The Arbitration Problem

Decentralized dispute resolution for tree status, registration challenges, and the constraint that no arbiter may profit from any ruling.

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Abstract

Every registry that accepts public submissions must adjudicate disputes. Trees will be fraudulently registered, incorrectly classified, or reported dead when they are alive. The Arboreal Capital protocol requires a dispute resolution mechanism that operates without courts, without centralized administrators, and without creating economic incentives for any participant to manipulate outcomes. This paper presents a decentralized arbitration system adapted from the Kleros protocol, modified with the cardinal constraint of the Arboreal Capital mechanism: no party may profit from a tree being classified as dead. We address the five dispute types the system must handle, the staking and selection mechanics for arbiters, the appeal process, and the edge cases that arise when biological reality resists binary classification.

1. Why Disputes Are Inevitable

The Arboreal Capital registry accepts submissions from anonymous participants with financial incentives to register trees (Research Note 003). The confirmation layer filters obvious fraud, but it cannot catch every error or every sophisticated attack. Disputes will arise in five categories:

Fraudulent registration. A token was minted for coordinates where no eligible tree exists. The submission passed the confirmation layer through collusion, error, or ambiguous imagery.

Duplicate registration. The same tree was registered twice under slightly different coordinates, evading the exclusion radius. One token must be deregistered.

Age reclassification. New evidence (dendrochronological study, species identification correction) indicates a tree is younger than 250 years. The token's eligibility is challenged.

Death status. A death claim has been filed (per Research Note 002) and the token holder disputes it, asserting the tree is still alive. Or: a tree is visibly damaged and the community disagrees about whether it qualifies as dead.

Coordinate correction. A tree was registered at slightly incorrect coordinates and a participant seeks to update the metadata without deregistering the token.

Each of these disputes has financial consequences for token holders. Each must be resolved without a centralized authority. And each must be resolved under the constraint that no arbiter benefits from any particular outcome — especially the outcome that a tree is dead.

> **Design Constraint: The dispute mechanism must resolve five categories of disagreement, handle biological ambiguity, and operate under the cardinal rule that no participant profits from a death classification.**

2. The Kleros Model

Kleros is a decentralized dispute resolution protocol launched in 2018 on Ethereum. It applies game-theoretic principles to create a court system with no judges, no jurisdiction, and no physical presence. Disputes are adjudicated by randomly selected jurors who stake tokens to participate. Jurors who vote with the majority earn fees; jurors who vote against the majority lose a portion of their stake. The mechanism relies on Schelling point coordination: when the truth is obvious, rational jurors independently converge on the same answer because they expect other rational jurors to do the same.

Kleros has resolved over 1,600 disputes across domains including content moderation, insurance claims, and decentralized exchange token listings (Kleros, 2024). Its design has been formally analyzed by Ast and Lesaege (2019) and is deployed on Ethereum mainnet with over $1 million in staked tokens.

The Arboreal Capital arbitration system adapts the Kleros architecture with three modifications specific to tree status disputes: (1) arbiter compensation is flat, not outcome-dependent; (2) death rulings

trigger additional safeguards that do not apply to other dispute types; and (3) evidence standards are tailored to the capabilities and limitations of satellite imagery.

3. Arbiter Selection and Compensation

3.1 The Arbiter Pool

Any participant may join the arbiter pool by staking collateral. The minimum stake is set high enough to deter casual or malicious participation but low enough to allow broad access. Initial calibration targets the equivalent of $50–500 USD, adjustable by governance as the protocol matures.

Arbiters are not required to be arborists, ecologists, or satellite imagery analysts. The disputes they adjudicate are designed to be resolvable by any person with internet access and reasonable judgment: does the satellite imagery show a large tree at these coordinates? Is the evidence of death convincing? Do two sets of coordinates appear to reference the same tree? These are observational judgments, not technical ones.

3.2 Random Selection with Stake Weighting

When a dispute is filed, arbiters are randomly selected from the pool. Selection probability is proportional to stake size: a participant who stakes $500 is ten times more likely to be selected than one who stakes $50. This is not plutocratic — it is a Sybil resistance mechanism. Creating ten accounts with $50 stakes each yields the same selection probability as one account with $500, but with ten times the operational overhead and no strategic advantage.

Panel size depends on the dispute type and the value at stake. Low-value disputes (coordinate corrections, minor reclassifications) are resolved by panels of 3 arbiters. High-value disputes (death status, deregistration of hero trees) are resolved by panels of 7 or more. The panel size is calibrated so that the cost of bribing a majority exceeds the expected gain from manipulating the outcome.

3.3 Flat Compensation

In standard Kleros, jurors who vote with the majority receive a share of the losing side's stake. This creates an incentive to vote correctly — but it also creates an incentive to vote with the perceived majority regardless of the evidence, a known failure mode in Schelling point mechanisms called 'lazy consensus.'

The Arboreal Capital modification: arbiters receive a flat fee for participating in a dispute, regardless of how they vote and regardless of the outcome. The fee is funded by the dispute filing fee (paid by the party initiating the dispute) and, if necessary, supplemented by the protocol's verification pool (Research Note 002, Section 4). Arbiters who vote against the final consensus lose a small portion of their stake — enough to discourage random voting, but not enough to make the optimal strategy 'guess what others will guess.'

The result is a compensation structure where the arbiter's dominant strategy is to evaluate the evidence and vote honestly. Voting with the majority earns a flat fee and preserves the stake. Voting against the majority earns the same flat fee but costs a small stake deduction. The incentive gradient favors accuracy over coordination.

> **Design Principle: Arbiters are paid to participate, not to rule. Flat compensation eliminates the incentive to coordinate on outcomes and redirects the arbiter's attention to evidence.**

4. The Death Ruling Safeguard

Death status disputes are the highest-stakes category. A death ruling triggers a permanent token freeze (Research Note 002), irrecoverably destroying the holder's investment. The consequences are irreversible. The safeguards must be commensurate.

4.1 Elevated Panel Size

Death disputes are always resolved by the largest available panel — a minimum of 7 arbiters, scaling to 11 or more for hero trees. A supermajority (not a simple majority) is required to confirm death. For a 7-member panel, at least 5 must vote to confirm. For an 11-member panel, at least 8. The threshold is deliberately set higher than for other dispute types.

4.2 Mandatory Cooling Period

A death ruling does not execute immediately. After the panel votes to confirm death, a mandatory cooling period (initially 30 days) begins. During this period, any party may file an appeal (Section 5) or submit new evidence. The token remains tradeable during the cooling period. This creates a market signal: if informed participants believe the death ruling is incorrect, they can buy the token at a discount during the cooling period. A rising price during the cooling period is a quantitative signal that the market disagrees with the panel.

The cooling period is not a delay for its own sake. It is a mechanism for incorporating information that the panel may not have seen. Biological reality is slow — a tree that appears dead after a wildfire may show new growth weeks later. A 30-day window captures this possibility.

4.3 The Profit Prohibition

The cardinal rule of the death profit paradox (Research Note 002) applies to arbiters as forcefully as it applies to reporters and holders. An arbiter who votes to confirm death receives the same flat fee as an arbiter who votes to deny it. No arbiter has a financial interest in any specific death ruling.

Additionally, arbiters selected for a death dispute are screened for direct financial interest: any arbiter who holds a token in the disputed tree is automatically recused. This is enforced at the smart contract level — the selection algorithm cross-references the arbiter pool against the token's holder history and excludes any address that has held the token within the previous 365 days.

The recusal mechanism cannot detect all conflicts of interest. An arbiter could hold tokens in a *competing* tree and have an indirect interest in the death of the disputed tree (if the dispute generates market attention that benefits their holdings). This second-order effect is real but small — the marginal price impact of a single death ruling on unrelated tokens is negligible at any reasonable scale. The mechanism tolerates it for the same reason it tolerates the circulating supply effect described in Research Note 002, Section 2.2: the incentive is too diffuse to motivate action.

> **Design Principle: No arbiter profits from death. Flat fees, automatic recusal, and elevated supermajority thresholds ensure that death rulings are the most scrutinized and least manipulable decisions in the system.**

5. The Appeal Process

Any dispute ruling can be appealed. The appellant pays an appeal fee and stakes additional collateral. A new panel — larger than the original — is randomly selected from the arbiter pool, excluding all members of the original panel. The appeal panel reviews the same evidence plus any new evidence submitted during the cooling period.

Appeals can be filed up to a configurable maximum number of times (initially 3). Each appeal increases the panel size. A first appeal might escalate from 7 to 11 arbiters; a second from 11 to 15. This ensures that contested disputes receive progressively broader review, while the escalating cost of appeals (increasing stake requirements and filing fees) prevents frivolous use of the process.

If the appeal overturns the original ruling, the appellant's stake and fees are returned. If the appeal upholds the original ruling, the appellant's stake is forfeited. The asymmetry is deliberate: appealing a correct ruling is expensive. Appealing an incorrect ruling is free.

5.1 The Final Ruling

After the maximum number of appeals has been exhausted — or after the cooling period expires with no appeal filed — the ruling becomes final. For death rulings, final confirmation triggers the permanent token freeze. For deregistration rulings, the token is burned. For reclassification rulings, the token's metadata is updated on-chain.

Final rulings are immutable. No governance mechanism can reverse a final ruling. This is a deliberate design constraint consistent with Research Note 001: the mechanism must not depend on any centralized authority, including its own governance. If the arbitration system makes an error that survives three rounds of appeal, the error stands. The mechanism prioritizes finality over perfection, because a system that can always be re-litigated provides no certainty to anyone.

6. Biological Ambiguity

Trees do not die like animals. They do not have a single moment of death. A tree can lose all its foliage, appear dead for a season, and regenerate from dormant buds. A tree can be 90% dead — hollow

trunk, no canopy — and still produce a few green branches. A tree can be struck by lightning, split in half, and continue growing from the surviving portion. The binary alive/dead classification that the token freeze requires does not map neatly onto biological reality.

6.1 The Operational Definition

For the purpose of the Arboreal Capital protocol, a tree is alive if it exhibits any photosynthetic activity visible from satellite imagery or confirmable by ground observation. A tree with a single living branch is alive. A tree that is leafless in winter is alive (deciduous dormancy is not death). A tree that shows no photosynthetic activity for two consecutive growing seasons in its climate zone is presumed dead.

The two-season requirement is critical. It prevents premature death rulings for trees recovering from fire, drought, or pest damage. A tree that loses all its foliage in a wildfire but regenerates the following spring was never dead. A tree that shows no recovery after two full growing seasons is, for practical purposes, dead — even if a cellular biologist could find living tissue in its root system. The protocol requires an operational definition, not a botanical one.

For species in tropical climates without distinct growing seasons, the two-season rule translates to a time-based threshold: 24 consecutive months with no observable photosynthetic activity. The principle is identical — a generous window for recovery before the protocol acts — adapted for biology that does not follow seasonal cycles. A tropical tree in slow decline from disease may persist in diminished form for years; as long as any photosynthetic activity is detectable, the token remains active.

The cardinal rule underlying every edge case: where ambiguity exists, the protocol errs toward life. A tree that is not definitively dead is not dead. This is not a technicality — it is the foundation of the mechanism. The entire conservation incentive depends on holders believing that the system will not capriciously destroy their investment. Erring toward life preserves that trust.

6.2 The Partial Death Problem

Some trees die in stages. A massive oak might lose half its canopy to disease and persist in a diminished state for decades. Is it alive? Under the operational definition, yes — any photosynthetic activity qualifies. The token remains active. Its market value may decline to reflect the reduced vigor (the market can price in risk as it sees fit), but the freeze does not trigger.

This creates a soft gradient between full health and death. The binary token state (active or frozen) does not capture this gradient, but the *market price* does. A tree in visible decline will trade at a discount to a tree in full health. The token state is a floor — alive means tradeable — and the price provides the nuance.

> **Key Insight: The token is binary. The market is analog. Biological ambiguity is handled by price, not by the protocol. The protocol only needs to answer one question: is there any life? Everything else is priced by traders.**

7. Dispute Filing Incentives

Who files disputes? The party who initiates a dispute pays a filing fee and stakes collateral. If they win, both are returned. If they lose, the stake is forfeited. This creates a natural filter: only parties who believe they have strong evidence will file.

For each dispute type, the likely filer differs:

Fraudulent registration: Filed by any community member who identifies coordinates pointing to a non-tree. The reward is not a bounty — it is the return of their stake plus the satisfaction of cleaning the registry. The forfeited tagger's tokens (now deregistered) exit the registry permanently.

Duplicate registration: Filed by the holder of the original token, who has a financial interest in preventing a duplicate from diluting the value of their genuine registration.

Age reclassification: Filed by any participant with evidence that a tree is younger than 250 years. The motivation is registry integrity — a registry full of misclassified young trees loses credibility, which devalues all tokens.

Death status: Death claims are filed through the mechanism described in Research Note 002 (Section 3). Disputes of death claims — assertions that a reported tree is actually alive — are filed by token holders who stand to lose their investment if the death ruling is confirmed.

Coordinate correction: Filed by the token holder seeking to correct their own metadata. The correction must be confirmed by a small panel to prevent holders from 'moving' their token to a different tree.

8. Governance of the Arbitration System

The arbitration mechanism itself has parameters that may need adjustment: stake minimums, panel sizes, cooling periods, appeal limits, filing fees. These parameters are governed by the same progressive decentralization roadmap described in Research Note 002 (Section 6): initially set by the protocol creator, transitioning to multisig governance, and ultimately to on-chain governance by token holders.

One parameter is immutable and cannot be changed by governance: the profit prohibition on death rulings. This is encoded in the smart contract without an admin function to modify it. No governance vote can create a bounty for death reporting, a bonus for death-confirming arbiters, or any other mechanism that generates profit from a tree being classified as dead. This prohibition is the hard constraint around which all other parameters are free to vary.

> **Design Principle: Everything in the arbitration system is tunable except the death profit prohibition. That rule is immutable because it is the foundation on which the conservation mechanism rests. If it can be changed, the mechanism can be destroyed.**

9. Edge Cases and Failure Modes

9.1 Arbiter Apathy

If arbitration fees are too low, qualified participants will not bother joining the pool. Disputes will be resolved by whoever is willing to show up for minimal compensation, which may not produce reliable outcomes. The fee structure must be calibrated so that arbitration is economically attractive to participants with genuine judgment — not just bot operators farming micro-fees.

The calibration mechanism is straightforward: if dispute resolution quality degrades (measured by appeal reversal rates), governance increases arbitration fees until quality improves. The feedback loop is slow — quality degradation must be measured over many disputes — but it is self-correcting.

9.2 Coordinated Attack on a Specific Tree

An adversary who wishes to freeze a specific tree's token could file a death claim, bribe a majority of arbiters on the panel, and push through a fraudulent death ruling. The cost of this attack is the sum of: the death claim stake, the bribes to the panel majority, and the risk that an appeal reverses the ruling (forfeiting the claim stake and exposing the bribed arbiters to stake slashing).

For the attack to succeed, the adversary must bribe the panel at every appeal level — up to three panels of increasing size. The total cost scales with the number of appeals and the size of each panel. For a hero tree with a large arbiter panel and high stake requirements, the cost of a successful coordinated attack would exceed the value of the token itself, making the attack economically irrational.

For low-value bulk trees with smaller panels, the attack is cheaper. This is an acceptable risk because the value at stake is commensurately lower. The attacker spends real money to destroy a low-value token — and gains nothing, because the death profit prohibition ensures no party benefits from the freeze.

9.3 Arbiter Collusion Across Disputes

A group of arbiters who control enough stake to be selected for multiple panels could systematically manipulate rulings across the registry. This is the most serious long-term threat to the arbitration system. Mitigation relies on three factors: the randomness of panel selection (making it statistically unlikely that the same colluding group is selected repeatedly), the transparency of on-chain voting records (allowing the community to detect patterns of coordinated voting), and the governance mechanism's ability to blacklist addresses identified as colluding.

This is not a solved problem. Sybil resistance in decentralized systems is an active area of research with no perfect solution. The Arboreal Capital arbitration system makes collusion expensive and detectable, but cannot make it impossible. We state this honestly because the credibility of the mechanism depends on acknowledging its limitations rather than pretending they don't exist.

10. Honest Caveat

Decentralized arbitration is the youngest and least battle-tested component of the Arboreal Capital mechanism. The token freeze is simple: one smart contract function. The registration system adapts a

well-understood mining incentive. The verification funding model builds on established DeFi primitives. But decentralized dispute resolution at scale, for a domain as ambiguous as tree biology, is genuinely novel territory.

Kleros has demonstrated that the model works for binary disputes with clear evidence — but tree status disputes are not always binary, and satellite evidence is not always clear. The operational definition of death (Section 6.1) is our best current attempt to impose a binary framework on a non-binary reality. It may need revision as the protocol encounters real-world edge cases that we have not anticipated.

The progressive decentralization roadmap (Research Note 002, Section 6) is designed to absorb this uncertainty. In Phase 1, disputed cases are resolved by a multisig of known, accountable individuals who can apply judgment in ambiguous situations. The fully decentralized arbitration system described in this paper is the Phase 3 target — the destination, not the starting point. The path from Phase 1 to Phase 3 will be informed by real disputes, real evidence, and real failures.

11. Conclusion

The arbitration system is the immune system of the registry. It detects and removes bad data, resolves ambiguous cases, and provides a path for correcting errors — all without a central authority and all under the constraint that no participant can profit from a tree being classified as dead. In the language of gomboc engineering (Research Note 003, Section 10), the arbitration system is shaped so that every perturbation — fraud, error, ambiguity, attack — self-corrects toward the same equilibrium: an accurate registry of living trees.

The mechanism is imperfect. It will make mistakes. Some trees will be incorrectly deregistered; others will be incorrectly preserved. But the alternative — a centralized arbiter with the power to make these decisions unilaterally — is worse, because centralized arbiters can be captured, corrupted, or defunded. A decentralized system that is occasionally wrong is more durable than a centralized system that is usually right but can be dismantled.

The trees do not need a perfect system. They need a system that works well enough, for long enough, that the economic incentive to protect them persists across centuries. The arbitration mechanism is designed to be that system — not because it is flawless, but because it has no single point of failure.

References

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See also: Arboreal Capital Research Note 001, *The Permissionless Instrument* (March 2026); Research Note 002, *The Death Profit Paradox* (March 2026); Research Note 003, *The Gold Rush* (March 2026).

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