Quantifying the Value of Resilience: Applying the Physical Climate Risk Appraisal Methodology (PCRAM) in Northern Italy

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1 Scoping and Data Gathering

CONTEXT

Hail is among the most damaging acute climate hazards for viticulture. In Northern Italy, hail frequency already exceeds one event per year across most wine-producing provinces and is projected to intensify. Farmers currently rely on subsidised crop insurance, which compensates losses *after the fact* but leaves physical exposure unchanged. Anti-hail nets offer active protection, yet their economic case relative to insurance has never been rigorously quantified at provincial scale for Italian viticulture across grape denomination categories.

RESEARCH QUESTIONS

1. Where in Northern Italy do hail exposure and grape value make anti-hail nets economically preferable to insurance and for which grape denomination?
2. How quickly does the net CAPEX pay back relative to avoided crop damage and insurance premiums?

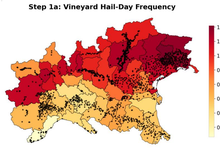
Approach: We apply the IIGCC PCRAM 2.0 framework[1] with the expected utility model of Rogna, Schamel & Weissensteiner (2019)[2] to 47 Northern Italian provinces, calibrated to ISMEA[3] insurance market data (2016–2022) and ISTAT[4] vineyard production statistics.

STEP 1 — BASELINE CHARACTERISATION

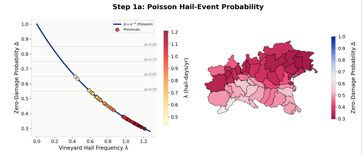
STEP 1A: HAIL HAZARD

- Overlays Punge et al. (2017)[5] hail proxy raster with EU HRL vineyard mask to derive mean annual hail-days λ per province which converts to zero-damage probability $\Delta = e^{-\lambda}$ under a Poisson distribution assumption
- Strong northeast–southwest gradient: Friuli and eastern Veneto reach λ > 1.1-1.2 hail-days/yr; Po plain and Ligurian coast λ ≈ 0.43-0.65
- Every province faces Δ < 0.65 → a >35% annual probability of at least one damaging event

Step 1a: Vineyard Hail-Day Frequency



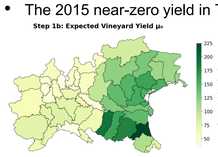
Step 1a: Poisson Hail-Event Probability



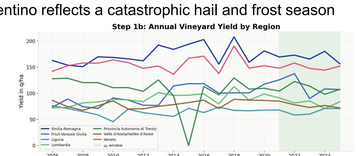
STEP 1B: YIELD BASELINES

- Establishes pre-hail revenue baseline from ISTAT 2006-2025; μ_0 = 5-year trimmed mean 2021-2025, yield variance σ^2_0 over the full 20-year series
- μ_0 ranges from 22 q/ha (Valle d'Aosta) to 225 q/ha (Emilia-Romagna); Alpine provinces show lower but more volatile yields
- The 2015 near-zero yield in Trentino reflects a catastrophic hail and frost season

Step 1b: Expected Vineyard Yield μ_0



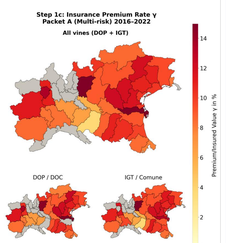
Step 1b: Annual Vineyard Yield by Region



STEP 1C: INSURANCE PARAMETERS

- Derives premium rates γ and expected indemnities E[I] from ISMEA data 2016-2022, disaggregated by packet (A, B, C) and denomination (DOP, IGT), area-weighted across provinces
- γ ≈ 9.5% under Packet A - three times Rogna et al.'s apple reference (3.1%), reflecting greater hail exposure of northern Italian vineyards
- Net-covered plots show area-weighted premium multipliers of 0.65-1.22 with uncovered DOP-Packet A charging a 22% **surcharge**, Packet C a 35% **discount** → insurers do not uniformly reward net installation

Step 1c: Insurance Premium Rate γ
Packet A (Multi-risk) 2016-2022
All vines (DOP + IGT)



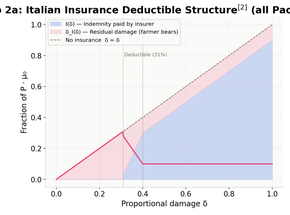
2 Materiality Assessment

STEP 2 — FOUR STRATEGIES, ONE WINNER

STEP 2A: DAMAGE DISTRIBUTION & DEDUCTIBLE

- Models the conditional distribution of proportional yield loss δ given a hail event as Beta(α, 2): a right-skewed distribution consistent with observed hail damage profiles, where most events cause moderate loss but a tail of severe events causes near-total crop failure
- Shape parameter α is fitted province-by-province by matching the model-implied expected indemnity to the ISMEA-observed value, ensuring the damage distribution is anchored to real insurance market outcomes rather than assumed
- Italian subsidised insurance follows a three-tier deductible: no indemnity below δ = 31%, partial recovery at 3×(δ-30%) between 31-40%, and full indemnity minus a 10% franchise above 40% → meaning farmers always bear some residual damage even under full coverage
- This deductible structure drives a substantial shift in expected proportional damage: μ = 0.176 uninsured → μ_I ≈ 0.103 under insurance → μ_N ≈ 0.041 under nets → nets reduce expected damage fourfold relative to the uninsured baseline
- μ_N clipped to μ×0.99 for 32 low-exposure western provinces (Liguria, Valle d'Aosta, western Lombardy) where the area-weighted net premium rate (derived from high-exposure provinces) would otherwise imply nets paradoxically increasing expected damage; a conservative correction that if anything understates the benefit of nets in those provinces

Step 2a: Italian Insurance Deductible Structure[2] (all Packets A/B/C)



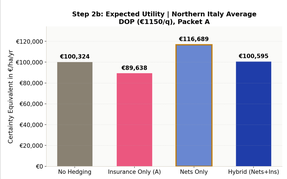
STEP 2B: DAMAGE DISTRIBUTION & DEDUCTIBLE

- Computes certainty equivalents for four strategies (No Hedging, Insurance Only, Nets Only, Hybrid (nets + discounted insurance)) via the mean-variance approximation, where λ is the Arrow-Pratt coefficient of absolute risk aversion and σ^2_W the variance of per-hectare wealth W:

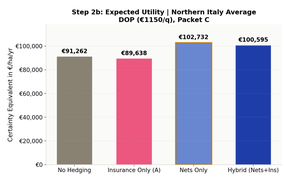
$$E[U(W)] \approx \bar{W} - \lambda\sigma^2_{\bar{W}} \qquad \text{with } \bar{W} = P \cdot \mu_0 \cdot (1 - \mu_x) - w^T x - C_x$$

- P is grape price, μ_0 expected yield (Step 1b), μ_x expected proportional damage under strategy x, $w^T x$ production costs (€2,757/ha), and C_x the strategy cost: annual insurance premium paid by the farmer, annualised net CAPEX (approx. €2,800/ha/yr) for nets, or both for Hybrid
- DOP northern Italy average: Hybrid (€100,595/ha/yr) > Nets Only (€93,329) > Insurance Only (€89,638) > No Hedging (€84,055) under Packet A → ranking holds across all 47 provinces; gap narrows substantially for IGT (P = €450/q) vs. DOP (P = €1,150/q), confirming **grape price as the primary adoption driver**

Step 2b: Expected Utility | Northern Italy Average DOP (€1150/q), Packet A



Step 2b: Expected Utility | Northern Italy Average DOP (€1150/q), Packet C



3 Resilience Building

STEP 3 — VALUE-ADD OF ANTI-HAIL NETS OVER INSURACNE

STEP 3A: RESILIENCE OPTIONS

- Evaluates two structural resilience options against material hail risk identified in Step 2: Insurance Only (financial risk transfer) and the Hybrid strategy (physical protection via anti-hail nets combined with a packet-discounted insurance contract)
- Annualised net CAPEX derived from Italian CAP Measure 4.1[6]: structure €20,000-40,000/ha over 20 years, fabric replacement €2,500-6,500/ha every 8 years, labour €700/ha/yr → total approx. €2,800/ha/yr at zero subsidy
- Net-covered plots re-enter the materiality assessment with updated damage parameters μ_N and σ^2_N, allowing direct comparison of risk-adjusted outcomes across all three insurance packets

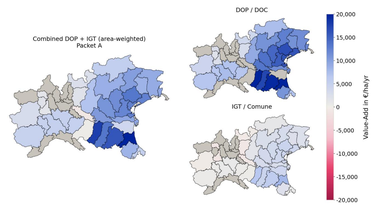
STEP 3B: VALUE-ADD & STRATEGY RANKING

- Value-add defined as the certainty equivalent gain of the Hybrid strategy over Insurance Only per province; positive values indicate nets are the preferred resilience investment:

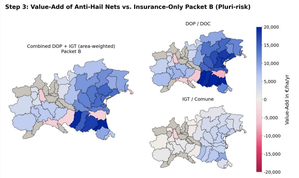
$$\text{Value−Add} = E\left[U\left(W_{Hybrid}\right)\right] - E\left[U\left(W_{Insurance}\right)\right]$$

- Under Packet A: 100% of DOP provinces and 84% of IGT provinces favour nets, the value-add reaches €20,000+/ha/yr in high-exposure northeast provinces (Friuli, eastern Veneto); Cremona is the sole province where insurance dominates across all packets and denominations, reflecting low hail exposure and generic grape prices
- Dominance of nets is robust across packets for DOP; IGT results are more packet-sensitive, with western low-exposure provinces switching to insurance under Packets B and C

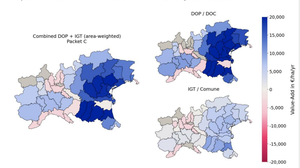
Step 3: Value-Add of Anti-Hail Nets vs. Insurance-Only Packet A (Multi-risk)



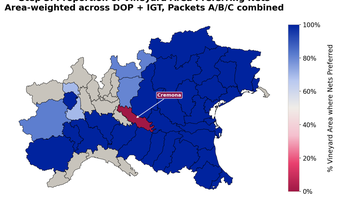
Step 3: Value-Add of Anti-Hail Nets vs. Insurance-Only Packet B (Pluri-risk)



Step 3: Value-Add of Anti-Hail Nets vs. Insurance-Only Packet C (Mono-risk)



Step 3: Proportion of Vineyard Area Preferring Nets
Area-weighted across DOP + IGT, Packets A/B/C combined



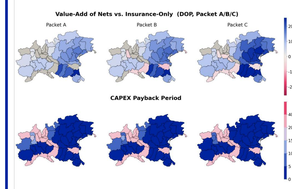
4 Value Enhancement

STEP 4 — ECONOMIC & FINANCIAL ANALYSIS

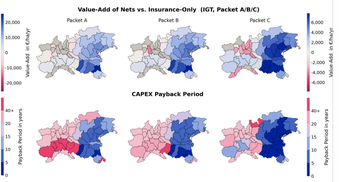
STEP 4A: CAPEX PAYBACK

- Payback = CAPEX_net / Value-Add: classifies provinces into Strong Buy (≤10 yr), Moderate (11-20 yr), Extended (21-40 yr), Hold
- DOP: median payback 1.8-2.7 yr → 60-64% of provinces Strong Buy across all packets
- IGT: median payback 6–11 yr → viable in high-exposure northeast, marginal in western low-hail provinces

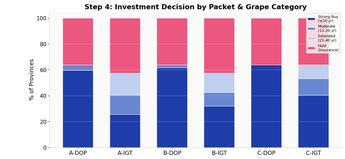
Value-Add of Nets vs. Insurance-Only (DOP, Packet A/B/C)



Value-Add of Nets vs. Insurance-Only (IGT, Packet A/B/C)



Step 4: Investment Decision by Packet & Grape Category



STEP 4B: CAP SUBSIDY SENSITIVITY

- Sweeps CAP SRD06 subsidy 0-65%; share of DOP provinces preferring nets rises only from 53% to 57% → near-flat response
- CAPEX is not the binding constraint; Packet A's 22% insurer surcharge on net-covered plots is the real adoption
- Sweeping the CAP SRD06 capital grant from 0% to 65% shifts the share of DOP provinces preferring nets by only 4 percentage points. For farmers where nets are already worthwhile, the subsidy is a windfall but not a deciding factor; for those where nets are not worthwhile, the subsidy is too small to change that. The adoption decision is driven by hail exposure and grape price, not installation cost suggesting CAP CAPEX grants are a less effective lever than reforming insurer pricing toward genuine premium discounts for net-covered plots.

- Results are highly sensitive to the DOP/IGT price binary (€1,150 vs. €450/q) — the single most influential parameter; the flat CAP subsidy curve and strong DOP dominance both depend critically on this assumption
- Net CAPEX based on annualised €2,800/ha/yr → on steep Alpine terrain costs can reach €50,000-60,000/ha

KEY FINDINGS

1. *Where in Northern Italy do hail exposure and grape value make anti-hail nets economically preferable to insurance and for which grape denomination?*

   Anti-hail nets outperform insurance under the Hybrid strategy in 75-100% of DOP provinces and 70-91% of IGT provinces depending on packet. Preference is spatially concentrated in the high-hail northeast (Friuli, eastern Veneto, λ > 1.0) and scales strongly with grape price → DOP appellations (€1,150/q) justify nets almost universally, IGT (€450/q) only where hail exposure is severe. Cremona is the sole province where insurance dominates across all packets and denominations, reflecting low hail frequency and generic grape prices.

2. *How quickly does the net CAPEX pay back relative to avoided crop damage and insurance premiums?*

   Where nets are preferred, payback is rapid: median 1.8-2.7 years for DOP and 6-11 years for IGT; well within the 20-year structure lifetime. The investment case is driven by large damage-reduction savings, not subsidy dependence.

References

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