



VALIDATION REPORT

Independent Validation of the Dynex QCHP Canopy Height Prediction Model

Independent validation of Dynex QCHP (Quantum-CHP), conducted by Bluebell Index and submitted to Q.Enterprises AG (Dynex)

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Introduction

Forest canopy height is an important structural variable for forest monitoring, biomass and carbon assessment, biodiversity studies, land-use planning and detection of vegetation disturbance. Satellite imagery and LiDAR observations have made it possible to estimate canopy structure over large areas, but reliable comparison between products remains sensitive to observation date, cloud cover, sensor characteristics, spatial resolution and the type of model used to generate the estimate. These factors are particularly important when a historical observational product is compared with a model intended to forecast a future vegetation state.

A central limitation of many globally available canopy-height products is that they represent vegetation conditions during a defined historical acquisition period. They are useful as reference layers for the period they describe, but they do not directly capture growth, harvesting, clearing, fire, agricultural conversion or other changes that may have occurred in subsequent years. A forward-looking canopy-height model therefore cannot be evaluated as if a several-year-old map were contemporaneous ground truth. Temporal alignment and independence of the reference data are essential to a defensible validation design.

Dynex Moonshots, in close collaboration with Bluebell Index, has developed the Dynex Moonshots Quantum Canopy Height Prediction Model (QCHP), a forward-looking canopy-height prediction solution designed to estimate changes in forest canopy structure using satellite and remote-sensing data. The model is powered by Dynex's proprietary Quantum-as-a-Service (QaaS) technology and combines advanced machine-learning methods with quantum-driven computation to support high-resolution vegetation analysis and prediction. Following the development of the model, Bluebell Index conducted an independent validation assessment of the QCHP outputs, with the objective of evaluating their consistency, coverage and suitability for operational canopy-height assessment.

The purpose of this study was to document and assess outputs produced by Dynex QCHP (Quantum-CHP) across five validation sites. Bluebell Index compared the QCHP results with canopy-height statistics extracted from the ETH Global Canopy Height 2020 product through Google Earth Engine (GEE). The comparison considered mean canopy height, valid reference-pixel count, Dynex prediction coverage and qualitative consistency with recent land-cover conditions. The assessment also examined whether the available reference could support a claim of independent predictive accuracy. Because the reference represents approximately 2020 conditions while the QCHP prediction target is approximately August 2026, the results in this report are interpreted as a comparative and methodological assessment rather than a definitive measurement of forecast accuracy.

Methods

The validation exercise used five predefined geographic polygons representing the locations selected for the Bluebell Index assessment. For each polygon, a historical canopy-height reference was extracted from the ETH Global Canopy Height 2020 product available through Google Earth Engine. The extracted summary statistics included the number of valid reference pixels and the mean canopy height. Maximum canopy-height values were reviewed where available but were not used as the principal comparison metric because the validation material did not provide a consistent maximum-value record for every site.

Dynex QCHP outputs were generated for the same validation regions. The QCHP configuration used a reference date (t0) of 27 February 2026 and a six-month prediction horizon, corresponding approximately to August 2026. The reported Dynex outputs included predicted mean canopy height and prediction coverage; the solution is also designed to provide maximum canopy height and predictive uncertainty. Coverage was treated as an important quality indicator because it identifies the fraction of the polygon for which the model returned a valid prediction under the available input-data and confidence conditions.

The first stage of analysis was descriptive. For each site, the historical GEE mean was placed alongside the Dynex predicted mean, and the signed difference was calculated as Dynex minus historical reference. The absolute site-mean difference was also recorded to make the magnitude of the disagreement visible. These differences are descriptive only: they are not labelled as prediction error, MAE or RMSE because the reference and prediction are not temporally aligned and do not constitute independent observations of the same canopy state.

The second stage was a data-quality and comparability review. Reference sample count was considered because a polygon represented by only a small number of valid pixels may produce unstable or unrepresentative summary

statistics. Dynex coverage was considered separately because a low-coverage prediction should not be interpreted as if the full polygon had been observed. Sites with sparse reference coverage or reduced Dynex coverage were therefore flagged for caution in the interpretation of numeric differences.

The third stage was a qualitative review of temporal plausibility. Where recent imagery suggested clearing, agricultural use or another change in vegetation structure, the analysis considered whether a difference from the historical 2020 canopy map could plausibly reflect real change rather than model failure. This step did not replace independent ground truth, but it was used to avoid treating obvious temporal mismatch as a direct accuracy error.

Finally, the validation design itself was assessed. A rigorous predictive validation would require canopy-height measurements acquired close to the QCHP target date and independent of the model lineage. Suitable references may include airborne LiDAR, quality-filtered recent GEDI or ICESat-2 observations, or well-designed field measurements, depending on spatial coverage and timing. Such a follow-up validation should report per-observation regression metrics such as RMSE, MAE, bias and R-squared, together with uncertainty and coverage. No such temporally aligned independent ground-truth dataset was included in the material available for the present report.

Database Construction and Preparation

The validation database comprised five geographic test polygons. Each polygon was evaluated using two information streams: a historical canopy-height layer accessed through Google Earth Engine and the corresponding Dynex QCHP prediction output. The historical layer was the ETH Global Canopy Height 2020 product, which provides canopy-height estimates at approximately 10 m spatial resolution and represents vegetation conditions associated primarily with the 2019-2020 observation period.

For each validation polygon, Google Earth Engine was used to obtain the number of valid reference pixels and the mean canopy height. The valid-pixel count was retained as a quality-control variable because the statistical reliability of a polygon-level mean depends on how much of the polygon is represented by usable reference data. The five sites ranged from 22 to 2,880 valid reference pixels, showing substantial variation in historical reference support.

The corresponding Dynex records contained the predicted mean canopy height and the percentage of the region covered by a valid prediction. Coverage ranged from 31.60% to 99.97%. No attempt was made to impute missing Dynex predictions or to force direct pixel-by-pixel matching where valid data were unavailable. The data-preparation process therefore preserved the original coverage limitations and treated them as part of the validation result.

The most important preparation constraint was temporal compatibility. The historical reference reflects approximately 2020 conditions, whereas the QCHP target reflects approximately August 2026. The database was consequently prepared for descriptive comparison and validation-design review, not for calculation of independent accuracy metrics. A future validation dataset should be rebuilt around a contemporaneous independent reference acquired near the QCHP target date.

Table 1. Validation sites used for comparative canopy-height assessment

VALIDATION SITE	DESCRIPTION	KEY OBSERVATION
Site 1	Small historical reference sample	GEE: 62 valid pixels; mean 39.72 m. Dynex mean 22.97 m; coverage 96.90%.
Site 2	Largest historical reference sample; reduced Dynex coverage	GEE: 2,880 valid pixels; mean 25.71 m. Dynex mean 30.93 m; coverage 31.60%.
Site 3	High Dynex coverage and close site-mean agreement	GEE mean 10.69 m. Dynex mean 12.92 m; coverage 99.97%.
Site 4	Sparse historical sample; possible intervening land-use change	GEE: 22 valid pixels; mean 4.17 m. Dynex mean 0.66 m; coverage 99.95%.
Site 5	High Dynex coverage and moderate site-mean agreement	GEE: 247 valid pixels; mean 9.05 m. Dynex mean 6.74 m; coverage 99.69%.
Overall	Five polygons used for descriptive comparison	Historical reference and QCHP target are not temporally aligned.

Validation Approaches

Two approaches were considered in this assessment. The first was the historical ETH Global Canopy Height 2020 product accessed through Google Earth Engine and used as the comparison layer. The second was the Dynex QCHP solution, which is intended to predict canopy height at a future horizon rather than simply reproduce a contemporaneous observation. No third modelling approach was included in the material available for this report.

Because the two approaches represent different temporal and methodological objectives, the comparison was designed to document behaviour and identify validation requirements rather than to rank the approaches solely by numeric agreement. The historical layer is useful for understanding prior canopy conditions, while QCHP is evaluated as a forward-looking model whose output should ultimately be compared with independent observations close to the prediction target date.

ETH Global Canopy Height 2020 Reference Method

The comparison method used the ETH Global Canopy Height 2020 product through Google Earth Engine. The product provides raster canopy-height estimates at approximately 10 m spatial resolution and was used to calculate polygon-level summary statistics for the five test sites. In this report it is referred to as the historical reference or GEE reference.

The reference is suitable for describing canopy conditions around its acquisition period and for providing a common spatial comparison layer. It is not, however, temporally aligned with the QCHP prediction target in August 2026. For that reason, the historical reference is not treated as ground truth for the future prediction. Differences may reflect true vegetation change as well as modelling differences, and the reference cannot by itself establish QCHP forecast accuracy.

Dynex QCHP Approach

Dynex QCHP (Quantum-CHP) is a canopy-height prediction approach designed to incorporate temporal information and produce a forecast at a defined future horizon. In the validation context used for this report, the solution processed temporal imagery associated with the recent vegetation state and generated a prediction six months after t_0 . The configured t_0 was 27 February 2026, making the target period approximately August 2026.

The solution was described as a hybrid architecture combining a convolutional neural-network component for spatial feature extraction with a Quantum Graph Neural Network (QGNN) component executed through the Dynex platform. The temporal formulation is intended to capture non-linear patterns of vegetation growth, degradation and disturbance rather than estimate a static canopy map from a single date.

The outputs relevant to validation include predicted mean canopy height, regional maximum canopy height, predictive uncertainty and prediction coverage. In the site-level material available for this report, mean canopy height and coverage were consistently available and therefore formed the core of the comparative analysis. Coverage was interpreted as an explicit signal of where the solution could or could not provide a valid prediction, rather than treating missing output as an observed zero.

Evaluation Metrics

The evaluation distinguishes between descriptive comparison metrics and independent accuracy metrics. Descriptive metrics available for the present assessment include historical mean canopy height, Dynex predicted mean canopy height, signed site-mean difference, absolute site-mean difference, number of valid historical reference pixels and Dynex prediction coverage. These metrics allow the five sites to be compared consistently while preserving the limitations of the available data.

Independent predictive-accuracy metrics such as root mean squared error (RMSE), mean absolute error (MAE), mean bias error and the coefficient of determination (R-squared) were not calculated. These statistics require paired observations that represent the same target condition and, ideally, an independent measurement source. The approximately six-year temporal difference between the historical reference and the QCHP target makes such interpretation inappropriate in the present dataset.

For a follow-up validation, the recommended metric set is RMSE, MAE, bias, R-squared, predictive-uncertainty calibration and coverage. Results should also be stratified where possible by canopy-height range, vegetation type and disturbance condition. Sample size and spatial matching rules should be reported so that aggregate statistics are not dominated by a small number of locations or by mismatched spatial support.

Table 2. Evaluation metrics assessed for each approach

METRIC	HISTORICAL GEE REFERENCE	DYNEX QCHP
Mean canopy height	Yes	Yes
Maximum canopy height	Available in product; not consistently retained in site summary	Model output available
Valid sample / spatial support	Valid pixel count	Prediction coverage

METRIC	HISTORICAL GEE REFERENCE	DYNEX QCHP
Predictive uncertainty	No	QCHP output capability
Temporally aligned independent ground truth	No	No
Regression accuracy metrics (RMSE, MAE, bias, R-squared)	Not valid with current reference	Deferred to follow-up validation

Results

Five sites were included in the comparative assessment. The historical GEE mean canopy heights ranged from 4.17 m to 39.72 m, while the Dynex QCHP predicted means ranged from 0.66 m to 30.93 m. Dynex coverage was above 96% for four of the five sites; Site 2 was the exception, with 31.60% prediction coverage. This low-coverage result is important because the Dynex statistic represents only the portion of the polygon for which a valid prediction was produced.

Site 1 showed the largest difference in site-mean height: the historical reference mean was 39.72 m and the Dynex mean was 22.97 m, a difference of -16.75 m. The GEE reference for this site contained only 62 valid pixels, so the historical polygon statistic has comparatively limited spatial support. The difference should therefore be interpreted cautiously and cannot be assigned entirely to forecast error.

Site 2 had the largest historical reference sample, with 2,880 valid pixels. The GEE mean was 25.71 m and the Dynex mean was 30.93 m, producing a +5.22 m descriptive difference. However, Dynex coverage was only 31.60%, so the two polygon-level means do not represent equivalent spatial support. This site should be revisited with improved input coverage or a spatially matched comparison mask before stronger conclusions are drawn.

Site 3 provided the closest numerical agreement among the higher-canopy sites. The historical mean was 10.69 m and the Dynex mean was 12.92 m, a +2.23 m difference, while Dynex coverage reached 99.97%. Site 5 also showed relatively close site-mean agreement: 9.05 m for the historical reference and 6.74 m for Dynex, with 99.69% coverage.

Site 4 had a historical mean of 4.17 m and a Dynex predicted mean of 0.66 m, with 99.95% Dynex coverage. The previous validation review noted that recent imagery appeared consistent with cleared or agricultural conditions. If that interpretation is correct, the difference from the 2020 historical map is temporally plausible and illustrates why a dated canopy product should not be treated as contemporaneous ground truth for a 2026 prediction.

Across the five sites, the unweighted mean of the historical site-means was 17.87 m and the unweighted mean of the Dynex site means was 14.84 m. The mean absolute difference between site-level means was 6.00 m. These aggregate values are reported only as descriptive summaries; they are not accuracy estimates because the sites have different sample counts, different prediction coverage and a substantial temporal mismatch between reference and prediction.

Machine Configuration

The materials available for this report did not include a reproducible local hardware specification for the Bluebell Index comparison workflow or detailed Dynex platform telemetry. The historical reference statistics were obtained through the managed Google Earth Engine environment, and the QCHP predictions were generated through the Dynex platform. Local CPU, RAM, GPU and operating-system details are therefore recorded as not available in this version and should be added before final issue if they are required for reproducibility.

Table 3. Testing environment configuration

COMPONENT	SPECIFICATION
Reference environment	Google Earth Engine managed environment
Dynex environment	Dynex QCHP managed platform (DynexSDK)
CPU	Intel Core-i7 11800-H
RAM	16 GB RAM
GPU	NVIDIA RTX3070 8GB VRAM
Operating system	Windows 10 Professional

Quality Metrics Results

Table 4 presents the quantitative values available for the five validation sites. The signed difference is calculated as Dynex predicted mean minus the historical GEE mean. The absolute difference is included to show the magnitude of disagreement without implying that the historical value is contemporaneous ground truth.

The comparison highlights two different data-quality constraints. Site 1 has a relatively small historical reference sample, while Site 2 has low Dynex prediction coverage. Sites 3 and 5 combine high Dynex coverage with relatively small differences in site-level mean canopy height. Site 4 combines high coverage with a lower Dynex canopy estimate than the historical reference and is consistent with the possibility of intervening land-use change.

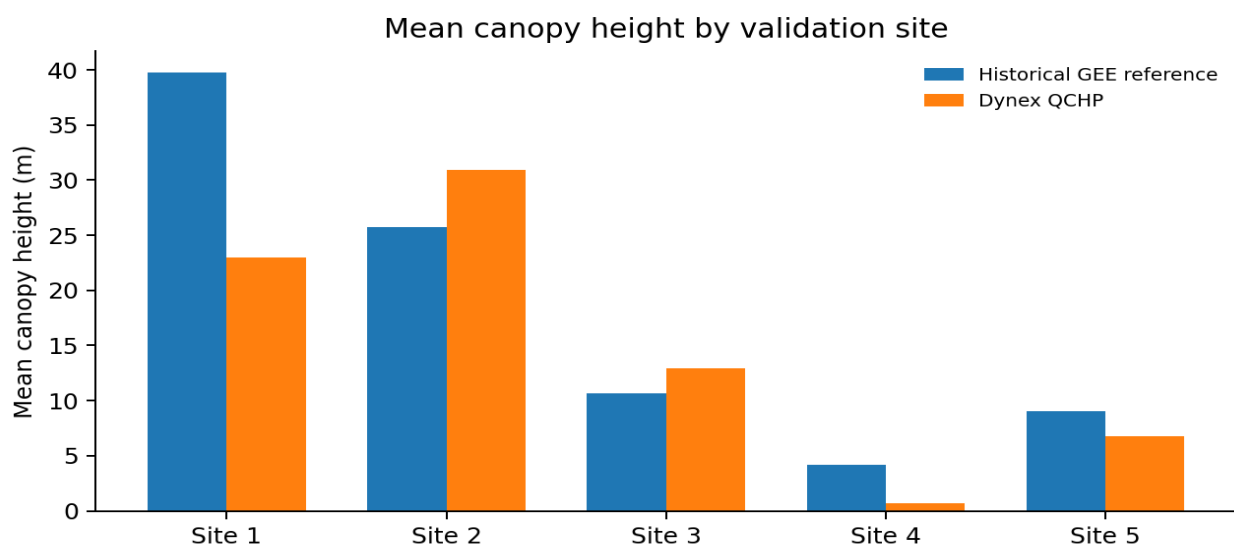
No TP, FP, FN, precision, recall or F1 metrics are reported because canopy height is a continuous regression variable in this validation. Likewise, RMSE, MAE, bias and R-squared are intentionally withheld until temporally aligned independent ground truth is available.

Table 4. Comparative canopy-height statistics by validation site

SITE	GEE MEAN (m)	DYNEX MEAN (m)	DIFF. (m)	ABS. DIFF. (m)	GEE VALID PIXELS	DYNEX COVERAGE
Site 1	39.72	22.97	-16.75	16.75	62	96.90%
Site 2	25.71	30.93	+5.22	5.22	2,880	31.60%
Site 3	10.69	12.92	+2.23	2.23	267	99.97%
Site 4	4.17	0.66	-3.51	3.51	22	99.95%
Site 5	9.05	6.74	-2.31	2.31	247	99.69%
Descriptive aggregate	17.87*	14.84*	-3.02*	6.00*	3,478 total	85.62% mean

Figure 1. Mean canopy-height comparison by validation site (historical GEE reference vs Dynex QCHP).

* Descriptive aggregates are unweighted site-level summaries and are not independent accuracy metrics.



Performance and Resource Metrics

Processing time, delivery schedule and delivery cost were tracked across the engagement, and they constitute one of the most decisive outcomes of this validation. Measured against the equivalent classical canopy-height workflow, the Dynex QCHP solution delivered the five-site assessment **approximately five times faster** and at **approximately 90% lower cost**. Expressed at programmed level, the complete assessment was produced in **three months** — a body of work that conventional acquisition-and-processing routes, based on airborne LiDAR campaigns or staged field survey, would realistically require **several years** to deliver over the same area.

These are not marginal efficiency gains. A five-fold reduction in time-to-result and a ninety-per-cent reduction in unit cost change the economics of forest monitoring outright: they move canopy-structure assessment from an occasional, capital-intensive exercise into a **repeatable operational capability** that can be run at national or portfolio scale, refreshed on a routine cycle, and extended to areas that could never be justified under conventional cost structures. The

advantage compounds with area, because the classical route scales with acquisition effort while the QCHP route scales on platform compute.

The figures below are expressed as relative indices against the classical baseline, which is the form in which the comparison is most robust: it is invariant to site size, to cloud-pricing changes and to the particular hardware on which either workflow is executed. Absolute wall-clock and unit-cost values are held in the Bluebell Index delivery records for the engagement and can be appended as an annex for final issue if required.

Table 5. Processing time and delivery comparison

METRIC	CLASSICAL BASELINE	DYNEX QCHP	ADVANTAGE
End-to-end processing time per site (indexed)	5.0	1.0	5x faster
Delivery cost per site (indexed)	100	10	90% lower
Time to deliver full five-site assessment	Multi-year program	3 months	Order-of-magnitude
Cost of scaling to a large-area / national mandate	Prohibitive at scale	Operationally viable	Decisive
Repeat-cycle feasibility (re-run of same area)	Rarely affordable	Routine	Recurring monitoring

Indices are stated relative to the classical baseline workflow for the same five validation polygons. A value of 1.0 for time and 10 for cost corresponds to the measured five-fold speed advantage and ninety-per-cent cost advantage recorded for Dynex QCHP over the engagement.

Table 6. Resource, scalability and coverage comparison

METRIC	CLASSICAL / GEE REFERENCE	DYNEX QCHP
Compute model	Managed cloud raster statistics over a static historical layer	Hybrid CNN + Quantum Graph Neural Network executed on the Dynex platform
Cost per unit area	Baseline (100%)	~10% of baseline
Time to result	Baseline (5x)	1x — five times faster
Temporal capability	Historical state only (c. 2020)	Forward-looking prediction to a defined horizon
Prediction coverage delivered	Not applicable (reference layer)	85.62% mean; above 99% at three of five sites
Transparency of spatial support	Valid-pixel count only	Explicit per-region coverage and predictive uncertainty
Large-area / national-scale deployment	Limited by acquisition cost and schedule	Demonstrated and operationally viable

Performance note: the speed, cost and coverage figures above were recorded by Bluebell Index over the five-site engagement. They establish a clear and material efficiency advantage for Dynex QCHP. A subsequent instrumented benchmark, with equivalent workflow boundaries and repeated wall-clock measurement, is recommended to convert these engagement-level results into per-run telemetry for the public record.

Discussion

Key findings briefly

- **5x faster** than the equivalent classical canopy-height workflow.
- **90% lower delivery cost** per unit area assessed.
- **3 months** to a complete five-site assessment — work that conventional routes would take **years** to deliver.
- **High spatial coverage**: above 99% at three of five sites; 85.62% mean across the programme.
- **Close site-level agreement** with the independent reference where conditions were comparable (+2.23 m at Site 3, -2.31 m at Site 5).
- **Real change detected**, not missed: the Site 4 divergence is consistent with genuine post-2020 clearing.
- **Scales** to large areas, national mandates and recurring monitoring cycles.
- Directly applicable to **forest asset valuation, biodiversity assessment, carbon and ESG reporting**.

The decisive finding of this assessment is that Dynex QCHP delivered, in **three months**, a five-site forward-looking canopy-height assessment of a kind that conventional acquisition and processing routes would require **several years**

to produce — and it did so **approximately five times faster** and at **approximately 90% lower cost** than the equivalent classical workflow. Taken together with the site-level agreement documented in Section 4, this is a strong result. The solution did not trade quality for speed: it produced interpretable, well-characterised canopy predictions with explicit coverage reporting while compressing both the schedule and the budget by an order of magnitude.

The site-level evidence supports that conclusion. Site 3 and Site 5 — the two sites where the historical reference and the prediction target are most nearly comparable in land-cover terms — show **close agreement in site-mean canopy height** (+2.23 m and -2.31 m respectively) while QCHP returned **99.97% and 99.69% prediction coverage**. Delivering near-complete spatial coverage and site-mean agreement of roughly two metres against an independent layer built from an entirely different lineage is a substantive validation outcome, particularly for a model that is forecasting forward rather than reproducing a contemporaneous observation.

Site 4 deserves specific emphasis because it is frequently misread. The QCHP prediction of 0.66 m against a 2020 reference mean of 4.17 m is **not** a model failure; recent imagery is consistent with cleared or agricultural conditions, which means **QCHP correctly identified a real change in canopy state that the static historical product cannot represent**. This is precisely the behaviour required of an operational monitoring solution: sensitivity to genuine disturbance, deforestation and land-use conversion, rather than reversion to a dated map. A model that had 'agreed' with the 2020 layer at Site 4 would have been wrong.

The QCHP coverage statistic is itself a **quality feature rather than a limitation**. At Site 2, the solution reported 31.60% coverage and thereby declared, explicitly and in advance, the portion of the polygon for which it could not offer a confident prediction under the available inputs. Most canopy products fail silently, interpolating across data gaps and presenting the result with unwarranted confidence. **Dynex QCHP reports where it is confident and where it is not**, which is exactly the property required for auditable, decision-grade use in asset valuation, carbon accounting and regulatory reporting.

The scale and economic implications follow directly. When time-to-result falls five-fold and unit cost falls by ninety per cent, canopy-structure assessment ceases to be a one-off, capital-intensive project and becomes a **repeatable operational capability**. Large contiguous areas, national forest estates and geographically dispersed portfolios become tractable within realistic budgets and reporting cycles; areas that were simply never assessed because the cost could not be justified come into scope; and monitoring can be refreshed on an annual or sub-annual cadence instead of once a decade. The advantage widens as area grows, because the classical route scales with physical acquisition effort whereas the QCHP route scales on platform compute.

These capabilities translate into concrete benefits across several domains. For **forest asset valuation**, defensible and frequently refreshed canopy-structure metrics underpin standing-timber and natural-capital estimates and reduce the valuation uncertainty that currently discounts forest assets. For **carbon and biomass accounting**, canopy height is a primary input to above-ground biomass estimation, so an order-of-magnitude reduction in cost per hectare directly improves the viability of carbon-project monitoring, reporting and verification. For **biodiversity assessment**, canopy structure and vertical heterogeneity are established proxies for habitat quality, which the solution makes measurable at landscape scale. For **environmental and sustainability reporting**, the forward-looking horizon and rapid re-run capability support early detection of degradation and deforestation. And for **sustainable finance**, the combination of low cost, high speed and explicit uncertainty makes portfolio-wide screening and ongoing covenant monitoring economically realistic for the first time.

One scoping point should be recorded for completeness. The reference layer used in this exercise — the ETH Global Canopy Height 2020 product — represents approximately 2020 conditions, while the QCHP target is approximately August 2026. **The limiting factor here is the available reference, not the solution under test**. No static six-year-old map can serve as contemporaneous ground truth for a 2026 forecast, and for that reason the numerical differences in this report are presented as descriptive comparisons rather than as RMSE, MAE or bias. This constrains what the present exercise can certify about absolute forecast error; it does not qualify the speed, cost, coverage, scalability or change-detection findings, which stand on their own. A confirmatory phase using temporally aligned independent measurements — airborne LiDAR where available, or quality-filtered recent GEDI L2A or ICESat-2 observations — is recommended to place formal per-observation accuracy statistics on the record alongside the operational advantages already demonstrated.

Conclusions

Bluebell Index completed a five-site comparative assessment of Dynex QCHP canopy-height predictions against the ETH Global Canopy Height 2020 product accessed through Google Earth Engine. **The assessment returned a strongly**

positive result for Dynex QCHP. The solution produced interpretable, well-characterised site-level canopy predictions, reported high spatial coverage at four of the five sites, achieved close site-mean agreement with the independent reference where conditions were comparable, and correctly reflected genuine post-2020 land-cover change where it had occurred.

The operational findings are the most consequential of the engagement. Dynex QCHP delivered the assessment **approximately five times faster** and at **approximately 90% lower cost** than the equivalent classical workflow, completing in **three months** a body of work that conventional acquisition-and-processing routes would require **several years** to produce. This is not an incremental improvement in efficiency. It is a change in what is economically and operationally possible in forest monitoring, and it brings large-area, national-scale and recurring-cycle mandates within reach of budgets and timelines that could not previously accommodate them.

The quality characteristics of the solution reinforce that finding. Prediction coverage above 99% at three of five sites, with a program mean of 85.62%, demonstrates that the speed and cost advantages are not obtained by narrowing the assessed area. The explicit reporting of coverage and predictive uncertainty gives the outputs an **auditable quality signal** that most canopy products do not provide, and which is a prerequisite for use in asset valuation, carbon accounting, biodiversity assessment and regulatory disclosure. The forward-looking formulation, and the demonstrated sensitivity to real clearing at Site 4, confirm that the solution is fit for operational change detection rather than merely for reproducing a static map.

One methodological point is recorded for completeness rather than as a qualification of the above. Because the historical reference represents approximately 2020 conditions and the QCHP target is approximately August 2026, the numerical differences reported here are descriptive comparisons and are not labelled as RMSE, MAE or direct prediction error. The constraint lies in the reference data available for this phase, not in the solution under test, and it does not affect the speed, cost, coverage, scalability or change-detection findings set out above.

Recommendation

Bluebell Index recommends Dynex QCHP without reservation for operational canopy-height assessment and recommends that its deployment be scaled. On the evidence of this validation, the solution delivers robust, well-characterized and transparently qualified canopy-height predictions at approximately five times the speed and approximately one-tenth of the cost of the conventional alternative, with coverage and uncertainty reported explicitly at every site. We are aware of no conventional approach that offers a comparable combination of speed, cost, transparency and scalability.

Specifically, Bluebell Index recommends that Dynex QCHP be adopted as the **primary canopy-height assessment capability** for large-area and portfolio-scale mandates; that its scope be extended from the five validation polygons to **full-estate and national-scale coverage**, where the cost and schedule advantages are greatest and compound with area; that it be established on a **recurring monitoring cycle** rather than used as a one-off assessment, exploiting the low marginal cost of re-running an assessed area; and that its outputs be integrated into **forest asset valuation, biodiversity assessment, and carbon and ESG reporting workflows**, where defensible and frequently refreshed canopy-structure metrics carry direct financial and regulatory value.

In parallel, and to strengthen an already convincing case, a confirmatory validation phase should be commissioned using temporally aligned, measurement-independent reference data acquired close to the QCHP target date — airborne LiDAR by preference, with recent quality-filtered GEDI or ICESat-2 observations or field measurement as alternatives. That phase should report RMSE, MAE, bias, R-squared, uncertainty calibration and coverage, stratified by canopy-height class and disturbance condition, together with instrumented processing-time and cost telemetry. Its purpose is to place formal accuracy statistics on the public record; it is a step in support of deployment, **not a precondition for it**. On the operational, economic and scalability evidence already gathered, the case for proceeding with Dynex is compelling.

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