change in perception, one in which "during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before" (Kuhn, 1962, p. 111). Here the instrument and the data are the familiar ones. What changes is what is drawn from them. Nature-disclosure frameworks are still consulting on a metric, and the remote-sensing reviews are still searching for the "functional" variable to observe from space. They are both hunting for a better signal, metric or single measurement. Function and condition, however, are properties of a system, and no single measurement is able to capture them as the literature indeed concedes (Nicholson et al., 2021). This way of seeing is not new. The author made the same argument in an earlier report (Greenham and Link, 2020), which named the missing measurement system "the missing link". The EDDE is an attempt to build it.

The step change is not another data point or another sensor. It is interpreting the same data as a coupled system, which gives a much fuller picture of how the land is working than any single measurement can. The quality of that coupled system is what the EDDE then expresses as a metric and a score.

As the four ecosystem processes are coupled, they move together: on healthy land all four are working, whereas on failing land all four are depressed. That coupling is why ecosystem health can be understood as a single sliding scale of interconnected functional relationships which extends all the way through ecosystem processes and into soil qualities including aggregate stability, infiltration and respiration.

The coupling also runs in a fixed order, as a cascade, with the water cycle leading the other three: without a working water cycle there is no energy flow, no movement of minerals and no ecological community to sustain them. Coupled and cascaded in this way, the whole can rise no higher than the process working worst, so the four move together at the level the weakest of them allows. Identifying the limiting process, the one holding systemic health back, is the root-cause logic at the heart of holistic management (Savory et al., 2019). Whilst not referenced in the respective literature, the root-cause diagnostic essentially is a novel application of Liebig's Law of the Minimum (von Liebig, 1840, which, for complete accuracy, originates with Sprengel, 1828; see van der Ploeg et al., 1999).

Assessing a parcel of land this way lets us infer the functional conditions that must be present for the land to work at its assessed level, and, of course, the opposite: what is absent that produces a lower functional score. The premise is that the condition of an ecosystem, i.e., "ecosystem condition", is the same as its state of ecological functioning and thus the EDDE assesses exactly what the nature-related disclosure frameworks refer to as ecosystem condition, the state of nature etc. The EDDE quantifies this as the Land Health Score on a scale from 1 to 9 (see below for details).

At the same time, the EDDE does not establish what specific species are present or absent beyond being able to infer what must be present or what is likely present to deliver the degree of any land-based ecosystem's functional health in a specific ecoregion at a specific level of functional health. Yet two examples show how powerful the EDDE's diagnostic capabilities nonetheless are:

1. In several not-connected arable fields on the same farm, the EDDE inferred the existence of a plough pan (a compacted layer in the subsoil left by years of cultivation at the same depth) which was stopping water moving down through the ground and which was thus holding back the water cycle. It also distinguished how the land was managed from any landscape-based phenomena.
2. On a beef grazing operation, the EDDE combined the grass's green-up through the season with two measures of the terrain: winter hillshade (a picture of how the low winter sun falls across the slopes) and the topographic wetness index (where water gathers). From these it diagnosed that cattle were being turned out too early in the greening cycle, before the grass had got going, on one specific field.

In both of these qualitative examples, the EDDE did more than assess the land. It diagnosed the underlying root-cause problem in the management approach which was holding the ecosystem processes and thus land-health back. The EDDE therefore links field ecology to the nature-related disclosure frameworks, using satellite- and GIS-data as the source of proxies for ecosystem condition assessment at low cost and scale. It provides assessments, diagnostics, practical recommendations and a range of reports tailored to different audiences: field managers, board members and ESG/sustainability teams in downstream supply-chain actors (i.e., farms reporting to food brands), as well as nature-impact disclosure reports.

For the EDDE to be able to use remote sensing data to assess ecosystem process functioning reliably, sufficient data points have been present in satellite datasets since 2018 allowing the following three critical questions to be answered:

1. How healthy is this land, i.e., what condition is it in?
2. Why is it the way it is, i.e., what is the root cause of this state?
3. What can be done next, i.e., how can we improve its condition?

From Ecological Health Index (EHI) via EcoDynamic Index (EDX) to Land Health Score

The Ecological Health Index (EHI)

The EDDE represents a remotely-sensed extension of the methodology articulated by the Ecological Health Index (EHI) (Xu et al., 2019). It assesses the same four ecosystem processes with the proxies arising from satellite- and GIS-data instead of in-field scorecard-based assessments.

The four ecosystem processes. The framework rests on four ecosystem processes: the water cycle, the mineral cycle, energy flow, and the dynamics of the living community. None of these is particular to this method. Energy flow, the capture of sunlight and its passage through the living system, was set out by Lindeman (1942) and is a founding principle of the standard ecology texts (Odum and Barrett, 2005). The water and nutrient cycles are the province of biogeochemistry (Schlesinger and Bernhardt, 2020). The control the living community exerts over how an ecosystem functions is itself a measurable, peer-reviewed subject (Chapin et al., 1997; Chapin, Matson and Vitousek, 2011). Terrestrial ecosystem ecology is conventionally organised around this exact set: the flow of energy, the cycling of water and nutrients, and the biotic controls over them. These four are the standard way to describe how an ecosystem works. Thus, the EHI methodology offers a novel instrument for the assessment of a single, repeatable ecosystem health score using an established conception of ecological science.

15 indicators map to the ecosystem processes. The four ecosystem processes cannot be measured directly at any sensible cost, so the EHI scores 15 field indicators instead, each a visible sign that stands in for one or more of the processes, and groups them by the process they belong to (Xu et al., 2019, drawing on Tongway and Hindley, 2004). The soil-surface indicators, the extent of bare soil, surface capping, and active wind and water erosion, report on the water cycle, because they decide whether rain is captured and held or shed and lost. The turnover indicators, the evidence of soil microfauna, the amount of litter and whether it is being worked into the soil, and the rate at which dung breaks down, report on the mineral cycle. Living canopy abundance reports on energy flow, the share of available sunlight the land converts into growth. The composition indicators, the vigour and reproduction of the four functional plant groups, warm-season grasses, cool-season grasses, forbs and legumes, and trees and shrubs, together with the frequency of desirable and of undesirable species, report on the dynamics of the living community. One indicator, the extent of bare soil, is treated as a sign of all four processes at once and weighted double, because exposed ground disrupts the healthy functioning of all.

How the EHI is established. Each indicator is scored by a trained field assessor on a short field visit, of the order of five minutes per checkpoint, and rated using a scorecard, following the reference-area procedure of Pellant et al. (2005). The indicator scores are combined into an index for each process, the Water Cycle Index (WCI), Mineral Cycle Index (MCI), Energy Flow Index (EFI) and Community Dynamics Index (CDI), using the departure-from-potential calculation adapted from Tongway and Hindley (2004). They also combine into a single cumulative figure, the Ecological Health Index (EHI).

In the initial study that established the EHI, the method was applied across 44 farms covering 398,949 hectares of Patagonia, each scored once per year (Xu et al., 2019).

The EcoDynamic Index (EDX)

It is sometimes assumed that measuring biological indicators closer to the ground gives a more direct and reliable measurement than satellite data. Yet field indicators are often themselves proxies for processes that are not measured directly. The questions that matter are which proxies are useful, how closely each one tracks the process it stands for, how often it is sampled, and against what calibration.

Satellites record reflected light, radar backscatter and surface temperature and these can be paired with topographic models of land form. The satellite data the EDDE uses is available repeatedly throughout the year, which makes it possible to detect change, rate of change and direction. In function and condition assessment, that ability probably matters even more than precision of the signal.

The EDDE's methodology translates the EHI's scorecard into an ecoregion and land state aware zoning library and uses satellite- and GIS-data instead of in-field indicators as proxies.

The EcoDynamic Index (EDX) is the EHI, but derived from remote sensing data rather than from in-field proxies. Assessing it across time has a further advantage: we can build a time series, which shows that the function of an ecosystem varies over a period. The EDX time series establishes the maximum and minimum level of functioning over any given time period, and provides relative differences between factors over time, representing ways in which the EDDE builds on and extends the EHI's understanding of ecosystem process function and ecosystem condition.

How the EDX is established using remote-sensing indicators

Each of the four ecosystem processes has a set of remote-sensing proxies standing in for the field indicators the EHI scores in the field and by the human eye, set out below in the section The four ecosystem processes as seen through remote-sensed data. From those proxies the EDDE computes a value for each process every week. Where a gap in a data source (e.g. due to cloud cover) leaves a week without a measurement, the value is interpolated from the relative seasonal shape computed from the dynamic curve across the trajectory. The result is a continuous weekly record for each ecosystem process, and for the composite EDX beginning in 2018.

Satellite- and GIS-based assessment

The score is built from a range of global satellite and mapping sources which are peer-reviewed and standard:

- **Optical:** Sentinel-2 (10 metre, roughly every five days) supplies multiple vegetation and soil indices, among them the modified soil-adjusted greenness index MSAVI2 (Qi et al., 1994) and a red-edge chlorophyll index (Gitelson et al., 2005).
- **Radar:** Sentinel-1 (C-band, 10 metre) sees through cloud; at field scale its reliable role is flagging management events such as mowing and grazing from sharp drops in backscatter, rather than a continuous weekly moisture measurement. ALOS PALSAR-2 (L-band, annual) measures woody biomass.
- **Thermal:** Landsat 8/9 and ECOSTRESS supply land-surface temperature.
- **Context and productivity:** ERA5-Land (climate), SoilGrids 2.0 (soil carbon and texture), Dynamic World (land cover), MODIS (a productivity anchor, its 16-day vegetation-index series also a disturbance check; Didan, 2021), NIRv (a Sentinel-2-derived productivity proxy), GEDI lidar (biomass, and canopy height from GEDI L2A and a global canopy-height model; Dubayah et al., 2021; Potapov et al., 2021), and a terrain stack, elevation, slope, aspect, curvature and the topographic wetness index, built from NASADEM worldwide (Farr et al., 2007; NASA Jet Propulsion Laboratory, 2020), Environment Agency 1 metre LiDAR in the United Kingdom (Environment Agency, 2022) and TINITALY in Italy (Tarquini et al., 2007), with MERIT Hydro (Yamazaki et al., 2019) supplying flow accumulation where LiDAR is absent. Soil-moisture data from the SMAP satellite is also carried in the record, but it is used only as a consistency check against the satellite moisture index. It is not an input to the EDX.

Pixel sizes differ between data points and sources. This is discussed under Limitations. Every source provides multiple readings across the year going back to 2018, which enables the EDDE to assess and visualise seasonal rhythms and trajectories.

Data-audits ensure clean data

Each satellite scene passes a quality audit before use. The EDDE uses QC-ledgers provided by the different data sources as well as its own data audit. This includes assessing reflectance, cloud cover and cloud shadow.

A note on Sentinel-2: the EDDE uses Sentinel-2 from the harmonised collection throughout. In January 2022 the European Space Agency changed how the raw values are encoded. Multi-year comparisons that ignore the change will show a step.

Scored against local potential

Every parcel is scored against its own reference state, selected by three keys: the kind of system (grassland, arable land, woodland, wooded pasture, agroforestry, orchard and so on), the ecoregion (the Metzger environmental zone; Metzger et al., 2005), and brittleness, computed from rainfall variability and the seasonal water balance.

The scoring engine

Land states including grassland, arable, silvopasture, wooded pasture, agroforestry, other grazed and mixed-farmed systems, as well as closed forest and dense woodland are scored by different subsets of an ensemble of eight linear-regression models, named A through H. Each model is fitted against the in-field ground truth, and each analyses the ecosystem from a different combination of signals. The score is the median of whichever of the eight have their inputs available. This prevents model-quirks driving the result and also allows models to drop out where inputs are missing. A confidence label reflects the number of models involved. Different land states draw on different subsets of the eight models to suit their seasonal rhythms and profiles. However, the results are transposed on to the 1-to-9 scale of the EDDE's Land Health Score (see section The Land Health Score: a Beaufort Scale for Land Health), so a property or portfolio of properties with a mix of land types can be assessed as a whole.

The scoring is weather-corrected, drawing on a residual-trend method that separates the management signal from weather (Evans and Geerken, 2004; extended by Burrell et al., 2017), which prevents a hot and dry season from being mistaken for degradation.

Confidence labels

Each parcel/field carries a confidence label based on how much data was available: High where most of the models had sufficient data points, Moderate for a middle range, and Low where only a few did. For example, sometimes there is a gap in datasets leading to missing optical, radar or thermal data which then lowers the stated confidence.

The four ecosystem processes as seen through remote-sensed data

Each process is articulated on the same nine-level band scale as the Land Health Score, from 1 Collapsed to 9 Flourishing. Each level has a characteristic percentage range for that process, and the ranges differ from one process to the next:

Table 1. The nine-level band scale for each ecosystem-process index, with the characteristic percentage range for every band; the ranges differ from one process to the next.

Level	Water Cycle	Energy Flow	Mineral Cycle	Community Dynamics
9 Flourishing	85 to 95%	90 to 98%	85 to 95%	80 to 95%
8 Thriving	80 to 90%	85 to 95%	80 to 90%	75 to 90%

Level	Water Cycle	Energy Flow	Mineral Cycle	Community Dynamics
7 Healthy	75 to 88%	80 to 92%	72 to 88%	70 to 88%
6 Recovering	65 to 80%	70 to 85%	60 to 78%	60 to 80%
5 Transitional	55 to 72%	60 to 80%	50 to 70%	50 to 72%
4 Stressed	45 to 62%	50 to 70%	40 to 60%	40 to 60%
3 Degraded	35 to 55%	40 to 60%	30 to 50%	30 to 55%
2 Depleted	25 to 45%	30 to 50%	20 to 40%	20 to 45%
1 Collapsed	0 to 35%	0 to 40%	0 to 30%	0 to 35%

Water Cycle

Measured from: Weekly optical signals blended at pixel level: canopy moisture (NDMI), vegetation vigour (EVI), the bare-soil and dry-residue indices (BSI, NPV), and ground cover. The ensemble then adds seasonal variability (NDVI coefficient of variation, which registers whether vegetation holds steady through a dry spell), chlorophyll (MTCI) and terrain. Sentinel-1 radar is available every week regardless of cloud, but at the scale of a single small parcel it carries little continuous moisture signal, so it is used to flag management events rather than as a weekly proxy in this index. Land-surface temperature and topographic wetness are assessed elsewhere in the diagnosis. Neither is an input to this index. Soil-moisture products are not used in scoring at all.

When it is the limiting process: When the water cycle is the limiting process, the conversation is about infiltration, organic matter, ground cover and landscape-position interventions such as keyline patterns, riparian work and water-harvesting earthworks. It is not about irrigation.

Reported as the Water Cycle Index (WCI), on the 1-to-9 band scale.

Energy Flow

Measured from: Greenness (NDVI, EVI), red-edge chlorophyll where greenness saturates, live-versus-dead cover, and seasonal continuity. The index is weather-corrected. It tracks how the land is doing against its own possible best for that week, so a hot dry fortnight does not register as decline.

When it is the limiting process: When energy flow is limiting, the conversation is about cover, seasonality, root depth and species composition, not about applying inputs.

Reported as the Energy Flow Index (EFI), on the 1-to-9 band scale.

Mineral Cycle

Measured from: Satellite signals that proxy biological turnover: chlorophyll response indicators, vegetation maturity patterns, structural diversity in the canopy, dry residue, and bare-soil exposure over time.

When it is the limiting process: When the mineral cycle is limiting, the conversation is about livestock and decomposer integration, plant-species diversity, residue management and reducing reliance on synthetic inputs. The aim is for nutrients already on the property to keep circulating.

Reported as the Mineral Cycle Index (MCI), on the 1-to-9 band scale.

(Ecological) Community Dynamics

Measured from: The least directly observable of the four using satellite- and GIS-data which shows in how the index is built: 40 per cent is measured from L-band radar biomass, Sentinel-1 VH and VV backscatter and edge density; 60 per cent is inferred from the other three process indices.

When it is the limiting process: When this process is limiting, the work is on species composition, rest periods, seed banks, planting of trees and shrubs, and management of field edges. Diversity matters for a practical reason. A field with many species can lose some of them to a bad year and keep working, because the rest hold the ground and keep nutrients cycling. A field with few species has nothing to fall back on.

Reported as the Ecological Community Dynamics Index (CDI), on the 1-to-9 band scale.

The Land Health Score: a Beaufort Scale for Land Health

How the Land Health Score works

Using the EDX as a time series across a given period allows for the derivation of the maximum measure of ecosystem health in a given period, EDX max. To put this in plainer language and a simpler metric, EDX max for a given year is transposed into the Land Health Score: a number to one decimal place between 1 and 9. That number places the land on a spectrum of nine bands of ecological functioning, running from 1 (collapsed, dark red) at one end to 9 (flourishing, dark green) at the other.

This works in a similar way to the Beaufort scale which is a proxy-based method for assessing wind conditions. It does not report wind speed as a number in metres per second but rather defines 12 levels of wind quality, by using observable conditions that can be used to assess the level of wind force. The Beaufort scale can be used by anyone without any ambiguity without having to consult an underlying wind-speed table. The Land Health Score applies that approach to the condition of land. The Ecological Health Index supplies the basic in-field-proxy-to-function principle, the EcoDynamic Index translates that into remote-proxy-to-function assessment adding a time series, and the band makes the result immediately understandable.

The Land Health Score is reported to one decimal place alongside its band name, written as, e.g., **6.2 Recovering**. The decimal gives position within the band, so two farms both Recovering at 6.2 and 6.8 can be distinguished in their functional capacity. A whole-farm score rolls up from per-parcel/field scores weighted by area, with non-productive parcels/fields excluded, and the same logic applies upwards to an estate, a portfolio or a supply base.

The nine bands of the Land Health Score

Each band has a characteristic signature across the four process indices. The ranges below are the process-index values typical of land-based ecosystem condition in each band.

Table 2. The characteristic signature of each Land Health band across the four process indices.

Score	Description	WCI	EFI	MCI	CDI
9 Flourishing	Ecosystem at fullest expression. Strengthens under disturbance.	85 to 95%	90 to 98%	85 to 95%	80 to 95%

Score	Description	WCI	EFI	MCI	CDI
8 Thriving	All processes highly active. Strong biological diversity and vitality.	80 to 90%	85 to 95%	80 to 90%	75 to 90%
7 Healthy	All core processes functioning well. Minor vulnerabilities only.	75 to 88%	80 to 92%	72 to 88%	70 to 88%
6 Recovering	Measurable improvement underway. Trajectory clearly positive.	65 to 80%	70 to 85%	60 to 78%	60 to 80%
5 Transitional	Some processes functioning, others compromised. Trend unstable.	55 to 72%	60 to 80%	50 to 70%	50 to 72%
4 Stressed	Multiple processes impaired. System under significant strain.	45 to 62%	50 to 70%	40 to 60%	40 to 60%
3 Degraded	Most processes failing. Structural damage evident. Urgent action needed.	35 to 55%	40 to 60%	30 to 50%	30 to 55%
2 Depleted	Severe dysfunction across systems. Biological capital critically low.	25 to 45%	30 to 50%	20 to 40%	20 to 45%
1 Collapsed	System failure. Bare soil dominant, minimal vegetation or function.	0 to 35%	0 to 40%	0 to 30%	0 to 35%

Diagnostic capability

Lineage of the diagnostic approach

The diagnostic capability of the EDDE is broad, and a full account of it is beyond the scope of this document; it is the intended subject of a separate technical paper. What follows is a brief outline.

The EDDE's diagnostic toolkit draws on a variety of approaches. Its landscape-assessment order has its roots in the keyline design of Yeomans (1954, 1958) and the layered, climate-to-soil sequence of permaculture (Mollison, 1988) and the Regrarians platform (Doherty and Jeeves), while its four-process and brittleness framing comes from holistic management (Savory et al., 2019).

Three aspects in its diagnostics are innovations unique to the EDDE: computing a landscape-/ecoregion-visual index from satellite data so that it runs without a site visit; calculating brittleness from measured rainfall variability and the seasonal water balance; and the so-called BROWN diagnostic layer, the diagnostic cascade's explicit first stage, which puts a data-based assessment of climate, weather, topography and ecoregion etc into the initial context of the diagnostic.

EDDE's diagnostic is organised into a **cascade**: **BROWN or Context, then BLUE or Water Cycle, then GREEN or Living Systems, then BLACK or Carbon and Productivity.**

- **BROWN, the givens.** These are the long-term climate of the place, the weather in the year being assessed, the shape of the land, the ecoregion it sits in, its brittleness, and the human situation the land is managed within. The human situation includes the enterprise being run, the labour available and the constraints the manager is working under.

None of this can be changed by management. It is assessed first because it determines what is possible on this land, and therefore what a good result would look like here.

- **BLUE, the water cycle.** Whether rainfall is captured, held and used. The three processes below depend on it.
- **GREEN, living systems.** Energy flow, mineral cycling and community dynamics, assessed together.
- **BLACK, carbon and productivity.** The net result of all of it.

The BLUE, GREEN and BLACK sequence comes from the work of Darren Doherty and the Regrarians platform, itself built on the keyline design of P.A. Yeomans (Yeomans, 1954). BROWN is our addition. Holistic management (Savory et al., 2019) calls this layer context but treats it lightly, largely because weather, climate and topography are hard to measure on the ground. Those are exactly what satellite- and GIS-data resolve well, so we made the givens an explicit first stage rather than a background assumption. Assessing in this order is also why carbon comes last rather than first. A carbon figure on its own states how much carbon is present. It does not state why that amount is present, or whether it will still be there in five years. Assessed without the givens, the water cycle and the living systems, a carbon figure cannot be interpreted or acted on.

Bare ground is a priority rule inside the cascade rather than a stage of it. Where soil is exposed, three things happen at once. Rain runs off instead of soaking in. Sunlight falls on bare ground instead of on leaves. Nutrients wash away instead of being taken up. Restoring ground cover therefore comes before any work further down the sequence. Sowing a diverse seed mixture into a field whose surface still seals when rain hits it will not establish.

An example of the diagnostic capability: Brittleness as a dynamic environmental context attribute

Brittleness is part of the context of a piece of land, not something that can be influenced through management approach.

Given the importance of the water cycle, and how much water availability varies from one ecoregion to the next, the Brittleness scale is a critical diagnostic tool once it is adapted to the digital age and based on actual rainfall patterns. Brittleness is powerful because it reliably describes how an environment responds to rest after impact, which, counter-intuitively, is determined by the variability of the water cycle. In a non-brittle setting, rested land recovers on its own: fungi, soil fauna and mycorrhizal networks decompose litter and the cover knits back together. In a brittle setting, rest alone is not enough, because dead material oxidises standing on the stem instead of rotting back into the soil, and the land needs periodic disturbance such as grazing, trampling etc to stay healthy.

With regard to the Land Health Score, Brittleness matters because it changes what the score means. Two properties can sit at the same Land Health Score but need differing approaches to improve ecosystem condition. A non-brittle site at level 5, Transitional, responds to rest and species enrichment. A brittle site at the same level 5 responds to planned high-density grazing pulses and water design, because rest alone would let litter stand undecomposed, lead to surface capping etc. Brittleness therefore serves as a diagnostic tool that determines how the ecosystem processes are assessed, with real effect on the impact and rest intervals as well as on the timing of interventions and more.

Brittleness also matters greatly for satellite-based assessment of ecosystem condition. The same signal can mean opposite things at the two ends of the scale. Standing dead plant material is a case in point. In a brittle environment dead material stays on the plant and oxidises, turning grey like an old fence post, rather than returning to the soil, while in a non-brittle environment it breaks down quickly (Savory et al., 2019). So a field that shows as full of dry, non-photosynthetic vegetation is failing in a wet English pasture and functioning normally on a dry savanna. The satellite records the same thing in both. Brittleness is what tells them apart, which is why it sits in the first layer of the diagnosis and colours how every later signal is interpreted.

Brittleness was set out by Savory et al. (2019) in the Holistic Management Handbook. They place an environment on a scale of one to ten according to three things:

1. how humidity is distributed through the year,
2. how quickly dead plant material breaks down biologically, and
3. how reliable rainfall is.

At the non-brittle end, one to three, moisture is reliable, decay is rapid and biological, and rest alone produces recovery. At the brittle end, seven to ten, moisture arrives in a season rather than through the year, dead material oxidises standing on the stem rather than rotting into the soil, and rest alone produces bare ground. The middle of the range, four to six, is more forgiving of management error and responds variably to rest.

The three main factors of the method can be derived from climate records. The EDDE computes them by way of rainfall reliability (the coefficient of variation of monthly rainfall) taken from the ERA5-Land record, pooled across all assessment years. The coefficient of variation is the spread of the monthly totals divided by their average, so it rises as rainfall becomes less evenly distributed through the year.

The resulting value is mapped onto the one-to-ten scale by a single fixed curve that is the same in every environmental zone, with breakpoints at certain coefficients of variation.

The second factor is a water balance: the share of the year's evaporative demand that rainfall and stored soil water cannot meet, taken from the TerraClimate record for the property itself. It only accumulates in the months where demand outruns supply, so it carries both the timing and the severity. Where supply meets demand across the year the term sits near zero. It rises through the sub-humid range, and again through the semi-arid range. The breakpoints are provided by standard aridity classes.

Traditionally, Brittleness is regarded as a static (non-changing) figure. However, in the era of climate change, using historical climate records turns a static property into a dynamic indicator that shows both the direction and the speed of change. This answers a critical question: how quickly, and how significantly, is climate change altering the condition of this ecosystem?

This enables a critical layer of our diagnostic beyond GIS, radar, optical, thermal remote sensing data.

Examples of secondary outcome reporting: Carbon Sequestration and Climate Cooling Contribution

Conceptually, much of what is pursued in nature-related measurement and Natural Capital markets constitutes secondary-level outcomes (or lagging indicators as discussed above). The primary outcomes of any ecosystem are also its leading indicators. In its assessment, the EDDE focuses on primary outcomes to establish ecosystem condition. Conversely, once primary outcomes are available for assessment, secondary outcomes can be assessed in context: Why is carbon sequestering in this way here? Why is biodiversity behaving in this way? What are the risks given the land management approach?

Two further assessment areas of the EDDE are introduced briefly here. Both need fuller treatment, and the author intends to provide it in future dedicated technical papers.

Carbon flux and stock with an extensive authoritative cross-check registry

The EDDE reports carbon in two ways:

- as a **flux budget** (productivity captured, minus respiration, minus what is harvested or grazed) and
- as **stocks** (above-ground biomass, soil organic carbon, below-ground biomass).

Uncertainty is stated as a modelled range, and per-parcel/field carbon confidence is deliberately capped at moderate.

It is important to be clear about the EDDE's remit with regard to carbon: the EDDE does not constitute third-party verification, cannot be regarded as an assurance opinion, and in no way constitutes a verified carbon claim. Any carbon related outputs of the EDDE are only indicative however solid the output. For the avoidance of doubt, EDDE cannot be used to issue carbon credits. However, EDDE provides an extensive internal cross-check against authoritative public carbon datasets.

The EDDE cross-checks any carbon related output, parcel by parcel, against a registry of published reference sources, and assesses agreement as well as disagreement using the ecosystem condition score.

The EDDE authoritative carbon datasets registry holds 16 reference sources in total which are gated by jurisdiction, so a UK property may be cross-checked against 14 and an Italian property against 13 subject to land cover:

- **Seven spatial layers**, sampled at the parcel polygon: ESA CCI Biomass, NASA GEDI L4B gridded biomass, NASA GEDI L4A footprint biomass, ISRIC SoilGrids 2.0, the FAO Global Soil Organic Carbon Map, Copernicus tree-cover fraction, and Hansen Global Forest Change.
- **National inventories**, jurisdiction-specific: the UK National Forest Inventory and UKCEH Countryside Survey for Great Britain; INFC2015 and the LUCAS topsoil survey for Italy.
- **Lookup standards:** the UK Woodland Carbon Code v3.0, IPCC 2019 Refinement Tier-1 defaults, IPCC Tier-1 agroforestry biomass, and the AGFORWARD European agroforestry measurements.

- **A model:** the Rothamsted Carbon Model (RothC), re-run with parcel-specific climate, soil clay fraction and management inputs.

Each parcel-by-reference pair returns a verdict based on standard deviation of the reference.

(Local) Climate cooling contribution

The physical basis for treating a working water cycle as a cooling function has been set out most fully by the soil scientist Walter Jehne. Jehne argues that the water cycle, rather than carbon dioxide alone, governs most of the Earth's heat dynamics, and that a hydrated soil, what he calls the soil carbon sponge, sustains the vegetation and transpiration that carry solar energy aloft as latent heat and cool the land beneath (Jehne, 2017, 2019). Land that infiltrates and holds its rainfall keeps its plants transpiring through dry spells, and transpiring plants cool their surroundings; land that sheds its rainfall and bares its soil loses that cooling. The metric described below captures exactly this: the cooling that a functioning water cycle produces, at the scale of a single property.

Local cooling is reported as a further secondary-level outcome alongside carbon. When land runs a working water cycle it partitions more of the sunlight it absorbs into water vapour rather than into heating the air, and that is cooling by physics. The Water Cycle Index and Energy Flow Index already assess those processes, so the Land Health Score is in part a statement about the land's cooling function. This metric adds no fifth process. It expresses in degrees and watts what the score already measures, and it sits downstream of the four processes exactly as carbon does.

Three quantities are kept separate and never collapsed into one: the measured surface-temperature difference against surrounding comparable land; the mechanistic partition, meaning the evaporative fraction, the Bowen ratio and the split of evaporation into transpiration through living plants versus evaporation off bare soil; and the aggregate cooling power. They answer different questions and are reported side by side.

The transpiration split is the novel part, and it carries the argument. Both transpiration and bare-soil evaporation cool the surface, but only water moving through living plants is the work of a functioning system, and only that share is coupled to production. At the demonstration property about three quarters of the water leaving the land in the growing season passes through living plants, and about a quarter evaporates off bare ground. A wet bare field cools and fails at the same time, so it is the split that matters, more than the total.

The measured result at the demonstration property is seasonal. The land runs about a degree cooler than comparable land in its own landscape through the growing season, and sits level with it when the land is dormant. It comes from ECOSTRESS surface temperature, differenced within each satellite overpass against surrounding land matched on cover, elevation and coastal exposure: about a degree cooler across 211 growing-season overpasses, and within noise of zero across 182 dormant-season overpasses. In the growing season the direction is resolved, meaning the interval excludes zero, though the magnitude sits inside a systematic uncertainty band of about three quarters of a degree. The seasonal contrast is itself the evidence that this is the water cycle at work, rather than a fixed offset between the farm and its surroundings. So the honest statement is measurably cooler than comparable land in the growing season, by roughly a degree, with the magnitude within that uncertainty. It is not a dramatic number.

The albedo trade-off is mandatory, and no net cooling figure is reported without it. A darker green canopy absorbs more shortwave radiation, which warms. The two wooded-pasture parcels on the demonstration property show the trade-off directly: they are among the strongest transpirers on the farm, and their darker canopy absorbs enough extra sunlight to measurably offset part of that cooling. On this property the offset is not large enough to move the sign of their net term, which stays a small net cooling that sits inside the albedo uncertainty, so the sign there is unresolved. In dark-canopy, low-transpiration systems the same trade-off can flip the sign of the result.

Three rules keep the claim honest. The cooling is local, never planetary: the latent heat is released again when the vapour condenses downwind, so the energy is redistributed, not removed. It is a flux, not a stock: cooling power is an instantaneous rate in watts, it does not accumulate, and there is no cooling-to-date figure. And carbon and cooling are reported side by side, never added and never converted into a CO2 equivalent. That conversion is the easiest thing in the whole metric to attack, and we refuse it.

The metric is reliable at site level and cautious at the parcel. At field scale in rolling country the surface-temperature signal is driven more by landform, such as valley position and cold-air drainage, than by management, so a per-parcel cooling number would substantially report topography back to the farmer as if it were management. It is a recent addition, computed for every property today, and deliberately not yet in the client reports. It satisfies no disclosure-framework line item; there is no TNFD, SEEA, ESRS E4 or GRI 101 metric it meets. It belongs as supplementary evidence under ecosystem condition, stated in our own words with the physics and the uncertainty shown, informed by this science and never in accordance with a standard.

Functional layers of the EcoDynamics Diagnostic Engine

The EDDE is not intended to function as a certification or standards assessment tool. It is intended as an instrument to assess land health, also known as ecosystem condition, using indices that can be observed with remote sensing and GIS-modelling.

As at August 2026, the underlying methodology of the EDDE enables six different data output layers which are briefly sketched out here.

Table 3. The functional layers of the EDDE: what each layer assesses, its guiding question, and its output.

Functional Layer	Purpose	Output
Assessment	This layer includes a range of assessments including risk, opportunity, and sustainability and uses four impact scenarios from “let it slide” to Business as Usual, to modest and high ambition for positive impact. Guiding question: What condition is this land in, and where is it heading?	The Land Health Score with its band and trajectory, per parcel/field and for the whole property, every year back to 2018.

Functional Layer	Purpose	Output
Diagnosis	The diagnostic uses a five-layer approach to understanding the conditions which lead to the functions and its characteristics and how they may be influenced. Guiding question: Why is it in that condition?	Which of the four processes is limiting each parcel/field, the cascade order between them, and what the multi-year record says about cause.
Action	The EDDE can output parcel/field-based actionable insights against the different impact scenarios. Guiding question: What should be done, and in what order?	Prescriptions matched to each diagnosis, ranked as quick wins and strategic investments, keyed to landscape position and enterprise suitability, meaning the enterprises the land can carry.
Reporting	Guiding question: How do I show this to someone else?	A tiered report suite, every report generated from the same scoring engine and satellite history: from the ten-minute Land Health Brief and the Strategic Action Brief decision pack, through the Field Operations Profile and the Visual Property Atlas, to the full Baseline Land Health Assessment and an ESG Sustainability and Disclosure Report for corporate teams. The full suite is published for the demonstration property and can be read without an account.
Disclosure	How do I answer a framework question? **Evidenced** means the item is supported by satellite measurement. **Positioned** means the platform addresses the item but the specific metrics are still to come. **Baseline** means the item requires a statement from the client. **Documented** means the client has provided that statement. The Land Health Score is informed by the main nature and disclosure frameworks and helps prepare for them. It is not offered as compliance with any of them.	The same figures organised by framework for TNFD, ESRS E4 and E1, the GHG Protocol and ISO 14064-2, with the status of each item stated honestly.
Credential	How does a buyer check it without asking me?	A signed, resolvable Land Health Credential the holder can publish voluntarily on a website, product label or supplier page. It states, for a named property and year, the Land Health Score and band, the four process indices, the trajectory across the monitored record and indicative carbon, each figure traceable to its substantiation record. It can be checked in two independent ways: a cryptographic signature that fails if any figure, date or name is altered, and a short status code that resolves against the EcoIntel register to current, superseded, withdrawn or not ours. A stable web address, such as ecointel.io/v/wilderwood-farm, always resolves to the property's current credential, so a label printed today still checks out after the next assessment. The credential describes the land's condition and trajectory; it is not a claim that a product is sustainable, regenerative or nature-positive.

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The role of artificial intelligence (AI)

Environmental impact of AI

The author acknowledges the irony that this AI-enabled instrument for assessing ecological condition carries a real and growing environmental footprint of its own. Training and running large models consumes considerable energy and emits greenhouse gases (Strubell, Ganesh and McCallum, 2019; Luccioni, Viguier and Ligozat, 2023), and the data centres behind them draw heavily on electricity and freshwater (Li et al., 2025; International Energy Agency, 2025). The full extent of that cost, and how it will scale, is not yet clear. The EDDE is built to be computationally modest relative to the land it assesses, but the author recognises that any use of AI at scale carries an environmental burden that must first be acknowledged.

Transforming slow, static, analogue tools to agile, dynamic, digital tools

One of the big opportunities latent in the development of the EDDE and other projects that use digital means to assess ecological realities is to transform ecology's rich suite of tools from their current analogue, slow and static nature into agile, dynamic diagnostics.

Here, the brittleness assessment may serve as an example. In its original form it is understood as a fixed property of place, assessed once as a static qualitative assessment. Computed instead from the historical climate record, the same concept becomes a dynamic figure which allows assessment of the direction and the speed at which its brittleness is changing. Brittleness thus transforms from a tool that supports land management decisions informed by the past of a locality into a tool for understanding the rate of climate change and its implications for land management decisions.

From linear to adaptive, threshold-aware computation

The EDDE's scoring model rests on an ensemble of statistical (linear-regression) models, calibrated against ground assessments, that assess the ecosystem processes from the satellite- and GIS-data that serves as proxies.

Ecological phenomena can be modelled with linear methods successfully but this approach reaches its limits when important thresholds are exceeded and suddenly major changes occur in non-linear dynamics. Especially climate-change related phenomena can have sudden impacts on ecosystems which are increasingly relevant and, here, AI-based approaches to adaptive, threshold-aware computation will have a major advantage. The EDDE is already being fed datasets that go well beyond the satellite- and GIS-data in order to develop adaptive, threshold-aware computational models.

AI-driven diagnostic, interpretation and reporting

The EDDE's diagnostic, interpretation and reporting layer uses AI to turn the computed assessments into readable, audience-specific language, so that a single underlying assessment can be expressed to a field manager, an organisational governance board, or a supply-chain buyer without being re-derived for each situation.

Preparing data for AI-agents to understand the provenance of food products

Beyond its wide range of reports produced for humans, the EDDE's reporting suite produces ecological credentials that can be made available to search engines and AI-agents. This enables the connection of a food product's SKU with the ecological credentials of the land it was grown in. As decisions about land, food and nature come to be mediated by AI-based systems, those systems will be only as good as the data they have available. The condition of land is currently largely missing from that data because it has been slow, costly and hard to express in a comparable form. By producing an assessment of ecosystem condition that is computed, versioned, traceable and machine-readable, the EDDE makes land health available to be reasoned over by people and by machines alike.

Evidence and calibration

The EDDE has been run across three jurisdictions and four very different ecoregions: the Atlantic Central zone of Britain, the Alpine South and Mediterranean North zones of Italy, and the Granite Lowveld Savanna of southern Africa. Other ecoregions are in advanced stages of being set up with a focus on the European ecoregions.

That span, from African savanna to oceanic temperate pasture, is a demanding test for any methodology, and in each region the assessment and diagnosis capabilities have been holding up. Land managers, in each different context, have repeatedly recognised the land health assessment and appreciated the diagnostic. In several cases it has articulated phenomena on the ground that had been hard to explain, and it has tracked specific management events and their effects.

The geographical reach across ecoregions rests on a modular library of environmental zoning characteristics. Each zone carries a profile of the satellite signals a healthy example of that land is expected to show through its season: its greenness, moisture, structure and phenological timing. Europe is keyed to the Metzger environmental stratification (Metzger et al., 2005); beyond Europe the Metzger global stratification and the RESOLVE ecoregions supply the frame (Metzger et al., 2013; Dinerstein et al., 2017), with a locally authored expected-signal profile. The method extends to new territories by adding a new zone-specific profile to the modular library: it translates the ecoregion catalogue into signal ranges, assesses the land against that expectation, and interprets the result in its context.

The calibration method

The EDDE's satellite- and GIS-data based scoring is calibrated against in-field assessments made on the ground by a trained assessor using the Ecological Outcome Verification protocol (Savory Institute), which assesses the same 15 indicators and four processes as the EHI set out above. Each assessment yields a ground-truth score for the four process indices and the composite EHI, parcel by parcel.

The available ground truth was pooled to provide 92 parcel-year observations, spanning grassland, silvopasture, wooded pasture, orchard, agroforestry and floodplain meadow, allowing for the coefficients to be fitted on a wide range of land states. The assessed parcels were part of two farms in the UK, which were assessed both individually and jointly. One property is a mixed farm with a four-year record of 12 fields, assessed across the seasons from 2022 to 2025. The other is a very diverse property of 44 fields, assessed in one year only. Between them the properties hold 56 parcels that were assessed.

The calibration itself is a correlation exercise. With the in-field process scores as the ground truth, a wide range of satellite- and GIS-data points was assembled for the same parcels and the same dates to assess how well each one tracks each ecosystem process. The coefficients were derived from this process. Those signals that showed alignment with the ground truth data were retained and weighted into an ensemble of eight scoring-engine modules.

A reasonable question is why calibration on two British properties should carry to savanna or Mediterranean systems at all. What the calibration establishes is not a set of British numbers but that the method works: that the four ecosystem processes can be assessed from satellite against ground truth. The four-process framework is not British; it is the established structure of terrestrial ecosystem ecology, and the surface-to-function proxy relationships it rests on (Landscape Function Analysis) hold across very different land. What differs from one ecoregion to the next is the expected seasonal signal of a healthy example of that land, and that is supplied per zone by the modular zoning library rather than borrowed from Britain. So the framework and the proxy logic transfer, the reference profile is local, and the coefficients are anchored to whatever local ground truth a property brings, which is why relative scale is available today across very different land while a single absolute cross-site scale still needs more ground truth in more places.

Calibration reveals two blind spots in the in-field ground truth

Weather-bias. During calibration work, the EDDE was able to identify that ground truth data is not necessarily the clean gold standard it may be assumed to be. The EDDE's time series was able to identify that in-field assessors systematically overrated good weather conditions which make land look healthier than its underlying capacity, and underrated land during poor weather conditions which suppress it.

In the calibration data available, assessors tended to mark down all indicators together including indicators that cannot ecologically change as fast as they were marked down such as soil microfauna or the cool-season grasses. It became obvious that those slow indicators moved almost in lockstep with the whole-field impression from one year to the next, while genuinely slow indicators such as trees and shrubs did not.

The EDDE corrects for this in-field assessment error by replacing the slow indicators with a multi-year average for each field which cuts the within-field noise in the ground truth by about a third and roughly halves the year-to-year band flips. This removes a weather-bias from the data used to calibrate against and also demonstrates the strength of dense time series data.

Ecosystem process conversion into biomass goes undetected. The second blind spot in the in-field EHI method is the conversion of energy flow into biomass. The in-field assessment scores the state of a field on the day of the visit and has no way of accounting in its assessment for the increase in biomass production during the season. On the four-year property this showed clearly. For several years the farm had to buy in approximately 150 bales of hay to carry its livestock through the winter; in the fourth assessment year the same land was capable of producing those 150 bales without any reduction in livestock density. In other words, the land was producing materially more from the same sunlight and rainfall (even under challenging weather conditions), yet the in-field score showed the farm as having plateaued because the scorecard records the state of a parcel/field but not its biomass production.

A satellite assessment that integrates the whole season's greening and regrowth accounts for this production in the time series where a single snapshot or field visit cannot. Therefore, some of what looks like a disagreement between ground truth and satellite data observations may actually be due to aspects which the in-field method does not detect, rather than the satellite being "wrong" as such. This is a candidate explanation for part of the disagreement, though not yet proven.

This and other work in progress is catalogued in Looking ahead.

What the calibration established

The pooled calibration data was assessed against four categories:

1. Does the score agree with the ground assessment, process by process?
2. Does it place a property's parcels/fields on the right relative scale, in the right order against each other?
3. Does it catch the direction each parcel/field is moving over time?
4. Can it place any parcel/field on a single absolute scale, one number comparable between properties?

Against the first three, the EDDE responded well; the fourth requires further calibration data.

Agreement with the ground assessment

The most direct test was whether the satellite assessment agreed with the score a trained in-field assessor would give in the field. The families of satellite- and GIS-data signals set out below were reviewed against the in-field process scores, parcel-by-parcel and date-by-date.

Table 4. The families of satellite- and GIS-data reviewed against the ground-truth process scores, and how each performed.

Data family	Representative of	Agreement with ground truth
Sentinel-2 seasonal optical	greenness, chlorophyll, moisture, bare soil and residue, and the shape of each through the season	the strongest single signals, up to about r = 0.80
Seasonal variability	how much a signal fluctuates across the season	about r = 0.55 to 0.59
ALOS PALSAR-2 (L-band radar)	woody biomass and standing structure	about r = 0.5
Sentinel-1 (C-band radar)	surface structure and moisture, and management events	about r = 0.4 to 0.5 in winter, plus event detection
Terrain	slope, aspect, curvature and where water gathers	context
Soil	modelled soil carbon and texture	context
Thermal (land-surface temperature)	surface heat	weak for scoring, about r = 0.15
Climate and brittleness	rainfall pattern and seasonal water balance	context and expected level

The data revealed two important initial findings with regard to the nature of satellite-data and how treating it as a time-series reveals systemic insights:

1. A single satellite snapshot or scene on its own is a poor guide for ecosystem process functionality: asked to predict the ground score from one snapshot, every process index does worse than simply guessing the average.
2. However, assessed across the whole season, the same signals agree well. This is the empirical reason the EDDE is a time series and not a snapshot.

On the four-year property, combined into the EDDE's scoring system, the score tracked the composite ground-truth score at a correlation of about 0.68. Process-by-process, the agreement is positive for all four, strongest for the water cycle. Thermal data, tested the same way, did not correlate positively at the scale of a single parcel/field.

Relative scale

Next, the testing enquired whether the EDDE places a property's parcels/fields in the same order of ecosystem health as trained in-field assessors would. On the 44-field property this was tested using the "leave-one-out" approach: each parcel/field was scored using only the ground data from the others, so none was ever scored against its own results. The satellite order and the assessors' order agreed at a rank correlation of about 0.77 (0.82 in-sample).

Therefore, the EDDE was found to recover relative scale well, reproducing very nearly the order the trained field assessors placed the fields in, from best to worst, where 1.0 would be a perfect match and 0 no better than chance.

Relative scale is what decision-making for land managers depends on.

Trajectory detection: Direction of change over time

The second property assessed brought a multi-year in-field record of four consecutive years of assessments across 12 fields. The record was used to re-calibrate the coefficients in order to bring to bear a time series of ground truth. Over one clean two-year interval, from 2022 to 2024, the direction of change scored by the EDDE was compared to the direction of change revealed by the trained in-field assessors.

The EDDE identified the same direction of change as the trained assessors on eleven of the 12 fields. Of those detections of trajectory, eight fields were improving and three were declining; the EDDE caught all eight improvements and all three declines.

The single miss was a field the assessor had recorded as unchanged. That single miss is itself informative: an unchanged-scored field is exactly where the ground truth's own blind spot bites, so the satellite detecting a movement there may be catching a real change the single in-field visit is not able to detect. However, further research is required to demonstrate this conclusively.

For comparison, a rule that simply predicted improvement for every field (the majority-class baseline) would score eight of 12.

The interval for trajectory or direction of change detection was set at two years rather than one because a single year of movement does not constitute a real change signal (Wessels et al., 2012).

The findings therefore demonstrate clear evidence that the EDDE possesses trajectory or change-detection skill.

Absolute scale

Relative scale makes parcels/fields comparable in terms of their land health, ecosystem function and condition against each other within the same property. Absolute scale makes any parcel/field and their aggregate land-holdings/properties comparable against the parcels/fields in other properties and the aggregate scores of those land-holdings/properties.

The properties assessed within and across ecoregions show empirically that the EDDE is able to rank properties well on the Land Health Score which allows cross-property comparison of their overall and their ecosystem process scores.

However, demonstrating this ability statistically requires further calibration on sites with multi-year in-field assessments. On the 44-field property for which only one year of data is available, the EDDE's absolute band matched the assessor's to within one band for about 45 per cent of parcels/fields. Whilst the reason for this is likely to be found in the importance of time series data to assess land-health function reliably, in statistical terms, this is too low to reliably demonstrate the EDDE's capability to make cross-property claims with the data available at this time.

This is a statistical quirk of available data rather than a major impediment.

Working from sparse optical data

It is encouraging that the results rely on very little clear optical data. Britain is among the more cloud-limited geographies: cloud holds a single field to between five and 25 clear scenes across a growing season, far from a dense, cloud-free record, and the diverse property's one assessment year was cloudier still, a median of about four clear scenes a field. When the clear scenes are thinned deliberately, the field ordering holds down to about three clear scenes a season, and the two-year direction of change holds down to about eight, with one condition: what matters is not how many scenes fall in the middle of the interval but whether a clean scene anchors beginning and end (which could come from the respective end or beginning of the adjacent years as long as it is within a reasonable range).

The reason the EDDE gets so much from so little optical data is that it is able to use the optical data as an anchor and interpolate the trajectory from other data points. Several of its inputs see through cloud or do not depend on it. Radar (Sentinel-1) sees through cloud and flags the management events, mowing and grazing, that reshape a field's recovery afterwards; terrain, modelled climate and soil layers are present every week; and brittleness, computed from the rainfall pattern and seasonal water balance of the place, sets the climatic context the field is assessed in. Against that context the EDDE predicts the seasonal curve a healthy example of the land state should follow, and fills a missing week from the field's own multi-year version of that curve, held within the range the field has actually shown. A gap is therefore not a straight line drawn between two optical readings; it is the expected seasonal shape for that field in that place, corrected by whatever signals did survive the cloud. The one case this cannot cover is a whole growing season lost to cloud in a drought year: with no clear scene to anchor either end, the EDDE flags the estimate low-confidence rather than reporting a direction.

So the optical data required by the EDDE is modest, a few clear scenes to order a property and about eight, well placed, to call direction, but not a continuous signal. That is a low bar, and regions with clearer skies than Britain, such as the drier zones of northern Italy and the Granite Lowveld Savanna, clear it with room to spare.

What the evidence covers

The calibration corpus spans grassland, silvopasture, wooded pasture, orchard, agroforestry and floodplain meadow. It establishes the general point that the engine can assess ecological condition from satellite against the four-process framework. The platform then applies that framework across grassland, arable, forest and woodland, and agroforestry, each assessed against its own seasonal profile and reference state.

The calibration does not yet cover closed forest and dense woodland, and any land beyond the ecoregions the corpus currently reaches. The EDDE, however, has assessed with impressive results considerably more land states and ecoregions than the calibration cohort covers.

Limitations

Inevitably, the method has limits. Some of these follow from the nature of satellite- and GIS-data, some from the current stage of calibration, and a third group arises because the platform is not currently certified or approved to operate as a verification or validation instrument for carbon credits.

Pixel size and observation frequency differ between sources. Pixel size is the area of ground covered by one pixel. Sentinel-2 records different parts of the light spectrum at different pixel sizes. The visible and near infrared bands are recorded at 10 metres, so one pixel covers a square 10 metres across. The red edge and shortwave bands are recorded at 20 metres. The chlorophyll and moisture indices are calculated from those bands, so those indices are 20 metre measurements. Thermal data is 70 to 100 metres. Climate data is modelled at about eleven kilometres. Soil properties are a modelled output at 250 metres.

The EDDE displays visualisation layers of the Land Health Score at 10 metre pixel size, each pixel covering a 10 by 10 metre square (100 square metres), following Sentinel-2's optical pixel size for visible and near infrared bands. The interpolation of the per-pixel Land Health Score uses other data beyond visible and near infrared bands which is necessarily shared with neighbouring pixels. This does not impact the accuracy of the relative distribution of Land Health Score within an assessed land parcel.

Observation frequency from optical data sources is limited by cloud. Over Britain, for example, a single field yields roughly five to 25 clear scenes across a growing season. The EDDE's weekly ecosystem process curve therefore requires interpolation where no clear data is available. The interpolation builds an expected curve using past curve form, evaluation of the ecosystem's health factors, weather data and other factors. However, climate stress events relative to an ecoregion's baseline such as drought and prolonged rainfall are harder to model the wider the gap between optical data points.

A directional call depends on clear optical data. Assessing which way a field has moved needs a clean optical scene near each end of the interval; in an extreme cloud year, when no clear scene falls near an assessment, the estimate is flagged as low-confidence. This is a limit of optical availability, and it is set out under Working from sparse optical data.

A proxy can point the wrong way. The mineral cycle index is built from bare-soil, residue and chlorophyll terms, so a field running on bought-in nitrogen with residues removed can score well on it while biological cycling is poor. No farm in our calibration set is managed that way. We therefore have no ground assessment of a field that is run on bought-in nitrogen with its residues removed, and no way to check what the mineral cycle index reports on that kind of land. On such a field the index is untested.

The (Ecological) Community Dynamics Index (CDI) does not identify species. The satellite data records the structure and condition of vegetation. It does not record which species are present. The Ecological Community Dynamics Index measures the variety of structure, and uses that as an indicator of the variety of species. It is not a species count and cannot be used for claims that require a list of species. This requirement can be met through an on-the-ground survey or eDNA sampling.

The EDDE is not at present certified or approved in any carbon-credit scheme. The EDDE provides assessment, diagnosis and practical guidance. It does not perform Measurement, Reporting and Verification for carbon credits, and it cannot issue credits. The EDDE's output is decision support, not a formal assurance opinion.

The calibration cohort is small and does not yet cover all land types. It is not yet large enough to support a general accuracy figure for all systems and all regions. The cohort grows with each property assessed.

The statistical models employed in the EDDE are linear and cannot predict sudden change. Each of the models employed in the EDDE is a linear regression model. They cannot represent a threshold, where a small further change in conditions produces a large change in outcome. Ecological systems do behave that way. Further work is planned, especially using AI tooling, to develop a dynamic prediction model.

The geographic reach is progressing but is currently limited to three jurisdictions covering four ecoregions. At the time of publication the EDDE operates in the UK and the EU, and promising exploratory work in southern Africa has begun.

Ongoing development

Several parallel lines of development work are in progress. These include in no particular order:

- Firming up the evidence of the EDDE's absolute scale cross-property comparison capabilities.
- Expanding the reference library of ecoregions and land states/land types.
- Connecting data services beyond satellite- and GIS-data including digital farm-management records covering crops, management events, inputs, yields, soil test results etc.

- Training of artificial intelligence models to recognise patterns of signals across data sources that strengthen the assessment of ecosystem condition in different ecoregions and land states.

Conclusion

Three bodies of work have converged on the same gap. The disclosure frameworks and the law in some jurisdictions, notably the EU, now require a measure of ecosystem condition, and they define condition in systems terms, yet no metric in common use meets that definition. Field ecology has built a systems-based, proxy method for assessing the four ecosystem processes, but it is slow, costly and hard to scale. And satellite- and GIS-data now resolve the land continuously, across space and over time, yet no systems-based assessment has been drawn from them.

This paper introduces the EDDE which closes that gap. It takes the peer-reviewed, field-based Ecological Health Index and computes it from public satellite- and GIS-data, turning a single annual field score into a weekly time series running back to 2018, and derives from that series a Land Health Score for any parcel/field, farm or portfolio, without a site visit and at low cost. Because it treats the four processes as one coupled, cascaded system, it assesses what the frameworks call ecosystem condition, diagnoses the process holding the land back, and prescribes where to act first; and it issues a portable, checkable credential for the result. Carbon and local cooling follow from the same assessment as do other secondary outcomes.

The evidence is that the method recovers relative variation well and identifies the direction of change over time, while an absolute, cross-site scale still needs deeper calibration.

What makes this possible is not a new sensor or a better single number, but a change in how the data is interpreted. The disclosure frameworks and the remote-sensing literature have both gone looking for one metric, or one signal, that would capture the state of nature. Condition, though, is a property of a system, and no single measurement holds it. The EDDE instead assesses the whole coupled chain: from the surface signs a satellite can see, through the four ecosystem processes, the water cycle, energy flow, mineral cycle and community dynamics, to the functional health of the land as a whole, and on into the soil itself, its aggregate stability, its infiltration, its nutrient cycling and respiration. That chain is not an assumption. Landscape Function Analysis has established that these surface indicators track the soil properties they stand for closely, at correlations above 0.8, and above 0.9 for nutrient cycling against respiration (Tongway and Hindley, 2004; Bartley et al., 2006), so what shows at the surface is a real measure of what is working below ground. Assessing the land as one coupled system in this way, rather than hunting for a single measurement of it, is what turns a score into a diagnosis, and what lets the method name the process holding the land back and where to act first.

More broadly, the EDDE turns the analogue, static tools of field ecology into digital, dynamic diagnostics, and in doing so makes the condition of land legible to people and to machines alike. It extends the reach of field ecology across space and time, so that the health of land can be seen, understood and acted on at the scale the wicked problem of ecosystem condition assessment urgently demands.

Notes

† "Community" is used here as an ecological term, meaning the assemblage of plants, animals, fungi and microbes that live together in a place and interact, not a human society. The philosopher David Abram writes of "the more-than-human world" (Abram, 1996), the living realm that includes humankind yet exceeds it. The EDDE is, in a modest way, an instrument for sensing into that more-than-human community and relating to it. The author has kept the word community precisely to make the point that ecology, understood in its widest sense, is a community, and that seeing it so is what would let it regain its foundational place in human value systems; and hopes that this method is a small contribution to that re-seeing of our "interbeing" with the natural world.

‡ Howard's own words, in The Soil and Health (Howard, 1945), were: "This law is true for soil, plant, animal, and man: the health of these four is one connected chain." The compressed "one and indivisible" rendering is a later distillation of the same idea, and is also associated with Lady Eve Balfour (Balfour, 1943).

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Data availability and reproducibility

This technical paper describes the method of the EDDE so it can be appreciated in greater detail and be challenged. Anything disclosed can in principle be re-derived from public satellite- and GIS-data using the methods described.

Properties which have been assessed by the EDDE/EcoIntel are kept confidential. The full demonstration report suite (for a real mixed farm, itself anonymised) is available at ecointel.io.

Corrections and feedback are welcomed.

Competing interests

The author, Marcus Link, has a financial interest as founder, CTO, director and shareholder of Ecological Intelligence Ltd (EcoIntel), a limited company registered in England and Wales under company number 16866497 and registered at Brimbles, Ashburton, Newton Abbot, TQ13 7HU. Ecological Intelligence Ltd is the commercial enterprise that employs the EDDE on its SaaS platform at ecointel.io. The company is funded by shareholding investors and platform revenue.

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