The Readiness Option

Conservation Priority over Space and Time*

Diana Weinhold† Lykke E. Andersen‡

September 2026

Abstract

The action of protecting land can build the institutional capacity needed for later conservation. We study how this readiness benefit changes the timing of protection, distinguishing *which* parcels contribute most to a conservation portfolio from *when* a given parcel should be secured. In a real-options model, protection creates legal, administrative, and political capacity that improves access to a later intervention and lowers its cost. Early acquisition can therefore be optimal even when near-term conversion pressure is low, particularly when favorable acquisition terms may disappear.

The effect of uncertainty on protection timing depends on initial institutional capacity. In the continuation benchmark, greater uncertainty favors earlier protection for weak agencies, whose main gain is access to future intervention, but can favor delay for capable agencies, whose main gain is lower intervention cost. When acquisition can respond to observed threats, uncertainty also changes the value of waiting for a favorable state. These results bear on additionality-based selection: a near-horizon impact measure can rank parcels or protection dates differently from the planner. Protection can also deter challenges before they form, creating benefits that contest records miss. When development blocked at the focal parcel follows a less damaging continuation path, as when conservation priority targets the highest value sites, that protection also improves the wider landscape.

Keywords: conservation priority, conservation timing, dynamic reserve selection, real options, institutional capacity, additionality, protected areas.
JEL: Q57, Q58, D81, C61, H43, Q24.

*We thank Eduardo Forno, Ben Groom, Charlie Palmer, Ben Balmford, and Sabrina Eisenbarth for the lively discussions that motivated this paper, and the Natural Environment Research Council (NERC) for funding. An AI-use disclosure statement appears in the Appendix.

†Department of International Development, London School of Economics. Email: `d.weinhold@lse.ac.uk`.
‡Universidad Privada Boliviana - SDSN Bolivia. Email: `lykkeandersen@upb.edu`

1 Introduction

Conservation planning is often presented as a question of *where* to act, but every spatial choice also contains a question of *when*. *Siting priority* compares parcels at a common date: which would contribute more to the conservation objective if secured now? *Timing priority* compares dates for a given parcel: does acting now beat preserving the option to wait? In this paper we distinguish between these two components of conservation siting and consider how timing priority should be optimally adjusted when protecting a parcel does not only secure it, but also builds institutional capacity—legal, administrative, political—that makes future conservation elsewhere more feasible. In that case, an ecologically valuable parcel can be worth securing well before it is visibly threatened.

Conservation planning already recognizes ecological complementarity, changing threats, and the value of flexibility (Margules & Pressey 2000, Costello & Polasky 2004, Armsworth et al. 2025). The empirical literature also warns that protected areas are often located on inexpensive, weakly threatened land with little measured effect on conversion (Joppa & Pfaff 2009, Andam et al. 2008, Pfaff et al. 2009, Börner et al. 2020). Once siting and timing are distinguished, the near-versus-remote debate becomes an intertemporal problem. Armsworth (2018) shows that the apparent spatial trade-off between near-and-threatened land and remote-and-cheap land depends partly on how costs and ecological benefits are weighted through time. Remoteness records not only where a parcel is, but how long it may remain inexpensive and unthreatened. Waiting can improve information and preserve scarce resources (Arrow & Fisher 1974, Henry 1974, Dixit & Pindyck 1994), but conservation contains irreversibility on both sides of the decision. Delay can lose the natural asset or the opportunity to acquire it on favorable terms, while premature action can lock scarce resources into the wrong place (Pindyck 2000, Sims & Finnoff 2016).

We add an institutional reason for pre-emption: protection changes the agency's ability to act later. Establishing and managing protected land creates legal precedent, administrative routines, relationships with regulators and landowners, donor credibility, public legitimacy, and political support. These capabilities can develop through conservation activity, as emphasized by learning and organizational-capability theories (Arrow 1962, Cohen & Levinthal 1990, Teece et al. 1997, Zollo & Winter 2002), as well as through the public's experience of living with protected status over time, which can foster familiarity, attachment, and public legitimacy (Williams &

Vaske 2003). Conservation evidence links institutional and management capacity to stronger protected-area performance (Bonilla-Mejía & Higuera-Mendieta 2019, Powlen et al. 2021), while protection can also create constituencies that defend it (Pierson 1993, Campbell 2003). We call the resulting capacity *readiness*. Practitioners already use conservation readiness as a diagnostic of the ability to implement effective action (Wollstein et al. 2024, Barr & Lemieux 2021). Here we treat readiness not only as a condition for effective conservation, but also as something protection can produce. Waiting before protection may preserve flexibility and allow information to arrive, whereas establishing protection can initiate institutional and social changes that improve later conservation opportunities. Early protection may therefore be valuable not only because it secures the focal parcel, but because it changes the cost and feasibility of intervening in future conservation conflicts.

The model considers a parcel that may be ecologically valuable but is currently distant from a development frontier. The opportunity to acquire it on favorable terms can disappear at an uncertain time. Protecting the parcel yields direct conservation benefits and builds readiness for a distinct later conflict. The model asks two questions: would protection under current conditions yield a positive net benefit, once both direct conservation benefits and readiness are counted? And would protecting now deliver more value than waiting?

As in standard investment-option analysis, even when acquisition would yield a positive net benefit today, postponing a costly commitment can be preferable. Waiting keeps scarce resources available for longer, but risks losing favorable acquisition terms or reaching the later conflict without the readiness that protection could have created. Either side of this trade-off can dominate, so the question is whether the gains from acting now outweigh the benefits of postponing a costly commitment. The model examines how the resulting timing decision depends on ecological quality, changing acquisition terms, and the interaction between uncertainty and the agency's initial institutional capacity.

Consider first ecological quality, holding other conditions fixed. Higher quality increases the direct conservation benefits of acquisition and, when higher-quality protection also builds more readiness, increases its institutional benefits. At a lower quality threshold, these combined benefits first become sufficient to cover the cost of acquisition under current conditions. At that point, however, waiting remains preferable: covering the cost of acquisition is not yet enough to justify giving up the benefit of delay. As quality rises further, the balance shifts toward earlier action, reaching a second, higher threshold at which immediate protection becomes optimal. Between the two thresholds, acquisition has positive current value but waiting is preferable; at or above the higher threshold, protection should occur now.

For a parcel of given ecological quality, the evolution of acquisition terms also changes the timing balance. Rising acquisition prices strengthen the case for early protection because development expectations can close the low-price window before physical conversion is imminent. A parcel can therefore warrant early acquisition not because it faces imminent loss, but because the opportunity to secure it on favorable terms is disappearing.

Uncertainty about future conservation stakes affects the same timing balance, but its effect depends on the agency's initial institutional capacity. For an institutionally weak agency, readiness principally makes future intervention possible at all. Greater uncertainty can make that access more valuable and strengthen the case for building capacity early. For an already-capable agency, marginal readiness mainly lowers the cost of an intervention already within reach. Greater uncertainty can reduce the marginal value of these cost savings and favor delay. This result uses a continuation-value benchmark, which values the later intervention as an option to act in the future. The fuller valuation also allows future states in which immediate intervention is optimal and need not give the same uncertainty response. In the planned-date benchmark, uncertainty works through the value of readiness. A separate extension allows the agency to condition acquisition on observed threats, introducing an additional value of waiting for a favorable state.

These findings also clarify when a measure of conservation impact can guide acquisition decisions. Here *outcome additionality* means the causal difference between outcomes with and without intervention over a stated horizon, distinct from project- or financial-additionality tests used by some funding mechanisms. It is an essential measure of impact within that frame. The difficulty arises when a finite-horizon impact measure is promoted into a universal eligibility or ranking rule. To preserve the two comparisons studied here, such a rule must agree with the planner on both which parcel is preferable at a common date and when a particular parcel should be protected. Threat that shifts across time can upset the first ranking; a closing acquisition window can upset the second. Readiness may also create benefits at other sites or dates. A strategic extension shows how protection can deter challenges before they form, placing some benefits outside observed contest records. The implication is that additionality's domain should match the decision it is asked to make.

Section 2 develops the conceptual framework. Sections 3 and 4 present the model and its implications for timing. Section 5 examines additionality-based selection and evaluation, including deterrence. Section 6 discusses policy design and limitations. The appendices collect notation, supporting derivations, and the limits of the continuation benchmark.

2 Conservation priority over space and time

2.1 Where to act, when to act, and what protection achieves

Siting priority compares parcels at a common date; timing priority compares alternative protection dates for a given parcel. In either comparison, the planner considers expected net conservation benefits over its horizon. These may include direct ecological benefits, complementarity with the existing portfolio, acquisition and management costs, the risk that the opportunity disappears, and the effect of protection on future conservation capacity. A full dynamic portfolio problem combines the two comparisons; keeping them distinct helps explain why a particular parcel or acquisition date is preferred.

Outcome additionality asks a third question: what changed because protection occurred? In a simple avoided-loss setting, the answer depends on the ecological or carbon value at stake, how much would have been lost without intervention over the evaluation horizon, and how effectively protection prevents that loss. This causal measure may cover a different horizon from the planner's decision and omit costs or institutional benefits at other sites. Table 1 summarizes the distinctions.

An additionality score can guide both siting and timing without distorting the planner's rankings only when it agrees with the planner on both comparisons: which parcel is preferable at a common date, and whether a particular parcel should be protected now or later. Agreement on one comparison does not ensure agreement on the other.

Nor can such an agreement be assumed. Current threat can raise measured impact while also increasing acquisition costs, making protection harder to implement, or leaving less time to build readiness for a later conflict. A higher additionality score can therefore coincide with

Table 1: Conservation siting, timing, and evaluation

Object	Central question	Principal inputs	Natural horizon
Siting priority	Which parcel contributes more if action occurs at a common date?	Ecological contribution, representation, complementarity, connectivity, condition, permanence, cost, and cross-site effects	Planner's portfolio horizon
Timing priority	For a given parcel, should the planner act now or wait?	Threat path, acquisition-price path, availability, information, finance, irreversibility, and institutional state	Decision and option horizon
Outcome additionality	What outcome changed because intervention occurred?	Counterfactual loss, intervention effectiveness, measured outcome, and evaluation window	Evaluation or crediting horizon

a less attractive acquisition opportunity. Sections 3 and 4 examine how these forces affect a candidate's value and optimal acquisition date. Section 5 then asks when additionality-based selection and evaluation capture those considerations.

2.2 How existing approaches map onto the distinction

Systematic conservation planning is principally organized around the siting comparison, asking how a set of sites can meet ecological objectives given costs, representation targets, complementarity, and other constraints (Margules & Pressey 2000). Threat-weighted return-on-investment rules add timing urgency to that spatial comparison, and can perform well when threat is a reliable proxy for the risk of losing valuable options and when costs and effectiveness are adequately represented. The empirical location-bias literature appropriately warns that choosing land merely because it is inexpensive or politically easy can generate protected areas with little causal effect on land conversion (Joppa & Pfaff 2009, Andam et al. 2008, Pfaff et al. 2009, Börner et al. 2020).

Dynamic reserve-selection models make the timing comparison explicit. Sites may disappear before acquisition, prices may change, budgets may expire, and waiting can alter the feasible portfolio (Meir et al. 2004, Costello & Polasky 2004, Strange et al. 2006, McDonald-Madden et al. 2008). Pre-emptive conservation and "fire-fighting" thus constitute alternative policies for an evolving opportunity set (Spring et al. 2007). The framework of Armsworth (2018) is especially close to the present distinction because distance from a development frontier is both spatial and temporal: it records where a site is and how long it may remain inexpensive and unthreatened. Armsworth et al. (2025) generalize the point by treating conservation return as a quantity that varies through time with biodiversity status, threat, cost, funding, and parcel availability.

Real-options analysis clarifies why timing cannot be reduced to urgency alone. Uncertainty and irreversible expenditure create an option value of waiting, while irreversible ecological loss and the disappearance of favorable acquisition terms create a value of pre-emption (Arrow & Fisher 1974, Henry 1974, Dixit & Pindyck 1994, Pindyck 2000). Financial instruments can partly separate the two margins: borrowing, revolving funds, multiyear budgets, and rights of first refusal allow organizations to preserve valuable sites without always making a full immediate commitment (Yoon & Armsworth 2022, Armsworth et al. 2025). The planner's task is therefore not to choose categorically between "act early" and "wait," it is to identify the state-dependent threshold at which the value of acting overtakes the option value of delay.

2.3 Readiness as an endogenous state variable

Most dynamic conservation models treat the organization's future ability to act as given (Costello & Polasky 2004, Meir et al. 2004, Strange et al. 2006, McDonald-Madden et al. 2008). In more recent frameworks, financial flexibility is allowed to evolve, but legal competence, administrative routines, public legitimacy, and political access do not enter as stocks produced by prior protection (Yoon & Armsworth 2022, Armsworth et al. 2025). However organizational economics suggests that institutional capacity is dynamic and builds on past experience; learning-by-doing and organizational-learning theories treat capability as the accumulated product of activity (Arrow 1962, Cyert & March 1963, Nelson & Winter 1982, Levitt & March 1988). Absorptive-capacity and dynamic-capabilities theories likewise emphasize that prior related experience improves the ability to recognize opportunities, coordinate action, and reconfigure resources (Cohen & Levinthal 1990, Teece et al. 1997, Zollo & Winter 2002).

In conservation, this internal capacity can be highly specific. Protecting a parcel in one jurisdiction may establish legal precedent, staff routines, regulator relationships, donor confidence, and monitoring systems that are useful in a later conflict. The value depends on relevance: experience in the same biome, legal regime, agency network, or political coalition should transfer more strongly than unrelated activity. The model captures this connection with a relevance parameter rather than assuming that every protected hectare builds equivalent capacity.

Protection can also create external readiness. Once a landscape is protected and used, it can become a reference point for residents, visitors, donors, agencies, and non-use beneficiaries. Policy feedback can create constituencies that defend existing benefits against retrenchment (Pierson 1993, 1994, Campbell 2003); environmental valuation and place-attachment research provide parallel reasons why protected status can become politically durable (Weisbrod 1964, Krutilla 1967, Williams & Vaske 2003). Developers can remain fully rational in this account. They need only anticipate higher legal, political, reputational, or administrative contest costs when protection has built a defensible status quo.

Readiness sits between quasi-option value and learning by doing. In the Arrow–Fisher–Henry tradition, waiting preserves flexibility while information arrives before an irreversible decision, so the benefit comes from deferring action (Arrow & Fisher 1974, Henry 1974). Readiness introduces a different consideration: protection today can improve the agency's ability to act in a distinct later conservation conflict. The institutional stock created by protecting R makes that later intervention more likely to be feasible and, when feasible, less costly. That stock generalizes a conventional within-task productivity effect along three dimensions (Arrow 1962, Cohen & Levinthal 1990, Teece et al. 1997, Zollo & Winter 2002). Its transfer to later conflicts is limited by institutional relevance ρ_R; it acts on both the ability to intervene and the cost of intervention; and part of it resides outside the organization, in legal precedent, political constituencies, donor confidence, and public legitimacy (Pierson 1993, Campbell 2003). Embedding this action-generated, partially transferable stock of organizational and political capital in a conservation real-options problem is the paper's substantive addition: quasi-option value favors preserving the option to wait, while readiness can make early action more valuable.

Readiness therefore changes the state in which later siting and timing decisions are made. Readiness also provides a disciplined reason why some early protections have system value while others do not: readiness must be produced, relevant to future conflicts, and sufficiently persistent to outweigh the direct cost and the option value of waiting.

3 Model

3.1 Overview

A broader conservation-planning exercise has identified a candidate parcel, R, whose ecological contribution may be high. The model evaluates the value of acquiring it now and the gain from waiting. Both depend on its marginal contribution to the current portfolio and the opportunity cost of scarce conservation resources. The central timing question addressed here is how the capacity created by protection changes the case for early acquisition.

Parcel R is currently far from the development frontier. It is inexpensive to protect in both financial and political terms, but its near-horizon probability of conversion is low. The frontier is uncertain, however. As it approaches, landowners' outside options rise, developers take interest, anticipated rents capitalize into land prices and a routine acquisition can become more expensive or even precipitate a contested fight. For example, in frontier settlements of the western Brazilian Amazon, distance to market alone explains close to one-third of the variation in farm land values, consistent with a von Thünen gradient (Sills & Caviglia-Harris 2008), and structural estimates confirm that lower transport costs raise the private demand for clearing (Souza-Rodrigues 2019). A parcel that is currently cheap *because* it is remote can therefore become expensive, and contested, through anticipated access, not only through imminent loss. We represent the closure of this cheap, low-conflict window by a hazard γ_R.

Protecting R also changes the agency. It builds an institutional stock S: legal precedent, administrative experience, public legitimacy, and political goodwill. That stock is useful when a future conservation conflict C, with uncertain stakes X_t, arrives. Greater readiness makes it more likely that the agency can intervene at all and, when intervention is feasible, reduces its cost. Protecting R is therefore valuable not only for the direct conservation benefit it secures, but also for the readiness it creates for later conflicts.

The model abstracts from a full reserve-network problem and from the spatial evolution of the development frontier; we do not model adjacency, leapfrogging, or the redirection of development paths. Those channels are important, but they are not needed for the core distinction between current acquisition value and optimal timing. The baseline carries only one implication of spatial dynamics: a currently favorable acquisition window can close.

Section 5.5 then adds a developer contest to distinguish focal-site deterrence from spatial displacement and address a related concern: does protecting R prevent ecological loss, or merely move it elsewhere? Greater readiness can deter challenges to protected status before they form, creating benefits that records of observed contests miss. But a developer discouraged from challenging protection may still relocate the project, just as one defeated in a contest may do, leaving the broader net ecological impact on the landscape ambiguous. We show that when conservationists prioritize the highest ecological value sites (value-first targeting) blocked developers are prevented from relocating to a more damaging available site, and protection of the focal site always generates a non-negative landscape effect, with the magnitude of the landscape gain determined by whether development was deterred or defeated.

3.2 The candidate's contribution to the portfolio

The model evaluates one candidate conditional on the agency's existing conservation portfolio and resource constraints. Its direct benefit, $B_R(q_R)$, is the parcel's marginal contribution to that portfolio. It can reflect representation, connectivity, complementarity, and redundancy. Its effective acquisition cost, P_R, includes both direct burdens and the opportunity cost of the conservation resources it uses, with each cost counted only once.[1]

Readiness is likewise valued at the margin: experience that duplicates existing capabilities may contribute less than experience that fills an institutional gap. Throughout the focal timing problem, the surrounding portfolio and the opportunity cost of resources are held fixed. The model therefore evaluates a candidate conditional on those objects; it does not determine the globally optimal portfolio or the evolution of its resource shadow value. Appendix A collects the core notation.

3.3 Primitives and the closing window

Time is continuous, $t \in [0, \infty)$, and the agency discounts costly commitments at rate $r > 0$. The discount rate is the opportunity cost of scarce money, staff, legal effort, and political capital. It is not a claim that future biodiversity is intrinsically less valuable. Ecological quality is

[1] For example, write $P_R = d_R + \nu c_R$, where d_R is a direct burden not already represented by use of a common resource, c_R is the amount of that resource used, and ν is its marginal opportunity cost. In a continuous portfolio problem, ν is the multiplier on the resource constraint. More generally, it represents the value of displaced conservation opportunities.

fixed at $q_R \geq 0$, and, conditional on the broader portfolio, securing R yields marginal direct portfolio contribution $B_R(q_R)$ over the planner's horizon, with $B_R(0) = 0$ and $B'_R > 0$. Current remoteness implies low near-horizon conversion pressure, but it does not determine q_R.

The current effective acquisition cost is $P_R > 0$, interpreted broadly to include monetary cost, political effort, and the opportunity cost of scarce resources as summarized in Section 3.2. Direct net value is

$$D_R(q_R) = B_R(q_R) - P_R,$$

and, in the core region where direct net value is negative, the direct shortfall is

$$L_R(q_R) = P_R - B_R(q_R) > 0.$$

The cheap window closes at a random time $T_R \sim \text{Exp}(\gamma_R)$, with $\gamma_R > 0$. The assumption $\gamma_R > 0$ means that the favorable acquisition terms are not guaranteed to remain available indefinitely. The hazard may be arbitrarily small. A fragile acquisition window does not by itself give a parcel positive current surplus.

3.4 Institutional readiness and the future conflict

Institutional readiness is a stock $S_t \geq 0$. Protecting R raises readiness by $\kappa_R(q_R, \rho_R)$, where $\rho_R \geq 0$ measures how relevant the protection is to future conflicts: for example, whether it shares a jurisdiction, biome, legal regime, agency, or political coalition. We assume

$$\kappa_R(0, \rho_R) = 0, \qquad \frac{\partial \kappa_R}{\partial q_R} > 0 \text{ for } \rho_R > 0, \qquad \frac{\partial \kappa_R}{\partial \rho_R} > 0 \text{ for } q_R > 0.$$

Higher ecological quality and greater institutional relevance are assumed to increase the readiness created by protection. We represent these gains as an initial addition to the agency's capacity. This benchmark captures the institutional consequences of establishing protection without separately modelling the gradual development of public familiarity or political support after designation.

The new capacity need not retain all of its usefulness until a later conflict arises. We allow the readiness increment to depreciate at rate $\delta \geq 0$, leaving $\kappa_R(q_R, \rho_R)e^{-\delta t}$ available t periods after protection. When $\delta = 0$, the increment persists unchanged; a positive δ allows its usefulness to diminish over time. The agency's pre-existing capacity S is maintained at its current level, so depreciation applies only to the additional capacity created by protecting R.

The future conflict's stakes follow a geometric Brownian motion,

$$dX_t = \mu X_t\, dt + \sigma X_t\, dW_t, \qquad r > \mu, \quad X_0 = x > 0, \quad \sigma > 0,$$

and the conflict arrives at $T_C \sim \text{Exp}(\lambda)$, with $\lambda > 0$, independent of T_R. The stake process X_t is independent of both event times. The two hazards have different meanings: γ_R governs the closing of the current acquisition window, while λ governs the arrival of the future conflict in which readiness is useful.

In the benchmark, readiness available when conflict C arrives determines the agency's access and intervention-cost terms for that conflict. Those terms remain fixed while the agency decides when to intervene; acquiring R after conflict arrival cannot improve them.

When conflict C arrives, the agency holds a standard perpetual investment option conditional on being able to intervene: it can wait until the conservation stakes justify the intervention cost $I(S)$ (Dixit & Pindyck 1994, Chapter 5). Readiness lowers this cost, $I'(S) < 0$, and raises the probability that intervention is feasible. The standard option value $F(x; I)$ and its exercise threshold $x^*(S)$ are given in Appendix B.1.[2]

Readiness affects future value on two margins. It may make future action feasible at all, captured by an access probability $p(S) \in [0, 1]$ with $p'(S) > 0$, and conditional on feasibility it lowers intervention cost. Define

$$\mathcal{F}(x, S) = p(S) F(x; I(S)).$$

Then

$$\mathcal{F}_S = \underbrace{p'(S) F}_{\text{access margin}} + \underbrace{p(S) F_I I'(S)}_{\text{cost-reduction margin}} > 0 \tag{1}$$

in the continuation region. The two margins respond differently to uncertainty, which drives Proposition 2. The cost-reduction term is closest to conventional learning by doing: prior

[2] The baseline treats the closing window and the later conflict as independent. Appendix B.3 considers dependence; correlation alone does not determine its effect on optimal delay.

activity lowers the cost of a later intervention. The access term changes whether that later option can be exercised at all. Section 5.5 studies an analogous external-readiness mechanism at the focal parcel R, where stronger protected status can deter challenges before they form. The baseline access probability $p(S)$ for the distinct later conflict C, together with other political and constituency effects, remains represented in reduced form.

Protecting R before the conflict arrives buys the readiness option

$$K(q_R) = \mathbb{E}\Big[e^{-rT_C}\{\mathcal{F}(X_{T_C}, S + \kappa_R(q_R, \rho_R)e^{-\delta T_C}) - \mathcal{F}(X_{T_C}, S)\}\Big]\,. \tag{2}$$

For a small increment, readiness value is approximately the capacity created by protection multiplied by the marginal value of capacity in the later conflict, adjusted for depreciation before that conflict arrives. Evaluating the future option on its continuation branch gives the benchmark

$$K(q_R) \approx \kappa_R(q_R, \rho_R)\mathcal{F}_S(x, S)\frac{\lambda}{\lambda + \delta}. \tag{3}$$

The factor $\lambda/(\lambda + \delta)$ reflects the loss of the new capacity before it is used. Appendix B.1 derives this expression. It combines a small-increment approximation with a continuation-branch valuation; it is not the full readiness value when future states can trigger immediate exercise of the later intervention. The implications of that boundary remain explicit below and in Appendix D.

4 Value and timing results

The baseline is a planned-date benchmark. Before conflict C arrives, the agency knows the distribution of future stakes but cannot condition acquisition on their continuously evolving state. It chooses an acquisition date $\tau \geq 0$, contingent on the favorable window remaining open and, when readiness is needed to justify acquisition, on conflict C not having arrived. Section 4.4 allows acquisition to respond to observed stakes.

4.1 Current value and the decision to wait

Current structural surplus is direct benefit less acquisition cost plus readiness value, $\mathrm{SV}_R(q_R) = B_R(q_R) - P_R + K(q_R)$. Let q^0 denote the quality at which this surplus is zero. If B_R and K are continuous and strictly increasing from zero, and their sum eventually exceeds P_R, the threshold exists and is unique. Parcels at or above q^0 have non-negative current surplus, conditional on the existing portfolio and resource costs. Remoteness alone does not help a parcel pass this test.

Positive current surplus does not settle when to acquire. To derive the timing rule, write $h_R = \gamma_R + \lambda$ for the combined hazard that the window closes or the later conflict arrives. In the continuation benchmark, expected appreciation of readiness value exactly offsets ordinary discounting. The stationary direct shortfall retains the discount factor $e^{-r\tau}$, while readiness loses value with delay through the risk that one of the two events occurs first. Appendix B.2 gives the cancellation and the full planned-date calculation.

In the core case, direct benefit falls short of acquisition cost by $L_R(q_R) = P_R - B_R(q_R) > 0$. The agency acquires only if both events remain in the future; once conflict C has arrived, the readiness rationale for this acquisition is exhausted. Its date-zero payoff from planning to protect at τ is

$$V_-(\tau; q_R) = K(q_R)e^{-h_R\tau} - L_R(q_R)e^{-(h_R+r)\tau}. \tag{4}$$

Delaying reduces both readiness value and the present cost of the direct shortfall. The balance gives the acquisition rule.

Proposition 1 (When to protect)**.** *In the planned-date continuation benchmark, immediate protection is optimal if direct benefit covers acquisition cost. Otherwise, it is optimal among all planned dates if and only if*

$$K(q_R) \geq m[P_R - B_R(q_R)], \qquad m = 1 + \frac{r}{\gamma_R + \lambda}.$$

When $K(q_R) > 0$ and the inequality is reversed, there is a unique positive optimal delay.

Readiness must do more than cover the direct shortfall: it must also compensate for giving up the benefit of postponing that shortfall. Thus a parcel can have positive current surplus while still being worth acquiring later. The proof in Appendix B.2 shows that the payoff's derivative crosses zero at most once, making the condition global among planned dates.

Under the same monotonicity assumptions, the timing condition has at most one quality crossing. If it is satisfied at some quality, let q^* denote the unique quality at which readiness just meets the immediate-action hurdle. With positive readiness value and $m > 1$, $q^* > q^0$: between the two thresholds, current surplus is positive but immediate acquisition is not optimal. A more fragile window lowers m and brings protection forward. Higher ecological quality also reduces delay because it shrinks the direct shortfall and, under the readiness-productivity assumption, raises the readiness payoff. The first channel alone suffices when readiness value is constant in quality.

Figure 1(a) distinguishes parcels that fail the current-surplus screen, pass it but should wait, or should be protected now. The first category is an assessment of acquisition under current conditions, not a finding that all future acquisition is worthless. Indeed, when $K > 0$, the frictionless perpetual benchmark assigns a positive delayed payoff even below q^0, because the negative direct term discounts away faster. Permanent exclusion would require a broader portfolio decision or additional frictions. The model's timing result does not depend on interpreting the current-surplus screen as such an exclusion rule.

4.2 Linear benchmark and the acquisition-price path

For comparative statics, take $b, \eta, \psi, \chi, I_0 > 0$ and $\rho_R > 0$, and specialize to

$$B_R(q_R) = bq_R, \qquad \kappa_R(q_R, \rho_R) = \eta\rho_R q_R, \qquad p(S) = 1 - e^{-\psi S}, \qquad I(S) = I_0 e^{-\chi S}.$$

Under the linear readiness approximation, write $K(q_R) = kq_R$ with

$$k = \eta\rho_R \mathcal{F}_S(x, S)\frac{\lambda}{\lambda + \delta},$$

so

$$q^0 = \frac{P_R}{b + k}, \qquad q^* = \frac{mP_R}{k + mb}. \tag{5}$$

The immediate-action threshold exceeds the current-value threshold when $k > 0$ and $m > 1$. It rises with acquisition cost P_R and falls with readiness productivity k. It therefore falls with relevance ρ_R, learning productivity η, and the arrival rate of the future conflict λ; it rises with readiness depreciation δ. The current-window hazard γ_R enters through $m = 1 + r/(\gamma_R + \lambda)$: a more fragile window lowers the quality bar because waiting is a worse gamble.

The baseline holds the current acquisition cost fixed. If instead it follows a differentiable path $P_R(\tau)$ with $P_R(0) = P_R$, the first-order condition against infinitesimal delay is

$$h_R K(q_R) \geq (h_R + r)[P_R - B_R(q_R)] - P_R'(0). \tag{6}$$

Rising acquisition costs lower the readiness hurdle for acting now. This gives the price channel a direct timing role: the low-cost window may disappear before ecological conversion becomes imminent. Strict inequality in equation (6) makes immediate protection locally optimal; equality requires examining higher-order behavior. Global optimality for an arbitrary price path requires additional restrictions. Appendix B.2 gives the derivative. Effective cost can also rise because the opportunity cost of scarce conservation resources increases. Determining that shadow value's evolution remains a task for a full portfolio model.

4.3 Uncertainty and institutional capacity

The relevant question is whether uncertainty raises the marginal value of the capacity created by protection today. For a weak agency, that capacity principally improves access to future intervention. For a more capable agency, it principally reduces the cost of an intervention already accessible. Under the following conditions, these margins produce opposite timing responses.

Proposition 2 (Uncertainty and initial capacity)**.** *Consider the planned-date continuation benchmark with $B_R(q_R) = bq_R$, $\kappa_R(q_R, \rho_R) = \eta\rho_R q_R$, positive b, η, ρ_R, and the small-increment readiness valuation in equation (3). Suppose access starts at zero and increases at a diminishing rate, while intervention cost falls at a constant or increasing proportional rate:*

$$p(0) = 0, \quad p' > 0, \quad p'' \leq 0, \qquad -I'/I > 0, \quad (-I'/I)' \geq 0.$$

Fix the current stakes $x > 0$ and volatility $\sigma > 0$. Suppose $x < x^*(S)$ for $0 \leq S < S_x$ and $x = x^*(S_x)$ at some finite $S_x > 0$. There is a unique capacity threshold $S^* \in (0, S_x)$ such that *greater uncertainty lowers an interior immediate-protection quality cutoff for $S < S^*$ and raises it for $S^* < S < S_x$, holding x and S fixed.*

For an initially weak agency, uncertainty makes access to the later option more valuable and strengthens the incentive to build readiness. At higher capacity, uncertainty reduces the marginal value of lowering the intervention cost, weakening that incentive. In this planned-date benchmark, the multiplier m is independent of volatility: both effects operate through readiness value. Waiting to acquire in response to an observed state is a separate source of flexibility, introduced below.

The exponential access and cost functions used in the linear illustration satisfy these shape restrictions. Figure 1(b) shows the capacity crossing, and Appendix B.4 provides the proof. Smoothness and a small readiness increment preserve the crossing locally; the appendix states the qualifications for finite increments.

The continuation restriction is substantive. The proposition uses the homogeneous continuation value of the later intervention. In the full option, future states may instead lie on the exercise branch, altering readiness's sensitivity to uncertainty. Near that boundary, the capacity crossing can shift and need not remain unique. Appendix D gives the full expression without imposing a global sign.

4.4 Observable threats and the option to wait

If the agency observes the evolving stakes X_t and can condition acquisition on them, it can also wait for a favorable state. The optimal acquisition rule again requires readiness to cover a multiple of the direct shortfall, now $K \geq M(\sigma)L_R$. The multiplier M captures the additional value of choosing the acquisition date in response to observed stakes. Appendix C derives the stopping rule and defines M.

Proposition 3 (Acquisition in response to observed threats)**.** *In the observable-threat continuation benchmark, with $B_R(q_R) = bq_R$ and $\kappa_R(q_R, \rho_R) = \eta\rho_R q_R$, the immediate-protection quality cutoff at fixed x and S is*

$$q^*(\sigma) = \frac{M(\sigma)P_R}{k(\sigma) + M(\sigma)b}. \tag{7}$$

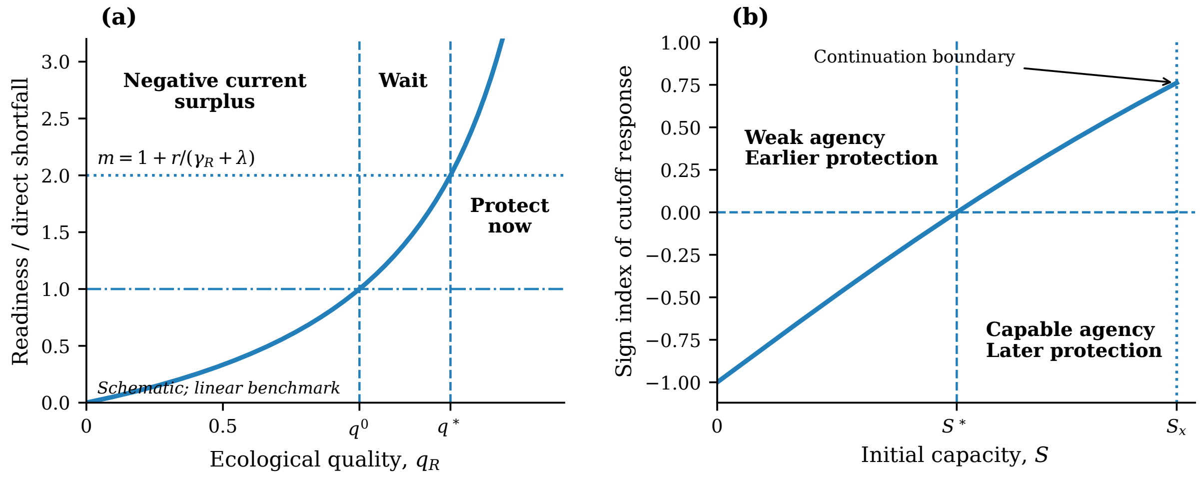

Figure 1: **Current acquisition value, timing, and uncertainty.** Panel (a) plots readiness value relative to the acquisition cost not covered by direct benefit. The lower cutoff q^0 marks zero current surplus; the higher cutoff q^* marks optimal immediate acquisition. Negative current surplus does not imply zero future option value. Panel (b): in the continuation benchmark, uncertainty lowers the immediate-action cutoff below capacity S^* and raises it above that capacity, until the continuation boundary S_x. Both panels are schematic. Appendix E.3 gives the plotted quantities.

For $k > 0$, greater uncertainty lowers this cutoff if and only if its proportional effect on readiness value exceeds its proportional effect on the waiting hurdle: $k_\sigma/k > M_\sigma/M$.

The planned-date result therefore does not determine the answer when acquisition responds to observed threats. Uncertainty changes both the marginal value of readiness and the value of waiting for a favorable state. In this model M increases with volatility when $\mu + \sigma^2/2 > 0$; the effect of volatility on M need not be positive for all drift rates. With positive drift, M tends to the planned-date multiplier m as volatility tends to zero. The continuation and small-increment qualifications remain in force.

5 Implications for additionality-based selection and evaluation

The preceding analysis characterizes conservation priority over space and time. This section draws out one implication for measuring additionality, where throughout, *outcome additionality* denotes the same type of causal object—the avoided loss caused by protection. Additionality's numerical value and interpretation depend on where the evaluation boundary is drawn: over what time horizon, across which sites and institutions, and whether losses that protection deters are counted. The subsections take these boundaries in turn, showing when a boundary too narrow to match the planner's decision makes the measure diverge from it, and when additionality is instead exactly the right object.

5.1 When short-horizon impact changes the parcel ranking

Consider a comparison based only on avoided loss, with effective protection and no cost dynamics or readiness spillovers. A sufficient condition for current-impact rankings to preserve full-horizon rankings is that every parcel's cumulative loss probability be the same positive multiple of its current loss probability. A moving frontier need not satisfy this condition.

For example, take two parcels and two periods. The near parcel has ecological value v_N and loss probability $\pi_N > 0$ in the first period, with no further loss risk in the second. The remote parcel has value v_R, no first-period risk, and loss probability $\pi_R > 0$ in the second period. A first-period evaluation credits the near parcel with avoided loss $v_N\pi_N$ and the remote parcel with zero. Over both periods, however, the remote parcel contributes more whenever $v_R\pi_R > v_N\pi_N$. The short evaluation window reverses the ranking simply by ending before the remote parcel is at risk. Cost escalation and readiness can create further differences between measured current impact and decision value.

5.2 When additionality requirements delay protection

As a development frontier approaches, near-horizon additionality may rise because counterfactual conversion becomes more likely. Acquisition costs and political conflict can rise at the same time, while the opportunity to build readiness shrinks. An impact threshold can then push protection past the planner's preferred date.

Corollary 1 (Additionality-based delay)**.** *Suppose immediate protection maximizes planner value under Proposition 1, while near-horizon additionality $A_R(\tau, H)$ rises with the planned protection date τ over an interval beginning at zero. An eligibility threshold above current additionality, $\bar{A} > A_R(0, H)$, delays or excludes an intervention the planner would undertake immediately.*

Here H is the evaluator's horizon. Low current additionality can reflect low ecological value, ineffective protection, or a horizon that ends before threat arrives. These explanations have different implications for acquisition. Treating them as equivalent can encourage intervention only after development pressure has raised its cost (Figure 2(a)).

5.3 Following readiness across dates and sites

Two protections can have the same effect on conversion at the focal parcel yet different values for the agency if one builds capabilities that are more useful in subsequent conflicts. A site-level evaluation can correctly estimate its intended causal effect without measuring this institutional spillover. Recovering the spillover requires following later interventions, their costs, their success probabilities, or the institutional capacity through which prior protection affects them. Greater precision within a narrow evaluation boundary cannot substitute for observing those outcomes. The implication is to match the evaluation to the policy objective while retaining a credible counterfactual.

5.4 When additionality defines the instrument

For an avoided-deforestation offset, additionality is part of the definition of the credited environmental service. Groom & Venmans (2023) value offsets through the climate damages they avoid, expressing that value relative to the social cost of carbon. In their avoided-deforestation model, the correction factor is zero when baseline clearing risk is zero and increases with that risk, holding the other valuation parameters fixed.[3] This is the appropriate valuation for carbon-offset equivalence. The broader decision to acquire land for conservation can nevertheless include benefits and costs outside that component.

To make the connection explicit, write the value of acquisition under current conditions as

$$J_R = V_{\mathrm{AD}}(\tilde{\phi}_R, q_R) + B_R^{\mathrm{other}}(q_R) - P_R(\tilde{\phi}_R) + K_R(q_R, \rho_R, S).$$

Here V_{AD} is the value of the avoided-deforestation benefit underlying carbon crediting, expressed in the same value units as the other terms. The term B_R^{other} includes only direct benefits not already counted in that component, P_R is the effective acquisition cost, and K_R is the readiness value created by protection. Carbon equivalence concerns the first term; a conservation organization deciding whether and when to secure the parcel may consider the full sum. This

[3] In their constant-hazard, constant-growth benchmark, with an immediate project start and as the project horizon tends to infinity, the correction factor is

$$A_{\mathrm{AD}}(\tilde{\phi}_R) = \frac{r - x_2}{r + \phi - x_2} - \frac{r - x_2}{r + \phi + \tilde{\phi}_R - x_2}.$$

Here $\tilde{\phi}_R$ is the baseline clearing hazard, ϕ is the hazard of project failure or the ending of additional storage, x_2 is the growth rate of the social cost of carbon, and $r > x_2$ is the discount rate. Thus $A_{\mathrm{AD}}(0) = 0$ and $A'_{\mathrm{AD}}(\tilde{\phi}_R) > 0$.

distinction is consistent with Groom and Venmans's recognition of costs and co-benefits beyond the climate benefit itself. Our model specifies how protection-induced readiness contributes to the broader acquisition decision.

To isolate the acquisition-price channel, hold ecological quality, the remaining offset-valuation parameters, and all readiness inputs fixed, while allowing acquisition cost to rise with baseline clearing risk, $P'_R(\tilde{\phi}_R) > 0$. The avoided-deforestation component then rises with threat, while the remaining net value, $B_R^{\text{other}} - P_R + K_R$, falls through the price channel. If the increase in acquisition cost exceeds the increase in the avoided-deforestation component, total acquisition value falls even as the carbon-crediting value rises. The two objects can therefore move in opposite directions without either being incorrectly measured.

5.5 Deterrence, observed contests, and displacement

Readiness can also help defend the focal parcel by making protected status more costly to challenge. A developer contests protection only when the expected gain exceeds the cost of the challenge. Greater conservation capacity can therefore prevent a contest from forming. This is a strategic consequence of readiness at R, distinct from the access probability $p(S)$ for intervention in the later conflict C. Appendix E supplies a simple developer-threshold model.

Contest records, a focal causal evaluation, and a landscape evaluation capture different effects. A contest record counts challenges that occur. A focal evaluation must also count loss avoided because challenges were deterred. A landscape evaluation must additionally follow the development project after R is blocked. A project can be deterred at R and then relocated; a developer defeated in a contest can also relocate.

What contest records miss. Let $c(S)$ be the probability of a contest, holding developer strength fixed, and suppose it decreases with conservation capacity. Let ξ be the probability that R would be developed without protection, $\Lambda_R > 0$ the resulting ecological loss, and $\pi_D \in (0, 1)$ the developer's probability of winning a contest. Assume $0 \leq c(S) \leq \xi$: contests come from projects that would have developed the parcel if it were unprotected. Holding ξ and π_D fixed isolates the effect of readiness on contest formation.

Only a successful developer challenge produces focal loss under protection. The essential accounting is therefore

$$
\begin{aligned}
A_R^{\text{obs}} &= (1-\pi_D)c(S)\Lambda_R, &&\text{successful defenses in observed contests,} \\
A_R^{\text{di}} &= [\xi - \pi_D c(S)]\Lambda_R, &&\text{total focal avoided loss.}
\end{aligned} \tag{8}
$$

Their difference, $[\xi - c(S)]\Lambda_R$, is loss avoided through deterrence. An observation of "no contest" cannot distinguish a parcel that was never at risk from a challenge that protection deterred. A credible comparison of outcomes with and without protection can, in principle, recover the full focal effect.

Proposition 4 (The observed-contest gap)**.** *With counterfactual development risk and conditional defense effectiveness fixed, greater readiness that reduces contest formation lowers contest-visible avoided loss while raising total focal avoided loss. Under full deterrence, the contest-visible measure is zero even though total focal avoided loss is positive whenever $\xi > 0$.*

The result follows directly from equation (8). Of the challenges that additional readiness newly deters, a fraction $1 - \pi_D$ would already have been defeated. Deterrence changes what is observed for those projects without changing whether R is saved. The remaining fraction π_D would have succeeded; deterring them newly prevents focal loss. Each newly deterred challenge therefore raises expected focal avoided loss by $\pi_D\Lambda_R$. This additional ecological gain tends to zero as defense approaches certainty, although avoiding contests can still save legal, administrative, and political resources.

From the focal parcel to the landscape. The focal accounting asks whether R is saved. A landscape evaluation must additionally follow the project after R is blocked. The developer need not go home. It may abandon, delay, downsize, redesign, or relocate after either deterrence or defeat.

Let L^C be expected subsequent landscape damage after protection defeats a contest, and L^D expected damage after a challenge is deterred. Each incorporates the probability, scale, timing, and destination of any continuation. Relative to development at the unprotected focal parcel, the landscape effect is

$$A_R^{\text{land}}(S) = \underbrace{c(S)(1-\pi_D)(\Lambda_R - L^C)}_{\text{successful contested defense}} + \underbrace{[\xi - c(S)](\Lambda_R - L^D)}_{\text{deterrence}}. \tag{9}$$

The ordering of continuation damage need not be an arbitrary favorable assumption: it can follow from the rule used to select the protected parcel. Consider a comparable-project setting in which blocked development is either abandoned or relocated to one alternative parcel. Suppose ecological value ranks the total damage that the development would cause, and conservationists select the highest-value parcel from the set that includes all of the developer's possible relocation destinations. Under this value-first rule, development at any remaining destination causes no more damage than development at R:

$$\Lambda_j \leq \Lambda_R \qquad \text{for every feasible relocation destination } j.$$

Both continuation losses are therefore bounded by the focal loss, $L^C, L^D \leq \Lambda_R$. Equation (9) then implies that protection weakly improves landscape outcomes, with non-negative contributions from both successful contested defense and deterrence. The gain is strict whenever protection prevents development with positive probability and the corresponding continuation is strictly less damaging.

Value-first targeting thus provides a reason why displacement need not erase the conservation gain. By securing the most ecologically valuable land in the relevant opportunity set, conservationists leave blocked developers with alternatives whose development would cause no more ecological damage. The sign of the landscape effect does not require knowing which of those alternatives the developer will choose, or require the same alternative to follow deterrence and defeat. The restriction concerns comparable total development losses: ranking per-hectare ecological quality alone would not suffice if relocation could substantially increase the development footprint. Nor does passing the current-value screen establish this ordering, because that screen also incorporates acquisition costs and readiness benefits.

A rule based on current threat offers no corresponding guarantee. Protecting a threatened but lower-value parcel can redirect development toward a more ecologically valuable site, producing a focal gain but a landscape loss. Threat can therefore inform the urgency of protection without determining which ecological values should be secured. The value-first benchmark connects the sign of displacement effects to the conservation targeting rule, rather than treating displacement as uniformly harmful or benign.

Whether *additional deterrence* improves the landscape is a separate comparison. If a project follows the same continuation after deterrence or defeat, $L^C = L^D = L$, newly deterring a challenge that would have been defeated does not change the ecological outcome. Newly deterring one that would have succeeded replaces damage Λ_R with L. The expected landscape gain per newly deterred challenge is therefore $\pi_D(\Lambda_R - L)$, which is positive when the continuation is less damaging (Figure 2(b)).

With different continuations, however, stronger deterrence can reduce the total landscape gain if it leads to sufficiently more damaging development than would follow a defeated challenge. Across both common and differential continuation paths, value-first conservation targeting (that ensures that R dominates the feasible relocation destinations in ecological value) guarantees protection of the focal parcel remains weakly beneficial to the landscape relative to no protection. Stronger deterrence can then reduce the size of the conservation gain without turning protection into a net landscape loss.

With different continuations, and holding π_D, L^C, and L^D fixed, additional deterrence reduces landscape value precisely when

$$L^D - L^C > \pi_D(\Lambda_R - L^C). \tag{10}$$

Under $L^C \leq \Lambda_R$, a reversal requires deterrence to produce a sufficiently more damaging continuation than successful defense. For example, contest costs or delay might otherwise cause abandonment or downsizing, whereas deterrence sends the intact project elsewhere immediately. Relocation alone does not establish this reversal. Appendix E gives the derivative and the branch accounting.

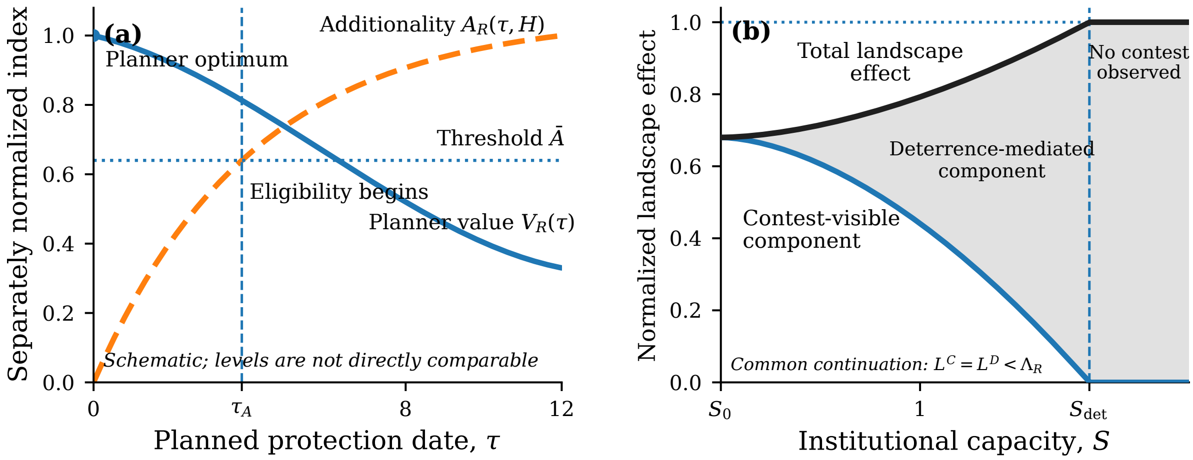

Figure 2: **Evaluation reversals.** Panel (a): immediate protection maximizes planner value, but a rising additionality score delays eligibility. The curves are separately normalized; their levels are not comparable. Panel (b): the contest-visible landscape component falls as capacity deters challenges, while total landscape benefits rise. The shaded gap is the deterrence component. Both paths assume the same, less damaging continuation after deterrence or defeat, $L^C = L^D < \Lambda_R$. Both panels are schematic; Appendix E.3 records the normalization.

Evaluation should therefore distinguish parcels never at risk from challenges deterred before they form, and track the scale, timing, and destination of projects after R is blocked. These observations are needed to separate avoided loss from relocated harm.

6 Discussion and conclusion

We consider two mechanisms that can strengthen the case for protecting ecologically valuable land before a short-horizon evaluation records much avoided loss. The first is readiness: protecting land can change the institutions and political environment that shape later conservation decisions. Legal precedent, administrative experience, donor confidence, and political support can make subsequent intervention feasible or less costly. The readiness benefit depends on the capacity protection creates, its relevance to later conflicts, and how much remains available when those conflicts arrive.

The second mechanism operates through acquisition costs, both financial and political. Development expectations can be capitalized into land prices before conversion becomes imminent, and growing development interest can make acquisition more politically difficult. A parcel may therefore remain physically intact even as the opportunity to secure it on inexpensive, low-conflict terms disappears.

Early acquisition nevertheless commits scarce resources that would otherwise remain available for longer, so the combined direct and readiness benefits may be sufficient to cover the acquisition cost without making today the best acquisition date. At a sufficiently high ecological quality threshold, the balance can favor immediate protection. At the same time, a remote parcel selected only because it is inexpensive can have insufficient current value to justify its cost, as the location-bias literature warns. A highly threatened parcel can also be a poor choice if ecological contribution is low, protection is ineffective, or the opportunity cost of acquisition is prohibitive. The relevant question is how ecological contribution, acquisition conditions, and readiness together affect the value of securing a parcel and the relative advantage of acting now.

For implementation, the distinction between a valuable acquisition opportunity and a reason to acquire immediately gives financial flexibility an important role. Rights of first refusal, options, revolving funds, bridge finance, and multiyear budgets can help organizations preserve valuable opportunities or obtain resources when favorable acquisition windows arise (Yoon & Armsworth 2022, Armsworth et al. 2025). Such instruments offer ways to avoid treating every valuable candidate as either an immediate full acquisition or an opportunity that must be abandoned.

Uncertainty adds a further consideration, because the value of additional readiness depends on the agency's initial capacity. In the planned-date continuation-value benchmark, greater uncertainty about future conservation stakes increases the marginal value of making intervention possible for an institutionally weak agency. For a sufficiently capable agency, however, additional readiness mainly reduces the cost of an intervention already within reach, and greater uncertainty can reduce the marginal value of those cost savings.

For conservation finance, our analysis highlights an analytical distinction between an impact measure and an acquisition decision. Outcome additionality remains essential for evaluating whether protection changed a specified outcome over a specified horizon, and defines the environmental service underlying avoided-deforestation credits. But a broader acquisition appraisal can include other ecological benefits, acquisition costs, and readiness for later intervention. As the comparison with Groom & Venmans (2023) illustrates, rising clearing risk can increase the avoided-deforestation component while reducing total acquisition value if, holding other benefits fixed, acquisition costs rise by more than the carbon benefit.

Our model illustrates how an additionality measure becomes an incomplete acquisition rule when the evaluation horizon ends before threat arrives, when the evaluation omits institutional benefits at other sites or dates, or when an eligibility threshold postpones protection until favorable acquisition terms have disappeared. A practical assessment would report the parcel's marginal ecological contribution, the case for acting now rather than waiting, and expected outcome additionality separately before combining those assessments under an explicit conservation objective.

The strategic extension in Section 5.5 shows how readiness can strengthen protection while making its benefits less visible in contest records. Greater readiness can make a challenge to protected status less attractive to a developer and deter the challenge before it forms. Holding underlying development pressure and the probability of defeating a challenge once it occurs fixed, stronger deterrence reduces the expected number of observed successful defenses while increasing total focal avoided loss. Fewer recorded successful defenses can therefore accompany more effective protection. Contest records alone cannot distinguish land that was never at risk from land whose protected status discouraged development before a challenge was made.

The landscape analysis further highlights the importance of conservation targeting, because developers blocked at the protected parcel may redirect their projects elsewhere. In the comparable-project setting of Section 5.5, protecting the parcel whose development would cause the greatest ecological loss among all of the developer's feasible destinations (value-first targeting) ensures that deterrence and successful defense each make non-negative contributions relative to leaving the parcel unprotected. A blocked project may relocate, but cannot move to a more damaging alternative within that opportunity set. This value-first guarantee does not require developers to respond in the same way after deterrence and after a defeated challenge. By contrast, a rule based on current threat offers no comparable guarantee, because protecting a threatened but lower-value parcel may leave a more damaging relocation opportunity open.

A separate question is whether stronger deterrence increases the landscape gain from protection. When developers follow the same alternative after being deterred or contesting and losing, deterring a challenge that would already have been defeated changes the route to protection but not the ecological outcome. Deterring a challenge that would otherwise have succeeded, however, prevents development at the focal parcel and replaces it with the alternative. Under the value-first ordering, that substitution cannot increase ecological damage, so additional deterrence is weakly beneficial.

On the other hand, if developers respond differently after deterrence and defeat— for example, avoiding a contest may allow a project to proceed elsewhere at full scale when contest costs or delay would otherwise have caused downsizing or abandonment—then the comparison is more complicated. If development following deterrence is sufficiently more damaging than development following a failed challenge, stronger deterrence reduces the landscape gain. Under the value-first ordering, protection nevertheless remains non-negative relative to no protection: additional deterrence can reduce the conservation benefit without turning protection into a net landscape loss.

This targeting implication complements Weinhold & Andersen (2026), who identify a different strategic reason for keeping conservation priorities value-led. In their sequential adversarial-procurement setting, benefit–cost targeting can defer contested high-value sites until developers remove them, while pure threat-targeting can sacrifice ecological selection quality. Here, value-first targeting secures the parcel whose development would cause the greatest ecological loss, so blocked development cannot relocate to a more damaging alternative within the specified opportunity set. The two analyses support keeping ecological value central to the ranking through distinct mechanisms: which land conservationists secure during competition, and which land remains exposed to development after protection.

Applying the framework in practice calls for evidence that distinguishes these economic mechanisms: the readiness argument concerns the capacity created by prior protection and whether that capacity makes later, institutionally related interventions feasible or less costly. The acquisition-price argument concerns changes in land prices and the financial or political costs of securing protection; and the deterrence argument concerns challenges that do not form and the subsequent scale, timing, and destination of development.

The analysis evaluates one candidate conditional on an existing portfolio and the opportunity cost of conservation resources. It does not determine the optimal portfolio, how the value of scarce resources evolves as acquisitions occur, or where displaced development will go. A broader portfolio model could examine those questions jointly. The analytical timing and uncertainty results also rely on a continuation-value benchmark for the later intervention, and the capacity-dependent uncertainty result uses a small readiness increment. Appendix D gives the full option valuation, including future states in which immediate intervention is optimal; the benchmark's uncertainty sign result is not established for that full expression.

For practitioners and conservation finance, the primary implication of readiness theory is to value a candidate not only for the biodiversity it protects and what it costs, but also for the institutional capacity that securing it builds for future conservation elsewhere. Ultimately, protection is not only a defense of land but an investment in the capacity to defend it: conservation today can preserve land and also improve the institution that will defend nature tomorrow.

Appendix

A Notation

Table 2: Core model notation

Symbol	Definition	Symbol	Definition
Portfolio and focal parcel			
R	Focal candidate parcel	C	Later conservation conflict
ν	Opportunity cost of a common conservation resource	d_R; c_R	Direct burden; use of the common resource
$B_R(q_R)$	Shorthand for marginal direct portfolio contribution	P_R	Shorthand for current effective acquisition cost
$D_R(q_R)$	Direct net value, $B_R(q_R) - P_R$	$L_R(q_R)$	Direct shortfall, $P_R - B_R(q_R)$
SV_R	Marginal structural value	$K_R(q_R)$	Readiness option value created by protecting R
Readiness, timing, and future intervention			
S_t; S	Readiness stock; current readiness	$\kappa_R(q_R, \rho_R)$	Readiness increment created by protecting R
ρ_R	Relevance of experience at R to later conflicts	δ	Readiness depreciation rate
T_R; γ_R	Window-closing time; its hazard	T_C; λ	Conflict-arrival time; its hazard
h_R	Combined survival hazard, $\gamma_R + \lambda$	r	Discount rate / opportunity cost of commitments
X_t; x	Future-conflict stake process; current state	μ; σ	Drift and volatility of X_t
$I(S)$	Cost of future intervention	$p(S)$	Probability that future intervention is feasible
$F(x; I)$	Standard intervention option value	$\mathcal{F}(x, S)$	Access-adjusted option value
$\Omega(x, S)$	Marginal value of a readiness increment	β	Positive characteristic root for F
τ; τ^*	Planned acquisition date; optimal delay	q^0; q^*	Structural-value and immediate-action cutoffs
m	Planned-date timing multiplier	$M(\sigma)$	Observable-threat timing multiplier
$x^*(S)$	Future-intervention exercise threshold	S^*	Capacity threshold in the uncertainty result
k	Readiness-value coefficient in the linear benchmark	$U_t = X_t^{\beta}$; σ_U	Transformed state and its volatility, $\sigma_U = \beta\sigma$
b; η	Direct-value slope; readiness productivity	ψ	Sensitivity of access to readiness
I_0; χ	Baseline intervention cost; benchmark proportional cost-reduction rate	$\chi_I(S)$	General proportional cost-reduction rate, $-I'(S)/I(S)$
$c(q_R)$	Coefficient on X_t^{β} in the observable-threat readiness payoff	α	Positive stopping root for the observable-threat problem
W_t	Standard Brownian motion		

Notes: The table records the core model notation. Evaluation-specific quantities in Section 5—including additionality A_R, the evaluation horizon H, and the deterrence variables n, θ, π_D, ξ, Λ_R, L^C, and L^D—are defined where introduced. Arguments held fixed are suppressed for readability: $K_R(q_R)$ conditions on the current state and relevance parameters, and the existing portfolio and resource opportunity cost are held fixed as described in Section 3.2.

B Supporting model derivations

B.1 The future intervention option and readiness value

Conditional on access, the future intervention yields payoff $x - I$ upon exercise. For $r > \mu$ and $\sigma > 0$, the standard perpetual investment option (Dixit & Pindyck 1994, Chapter 5) has continuation value

$$F(x; I) = \mathfrak{a}(\beta) I^{1-\beta} x^{\beta}, \qquad \mathfrak{a}(\beta) = \frac{(\beta - 1)^{\beta-1}}{\beta^{\beta}},$$

where $\beta > 1$ is the positive root of

$$\frac{1}{2}\sigma^2 \beta(\beta - 1) + \mu\beta - r = 0.$$

Its exercise threshold is $x^*(S) = \beta I(S)/(\beta - 1)$. With access probability $p(S)$, $\mathcal{F} = pF$. Differentiating in capacity gives equation (1).

For a small readiness increment, Taylor expansion of equation (2) yields

$$K(q_R) = \kappa_R(q_R, \rho_R)\Omega(x, S) + O(\kappa_R^2), \quad \Omega(x, S) = \mathbb{E}_x[e^{-(r+\delta)T_C} \mathcal{F}_S(X_{T_C}, S)].$$

The continuation formula has $\mathcal{F}_S \propto x^{\beta}$, while the root equation implies $\mathbb{E}_x[X_t^{\beta}] = x^{\beta} e^{rt}$. Evaluating that homogeneous formula over all future states gives

$$\Omega^{\text{cont}}(x, S) = \mathcal{F}_S(x, S) \frac{\lambda}{\lambda + \delta},$$

and hence equation (3). This expectation is exact within the maintained continuation-value benchmark. Starting below the exercise threshold is not sufficient for it to equal the full-option expectation, because future states can cross the threshold before conflict arrival. Appendix D includes those states. The approximation in the readiness increment is a separate restriction.

B.2 Proof of Proposition 1 and optimal planned delay

Write the continuation readiness value as $K_R(x, q_R) = \overline{K}_R(q_R, S)x^{\beta}$. The eigenfunction identity implies

$$e^{-r\tau}\mathbb{E}_x[K_R(X_\tau, q_R)] = K_R(x, q_R).$$

If $D_R = B_R - P_R \geq 0$, acquisition remains worthwhile for direct value even after conflict C arrives. The planned-date payoff is

$$V_+(\tau; q_R) = e^{-(r+\gamma_R)\tau} D_R + e^{-h_R \tau} K.$$

It is non-increasing, so immediate protection is optimal. If $D_R < 0$, contingent acquisition requires both clocks to survive, giving equation (4). Its derivative is

$$V_-'(\tau) = e^{-h_R \tau}[-h_R K + (h_R + r) L_R e^{-r\tau}].$$

The bracket is strictly decreasing. If non-positive at zero, it stays non-positive and immediate acquisition is globally optimal among planned dates. Otherwise, for $K > 0$, it crosses zero exactly once, giving

$$\tau^* = \frac{1}{r} \log \left(\frac{(h_R + r) L_R}{h_R K} \right) > 0.$$

This proves Proposition 1. If $K = 0$ and $L_R > 0$, all finite acquisition payoffs are negative and non-acquisition yields zero.

Under the main-text monotonicity assumptions, $K + mB_R - mP_R$ is continuous, strictly increasing, and negative at zero. If it reaches zero, the quality crossing is unique. At q^0, where $K = L_R > 0$, the timing expression is $(1 - m)L_R < 0$, so $q^* > q^0$. In an interior delay region,

$$\frac{\partial \tau^*}{\partial q_R} = \frac{1}{r} \left(\frac{L_R'}{L_R} - \frac{K'}{K} \right) < 0,$$

because $L_R' = -B_R' < 0$ and $K' \geq 0$.

For a differentiable acquisition-price path, the negative-direct-value payoff is

$$V_-(\tau) = e^{-h_R \tau} \{ K - e^{-r\tau} [P_R(\tau) - B_R] \}.$$

Its derivative at zero is $-h_R K + (h_R + r)(P_R - B_R) - P_R'(0)$, giving the first-order condition (6). No general global result follows without restrictions on the rest of the price path.

B.3 Dependence between the two event times

Independence is most natural when C is a distinct later conflict to which experience at R transfers. To isolate the survival effect of dependence, suppose the planned-date payoff retains the form $\overline{F}_{RC}(\tau)[K - L_R e^{-r\tau}]$, where $\overline{F}_{RC}(\tau) = \mathbb{P}(T_R > \tau, T_C > \tau)$ and the conditional readiness valuation retains the benchmark coefficient K. Define

$$\ell_0 = \lim_{t \downarrow 0} \frac{\mathbb{P}(T_R \leq t, T_C \leq t)}{t}, \qquad h_{RC}(0) = \gamma_R + \lambda - \ell_0.$$

The first-order condition against infinitesimal delay is $h_{RC}(0)K \geq [h_{RC}(0) + r]L_R$. Strict inequality makes immediate protection locally optimal; equality requires examining higher-order behavior. If joint arrival is negligible to first order, $\ell_0 = 0$, this condition is unchanged. Common shocks can give $\ell_0 > 0$ and lower the initial joint-exit hazard; the shape of joint survival also affects the interior optimum. Dependence can additionally change the conditional distribution of time remaining until conflict, making the readiness coefficient depend on the planned acquisition date. In that case, both the coefficient and its date derivative must be accounted for. Correlation alone therefore gives no generic sign for optimal delay.

B.4 Proof of Proposition 2

In the linear readiness benchmark, $k = \eta\rho_R\Omega^{\text{cont}}$ and the timing multiplier is independent of σ. Differentiating equation (5) gives

$$\operatorname{sign}(\partial q^*/\partial\sigma) = -\operatorname{sign}(\mathcal{F}_{S\sigma}). \tag{11}$$

Let $\chi_I(S) = -I'(S)/I(S) > 0$ and define

$$\mathcal{D}(S) = p'(S) + p(S)(\beta - 1)\chi_I(S), \tag{12}$$

$$\Xi(S) = \log\left(\frac{x}{x^*(S)}\right) + \frac{p(S)\chi_I(S)}{\mathcal{D}(S)}. \tag{13}$$

Since $\mathcal{F}_S = F\mathcal{D}$ and $\partial_\beta \log F = \log(x/x^*(S))$, differentiation gives

$$\mathcal{F}_{S\sigma} = F\beta_\sigma\mathcal{D}\Xi. \tag{14}$$

The positive option root has $\beta_\sigma < 0$. At fixed x and σ,

$$\Xi'(S) = \chi_I(S) + \frac{\chi_I(S)\{[p'(S)]^2 - p(S)p''(S)\} + p(S)p'(S)\chi_I'(S)}{\mathcal{D}(S)^2} > 0. \tag{15}$$

Here the strict inequality follows from $\chi_I > 0$, increasing concave access, and non-decreasing proportional cost reduction. At zero capacity, $p(0) = 0$ implies $\Xi(0) = \log(x/x^*(0)) < 0$. As $S \uparrow S_x$, the logarithm tends to zero while the second term is positive. Thus Ξ crosses zero once at $S^* \in (0, S_x)$. Equation (14) makes $\mathcal{F}_{S\sigma}$ positive below that crossing and negative above it, proving the proposition through equation (11).

B.5 Small finite readiness increments

This local robustness statement stays within the same homogeneous continuation-value benchmark. Let $\varepsilon > 0$ be the capacity increment, and let $K(\varepsilon; x, S, \sigma)$ denote its discounted value at conflict arrival. If the continuation valuation is three times continuously differentiable in (S, σ) locally, and differentiation can pass through expectation, Taylor expansion gives, uniformly on compact sets,

$$K = \varepsilon\Omega^{\text{cont}} + O(\varepsilon^2), \qquad K_\sigma = \varepsilon\Omega^{\text{cont}}_\sigma + O(\varepsilon^2).$$

Away from S^*, the linear-benchmark sign persists for sufficiently small increments. At the crossing, equations (14)–(15) give $\Omega^{\text{cont}}_{S\sigma} \neq 0$. The implicit-function theorem applied to K_σ/ε, continuously extended to $\varepsilon = 0$, yields a nearby threshold $S^*(\varepsilon) = S^* + O(\varepsilon)$. This is a local result; it does not establish a unique crossing for large increments or for the full option.

C Proofs for the observable-threat result

Lemma C.1 (Observable-threat stopping problem)**.** *Let $h_R = \gamma_R + \lambda > 0$. Suppose that, on the continuation branch of the future intervention option, protecting parcel R at state X_τ creates readiness payoff $K(X_\tau, q_R) = c(q_R)X_\tau^\beta$ with $c(q_R) > 0$. In the region $L_R(q_R) = P_R - B_R(q_R) > 0$, the observable-threat timing problem is*

$$V(u) = \sup_{\tau \geq 0} \mathbb{E}_u\left[e^{-(r+h_R)\tau}(c(q_R)U_\tau - L_R(q_R))\right], \qquad U_t = X_t^\beta.$$

Then $dU_t = rU_t\,dt + \sigma_U U_t\,dW_t$ with $\sigma_U = \beta\sigma$. Let $\alpha > 1$ be the positive root of $\frac{1}{2}\sigma_U^2\alpha(\alpha-1) + r\alpha - (r+h_R) = 0$. The optimal rule is the threshold $c(q_R)U_t \geq M(\sigma)L_R(q_R)$, $M(\sigma) = \alpha/(\alpha-1)$.

Proof. Ito's lemma gives $dU_t/U_t = [\beta\mu + \frac{1}{2}\beta(\beta-1)\sigma^2]dt + \beta\sigma dW_t$. Because β solves $\frac{1}{2}\sigma^2\beta(\beta-1) + \mu\beta - r = 0$, the drift is r. The continuation value solves $(r+h_R)V = ruV_u + \frac{1}{2}\sigma_U^2u^2V_{uu}$. A power solution $V = C_U u^\alpha$ requires $\frac{1}{2}\sigma_U^2\alpha(\alpha-1) + r\alpha - (r+h_R) = 0$, with a unique positive root $\alpha > 1$. Value matching and smooth pasting at u^* give $C_U u^{*\alpha} = c(q_R)u^* - L_R(q_R)$ and $\alpha C_U u^{*\alpha-1} = c(q_R)$, hence $u^* = \alpha L_R(q_R)/[(\alpha-1)c(q_R)]$. □

Lemma C.2 (Properties of the observable-threat multiplier)**.** *With $M(\sigma) = \alpha/(\alpha-1)$ and $\alpha > 1$ solving $\frac{1}{2}\sigma_U^2\alpha(\alpha-1) + r\alpha - (r+h_R) = 0$, $\sigma_U = \beta(\sigma)\sigma$, one has $M_{\sigma_U} > 0$ and $\operatorname{sign}(M_\sigma) = \operatorname{sign}(\mu + \sigma^2/2)$. If $\mu > 0$, then $\lim_{\sigma\downarrow 0} M(\sigma) = 1 + r/h_R$.*

Proof. Write $Q(\alpha, \sigma_U) = \frac{1}{2}\sigma_U^2\alpha(\alpha-1) + r\alpha - (r+h_R)$. Implicit differentiation gives $\alpha_{\sigma_U} = -\sigma_U\alpha(\alpha-1)/[\sigma_U^2(\alpha-\frac{1}{2}) + r] < 0$, and $M_\alpha = -1/(\alpha-1)^2 < 0$, so $M_{\sigma_U} > 0$. With $\sigma_U = \beta\sigma$, differentiating the defining equation for β gives $\operatorname{sign}((\sigma_U)_\sigma) = \operatorname{sign}(\mu + \sigma^2/2)$. The limit follows from $\sigma_U \to 0$ when $\mu > 0$, which yields $\alpha = 1 + h_R/r$. □

Lemma C.3 (Continuation-branch readiness payoff)**.** *On the continuation branch, $F(x; I(S)) = \mathfrak{a}(\beta)I(S)^{1-\beta}x^\beta$, and with $\mathcal{F}(x, S) = p(S)F(x; I(S))$ we have $\mathcal{F}_S(x, S) = \Gamma(S, \sigma)x^\beta$. The linear approximation to readiness value, evaluated within the homogeneous continuation benchmark, is*

$$K(x, q_R) = \kappa_R(q_R, \rho_R)\mathcal{F}_S(x, S; \sigma)\frac{\lambda}{\lambda+\delta}.$$

Under $\kappa_R(q_R, \rho_R) = \eta\rho_R q_R$, $K(x, q_R) = k(\sigma)q_R$.

Proof. Differentiating $\mathcal{F} = p(S)\mathfrak{a}(\beta)I(S)^{1-\beta}x^\beta$ in S gives $\mathcal{F}_S = \Gamma(S, \sigma)x^\beta$. Since $T_C \sim \operatorname{Exp}(\lambda)$ and $\mathbb{E}_x[X_t^\beta] = x^\beta e^{rt}$, evaluating the homogeneous continuation formula throughout the expectation gives $\mathbb{E}[e^{-(r+\delta)T_C}\mathcal{F}_S(X_{T_C}, S)] = \mathcal{F}_S(x, S)\lambda/(\lambda+\delta)$. □

Lemma C.4 (Readiness elasticity)**.** *Under $p(S) = 1 - e^{-\psi S}$ and $I(S) = I_0e^{-\chi S}$, the continuation-branch readiness elasticity is*

$$\frac{k_\sigma}{k} = \frac{\mathcal{F}_{S\sigma}}{\mathcal{F}_S} = \beta_\sigma\left[\log\!\left(\frac{x}{x^*(S)}\right) + \frac{p(S)\chi}{p'(S) + p(S)\chi(\beta-1)}\right].$$

Proof. Since $I'(S) = -\chi I(S)$ and $F_I = (1-\beta)F/I$, $\mathcal{F}_S = F[p' + p\chi(\beta - 1)]$. Use $\partial_\beta \log F = \log(x/x^*(S))$ and differentiate $p' + p\chi(\beta - 1)$ with respect to σ. $\square$

Proof of Proposition 3. Lemmas C.1 and C.3 give $kq_R \geq M(P_R - bq_R)$, and hence equation (7). For $k > 0$, differentiation at fixed x and S yields

$$\frac{\partial q^*}{\partial \sigma} = \frac{P_R M k}{(k + Mb)^2}\left(\frac{M_\sigma}{M} - \frac{k_\sigma}{k}\right),$$

which establishes the stated comparison.

D The full option and the continuation benchmark

The continuation-branch benchmark evaluates the future intervention option on the branch $F(x; I) = \mathfrak{a}(\beta) I^{1-\beta} x^\beta$. The full stopped call is

$$F(x; I) = \begin{cases} \mathfrak{a}(\beta) I^{1-\beta} x^\beta, & x < x^*(I), \\ x - I, & x \geq x^*(I), \end{cases} \qquad x^*(I) = \frac{\beta}{\beta - 1} I.$$

The full readiness coefficient is

$$\Omega^{\text{full}}(x, S) = \int_0^\infty \lambda e^{-(\lambda + r + \delta)t}\, \mathbb{E}_x[\mathcal{F}_S(X_t, S)]\, dt.$$

For $z = x^*(I(S))$, value matching and smooth pasting make $\mathcal{F}_S$ continuous at z, so splitting the expectation at z does not generate a moving-boundary term. The correction can be evaluated using truncated-lognormal moments. Its volatility derivative is nevertheless parameter-dependent near the exercise boundary. Accordingly, Proposition 2 is stated for the continuation-branch benchmark, and the paper does not claim a global stopped-call sign result. For applications in which the future intervention is already close to exercise, the full expression for Ω^{full} must be evaluated directly.

E Strategic extension and figure notes

E.1 A developer threshold for contest formation

A development opportunity arrives with incremental private prize $Z \sim G$, where Z is the gain from securing R relative to the continuation available if R is blocked, G is the cumulative distribution function, and g its density. The developer contests protected status iff $Z \geq J(S,\theta)$, where S is conservation capacity and θ is developer strength. In the benchmark below, the conditional probability that the developer prevails, $\pi_D \in (0,1)$, is held fixed, and

$$J(S,\theta) = \frac{c_D(S,\theta)}{\pi_D},$$

because contesting yields incremental expected payoff $\pi_D Z - c_D(S,\theta)$. The analysis requires only that the hurdle rise with conservation capacity and fall with developer strength,

$$\frac{\partial J}{\partial S} > 0, \qquad \frac{\partial J}{\partial \theta} < 0.$$

More general differences in the developer's private continuation after deterrence and defeat can be absorbed into the reduced-form hurdle $J(S,\theta)$.

The probability that no contest forms is

$$n(S,\theta) = \mathbb{P}[Z < J(S,\theta)] = G(J(S,\theta)).$$

On the interior of the support,

$$\frac{\partial n}{\partial S} = g(J)\frac{\partial J}{\partial S} > 0, \qquad \frac{\partial n}{\partial \theta} = g(J)\frac{\partial J}{\partial \theta} < 0.$$

Greater conservation capacity therefore reduces contest formation, whereas greater developer strength increases it.

If private prizes are bounded, $Z \leq \overline{Z}$, there can be a literal capacity threshold above which contestation occurs with probability zero. For the benchmark hurdle $J(S,\theta) = J_0 e^{\alpha_D S}/\theta$, with $J_0, \alpha_D > 0$,

$$S_{\text{det}}(\theta) = \max\left\{0, \alpha_D^{-1}\log(\theta\overline{Z}/J_0)\right\}.$$

For $S \geq S_{\text{det}}(\theta)$, no contest occurs almost surely under a continuous prize distribution. This is focal-site deterrence: it does not yet establish whether the project is abandoned, delayed, redesigned, or moved elsewhere.

The main text suppresses developer strength, writing $c(S) = 1 - n(S, \theta)$ at fixed θ. For its causal accounting, $\pi_D = 1 - s$ is held fixed, where s is conditional defense effectiveness, and contests are restricted to projects that would have developed R without protection: $c(S) \leq \xi$. At the perfect-defense boundary $\pi_D = 0$, positive contest costs make the hurdle infinite, so this rational-contest model predicts no challenges. The ecological marginal effect of deterring further contests then vanishes; saved contest resources lie outside this accounting.

E.2 Focal and landscape accounting

The four mutually exclusive branches under protection have probabilities $c(1 - \pi_D)$ (successful defense), $c\pi_D$ (successful developer challenge), $\xi - c$ (deterred development), and $1 - \xi$ (no counterfactual development). Only the second produces focal damage. This gives equation (8) and Proposition 4. For completeness,

$$\frac{\partial A_R^{\text{obs}}}{\partial S} = (1 - \pi_D)c'(S)\Lambda_R \leq 0, \qquad \frac{\partial A_R^{\text{di}}}{\partial S} = -\pi_D c'(S)\Lambda_R \geq 0.$$

Landscape damage under protection is $c\pi_D\Lambda_R + c(1 - \pi_D)L^C + (\xi - c)L^D$. Subtracting from the unprotected counterfactual $\xi\Lambda_R$ gives equation (9). Writing $n = 1 - c$, and holding the conditional win probability and continuation damages fixed,

$$\frac{\partial A_R^{\text{land}}}{\partial n} = \pi_D(\Lambda_R - L^C) - (L^D - L^C).$$

This proves the reversal condition (10). With common continuation $L^C = L^D = L$, the derivative is $\pi_D(\Lambda_R - L)$.

E.3 Figure definitions and normalization

Figure 1(a) plots $K/(P_R - B_R)$ in the region where direct benefit falls short of acquisition cost. The current-surplus threshold is at a ratio of one and the immediate-action threshold at m. Panel (b) plots the sign index $\Xi(S)$ from equation (13); its sign is that of $\partial q^*/\partial\sigma$. The parameters illustrate the geometry rather than estimate magnitudes.

Figure 2(a) separately normalizes planner value and near-horizon additionality; only their timing patterns are compared. Panel (b) assumes $L^C = L^D = L < \Lambda_R$ and normalizes by $\xi(\Lambda_R - L)$. The contest-visible component is $c(S)(1-\pi_D)(\Lambda_R - L)$, total landscape benefit is $[\xi - \pi_D c(S)](\Lambda_R - L)$, and their difference is the deterrence component $[\xi - c(S)](\Lambda_R - L)$. The schematic sets $c(S_0) = \xi$, so all at-risk projects contest at the baseline; capacity reduces this probability to zero at S_{det}. These are illustrative paths, not calibrated estimates.

F AI-use disclosure

Generative AI tools were used during manuscript preparation. OpenAI's ChatGPT Pro contributed to mathematical modeling, formal proof development, and structural editing; OpenAI's Codex assisted with manuscript revision and typesetting; Anthropic's Claude Opus contributed to proof checking and structural editing. The authors take sole responsibility for all claims, all errors, and all editorial decisions made in the paper.

References

Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A. & Robalino, J. A. (2008), 'Measuring the effectiveness of protected area networks in reducing deforestation', *Proceedings of the National Academy of Sciences* **105**(42), 16089–16094.

Armsworth, P. R. (2018), 'Time discounting and the decision to protect areas that are near and threatened or remote and cheap to acquire', *Conservation Biology* **32**(5), 1063–1073.

Armsworth, P. R., Hyman, A. A., Fovargue, R. E., Iacona, G. D., Sims, C. B. & Yoon, H. S. (2025), 'Strategically timing land protection decisions to enhance biodiversity benefits', *Conservation Biology* .

Arrow, K. J. (1962), 'The economic implications of learning by doing', *The Review of Economic Studies* **29**(3).

Arrow, K. J. & Fisher, A. C. (1974), 'Environmental preservation, uncertainty, and irreversibility', *The Quarterly Journal of Economics* **88**(2), 312–319.

Barr, S. L. & Lemieux, C. J. (2021), 'Assessing organizational readiness to adapt to climate change in a regional protected areas context: lessons learned from Canada', *Mitigation and Adaptation Strategies for Global Change* **26**(3), 34.

Bonilla-Mejía, L. & Higuera-Mendieta, I. (2019), 'Protected areas under weak institutions: Evidence from Colombia', *World Development* **122**, 585–596.

Börner, J., Schulz, D., Wunder, S. & Pfaff, A. (2020), 'The effectiveness of forest conservation policies and programs', *Annual Review of Resource Economics* **12**, 45–64.

Campbell, A. L. (2003), *How Policies Make Citizens: Senior Political Activism and the American Welfare State*, Princeton University Press, Princeton, NJ.

Cohen, W. M. & Levinthal, D. A. (1990), 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly* **35**(1).

Costello, C. & Polasky, S. (2004), 'Dynamic reserve site selection', *Resource and Energy Economics* **26**(2), 157–174.

Cyert, R. M. & March, J. G. (1963), *A Behavioral Theory of the Firm*, Prentice-Hall, Englewood Cliffs, NJ.

Dixit, A. K. & Pindyck, R. S. (1994), *Investment Under Uncertainty*, Princeton University Press, Princeton, NJ.

Groom, B. & Venmans, F. (2023), 'The social value of offsets', *Nature* **619**(7971), 768–773.

Henry, C. (1974), 'Investment decisions under uncertainty: The "Irreversibility Effect"', *The American Economic Review* **64**(6), 1006–1012.

Joppa, L. N. & Pfaff, A. (2009), 'High and far: Biases in the location of protected areas', *PLOS ONE* **4**(12), e8273.

Krutilla, J. V. (1967), 'Conservation reconsidered', *The American Economic Review* **57**(4).

Levitt, B. & March, J. G. (1988), 'Organizational learning', *Annual Review of Sociology* **14**.

Margules, C. R. & Pressey, R. L. (2000), 'Systematic conservation planning', *Nature* **405**(6783), 243–253.

McDonald-Madden, E., Bode, M., Game, E. T., Grantham, H. & Possingham, H. P. (2008), 'The need for speed: Informed land acquisitions for conservation in a dynamic property market', *Ecology Letters* **11**(11), 1169–1177.

Meir, E., Andelman, S. & Possingham, H. P. (2004), 'Does conservation planning matter in a dynamic and uncertain world?', *Ecology Letters* **7**(8), 615–622.

Nelson, R. R. & Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University Press, Cambridge, MA.

Pfaff, A., Robalino, J., Andam, K. S., Sanchez-Azofeifa, G. A. & Ferraro, P. J. (2009), 'Park location affects forest protection: Land characteristics cause differences in park impacts across Costa Rica', *The B.E. Journal of Economic Analysis & Policy* **9**(2), Article 5.

Pierson, P. (1993), 'When effect becomes cause: Policy feedback and political change', *World Politics* **45**(4).

Pierson, P. (1994), *Dismantling the Welfare State? Reagan, Thatcher, and the Politics of Retrenchment*, Cambridge University Press, Cambridge, UK.

Pindyck, R. S. (2000), 'Irreversibilities and the timing of environmental policy', *Resource and Energy Economics* **22**(3), 233–259.

Powlen, K. A., Gavin, M. C. & Jones, K. W. (2021), 'Management effectiveness positively influences forest conservation outcomes in protected areas', *Biological Conservation* **260**, 109192.

Sills, E. O. & Caviglia-Harris, J. L. (2008), 'Evolution of the Amazonian frontier: Land values in Rondônia, Brazil', *Land Use Policy* .

Sims, C. & Finnoff, D. (2016), ‘Opposing irreversibilities and tipping point uncertainty’, *Journal of the Association of Environmental and Resource Economists* **3**(4), 985–1022.

Souza-Rodrigues, E. (2019), ‘Deforestation in the Amazon: A unified framework for estimation and policy analysis’, *The Review of Economic Studies* **86**(6), 2713–2744.

Spring, D., Cacho, O., MacNally, R. & Sabbadin, R. (2007), ‘Pre-emptive conservation versus “fire-fighting”: A decision theoretic approach’, *Biological Conservation* **136**(4), 531–540.

Strange, N., Thorsen, B. J. & Bladt, J. (2006), ‘Optimal reserve selection in a dynamic world’, *Biological Conservation* **131**(1), 33–41.

Teece, D. J., Pisano, G. & Shuen, A. (1997), ‘Dynamic capabilities and strategic management’, *Strategic Management Journal* **18**(7).

Weinhold, D. & Andersen, L. E. (2026), Adversarial procurement in two-value space: Cost-effectiveness and the knapsack reversal. SSRN working paper 6705959.

Weisbrod, B. A. (1964), ‘Collective-consumption services of individual-consumption goods’, *The Quarterly Journal of Economics* **78**(3).

Williams, D. R. & Vaske, J. J. (2003), ‘The measurement of place attachment: Validity and generalizability of a psychometric approach’, *Forest Science* **49**(6).

Wollstein, K., Johnson, D. & Boyd, C. (2024), ‘Assessing conservation readiness: The where, who, and how of strategic conservation in the sagebrush biome’, *Rangeland Ecology & Management* **97**, 187–199.

Yoon, H. S. & Armsworth, P. R. (2022), ‘Timing land protection to exploit favorable market conditions’, *Biological Conservation* **270**, 109566.

Zollo, M. & Winter, S. G. (2002), ‘Deliberate learning and the evolution of dynamic capabilities’, *Organization Science* **13**(3).