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Investing in Natural Capital: Lessons from the American West

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Executive Summary

Innovative approaches to conservation finance are gaining momentum as a means to protect and invest in natural capital—the stock of natural assets that provide essential services and form the ecological infrastructure underpinning both human wellbeing and economic resilience. Despite the immense value of natural capital, it is often undervalued, underprioritized, and inadequately invested in within mainstream economic and policy decision-making. This disconnect has prompted interest in developing more holistic and targeted investment models to sustain or enhance natural capital.

Natural capital investments represent promising but contextual solutions that work best when thoughtfully aligned with local conditions and designed as integrated socio-ecological initiatives rather than purely financial mechanisms.

In this report we present a comparative analysis of four natural capital investment initiatives in the American West, examining their financing structures, governance models, and ecological and economic outcomes. Through interviews with key stakeholders and analysis of project documents, annual reports, feasibility studies, and media coverage, we investigated what makes these investments viable or vulnerable, successful or stalled.

The four cases include: Blue Forest's Yuba I Forest Resilience Bond, which launched a blended capital to fund to accelerate forest restoration and reducing wildfire risk; the May Ranch conservation easement and carbon credit project, which integrated permanent land protection with carbon market participation; Quantified Ventures' Environmental Impact Fund for wildfire mitigation, an ambitious but ultimately unlaunched pay-for-success model; and the Teton Basin Water Users Association's incidental aquifer recharge initiative, which has sustained voluntary participation despite the envisioned water market having not yet materialized.

The findings reveal five key insights. First, the strategic deployment of different types of capital is crucial. Successful initiatives blended philanthropic, public, and private capital to balance risk, attract partners, and sustain long-term efforts. Second, "sufficient science"— credible, actionable ecological data that supports decision-making despite uncertainty — was critical for building trust and justifying investment. Third, social capital emerged as foundational; strong networks of trust and collaboration often enabled collective action even in the absence of robust financial incentives. Fourth, scale mattered. Projects that designed interventions to cross ecological and economic thresholds, such as landscape-level forest treatments, were more likely to generate measurable benefits and justify continued investment. Finally, structural limitations persist. Many projects rely on philanthropic or public funding, and success often depends on unique legal, ecological, or institutional conditions that limit replicability across geographies and contexts.

These findings suggest that natural capital investments represent promising but contextual solutions that work best when thoughtfully aligned with local conditions and designed as integrated socio-ecological initiatives rather than purely financial mechanisms. While they cannot entirely overcome the fundamental challenge that many ecosystem services remain economic externalities, they offer valuable pathways to channel more resources toward conservation and restoration when enabling conditions exist.

Introduction

VALUE OF NATURE

Societies have recognized the intrinsic worth of natural systems for millennia—valuing them for their inherent right to exist independent of human utility, for their spiritual significance, and for their recreational and cultural importance. In recent decades, a more comprehensive understanding has emerged that increasingly acknowledges nature's substantial economic and financial value. Ecosystems, once viewed primarily through the lens of resource extraction, are now recognized for their multidimensional contributions that underpin human prosperity and security. This economic value derives from the natural capital contained within healthy ecosystems—the stock of renewable and non-renewable natural resources that yield flows of benefits to people over time (Figure 1).[1] Forests, wetlands, rivers, and grasslands represent natural capital assets whose structure and function generate the flows of services upon which societies and economies fundamentally depend. These ecosystem services include the provision of clean water, food, and timber and regulating functions like carbon sequestration and flood control. When functioning optimally, this natural capital effectively serves as fundamental infrastructure that sustains life and economic activity, delivering trillions of dollars in economic value annually.[2]

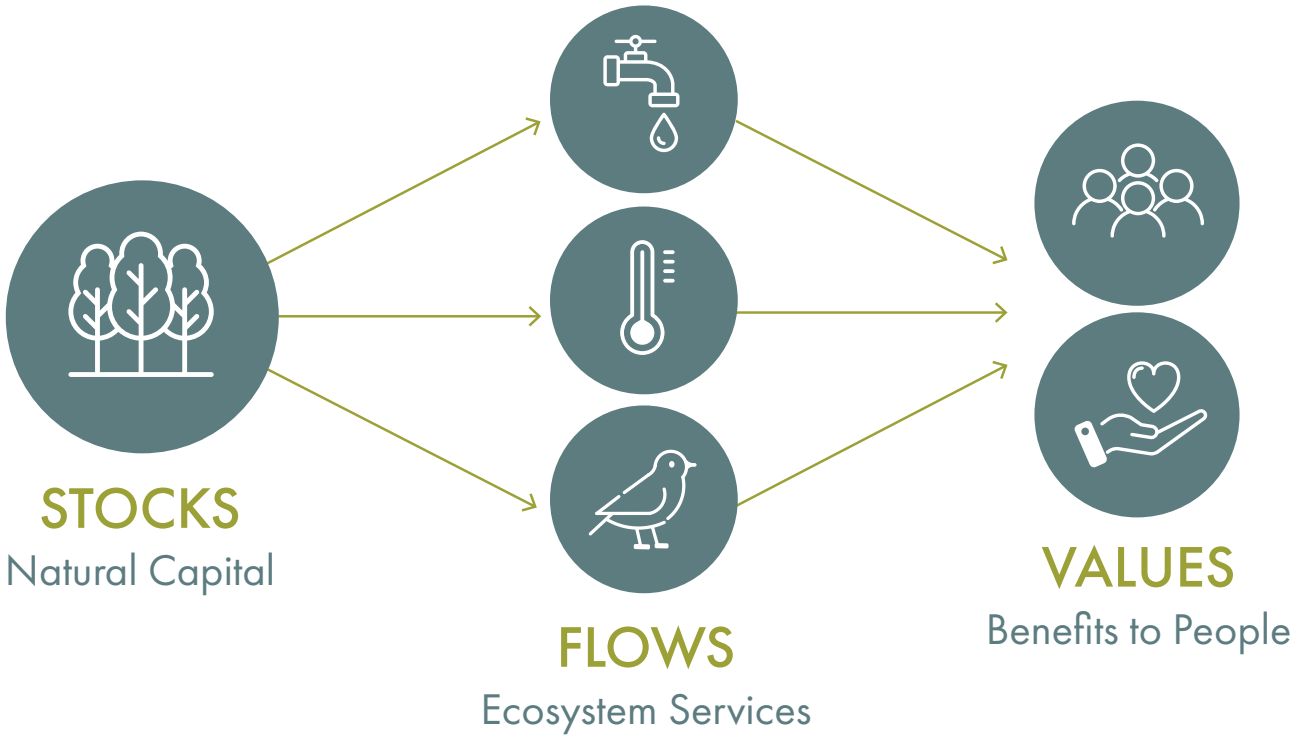


Figure 1. Basic conceptual model showing natural capital stocks that generate ecosystem service flows that benefit society.

1 Costanza, R., D'Arge, R., De Groot, R., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260.

2 Id. at 259.

Yet despite this growing recognition, global trends reveal an alarming decline in the stock of natural capital, with corresponding negative impacts on human wellbeing. This deterioration stems largely from a pervasive collective action challenge: the benefits generated by healthy ecosystems are widely dispersed among numerous beneficiaries, none of whom have sufficient individual incentive to protect these systems.[3] Meanwhile, the costs of conservation and sustainable management fall disproportionately on landowners and managers who face significant expenses and opportunity costs when forgoing alternative, more immediately profitable land uses such as residential development or intensive resource extraction (Figure 2). This misalignment of incentives has accelerated ecosystem degradation, creating an urgent need for innovative approaches that can better align economic incentives with ecological imperatives.

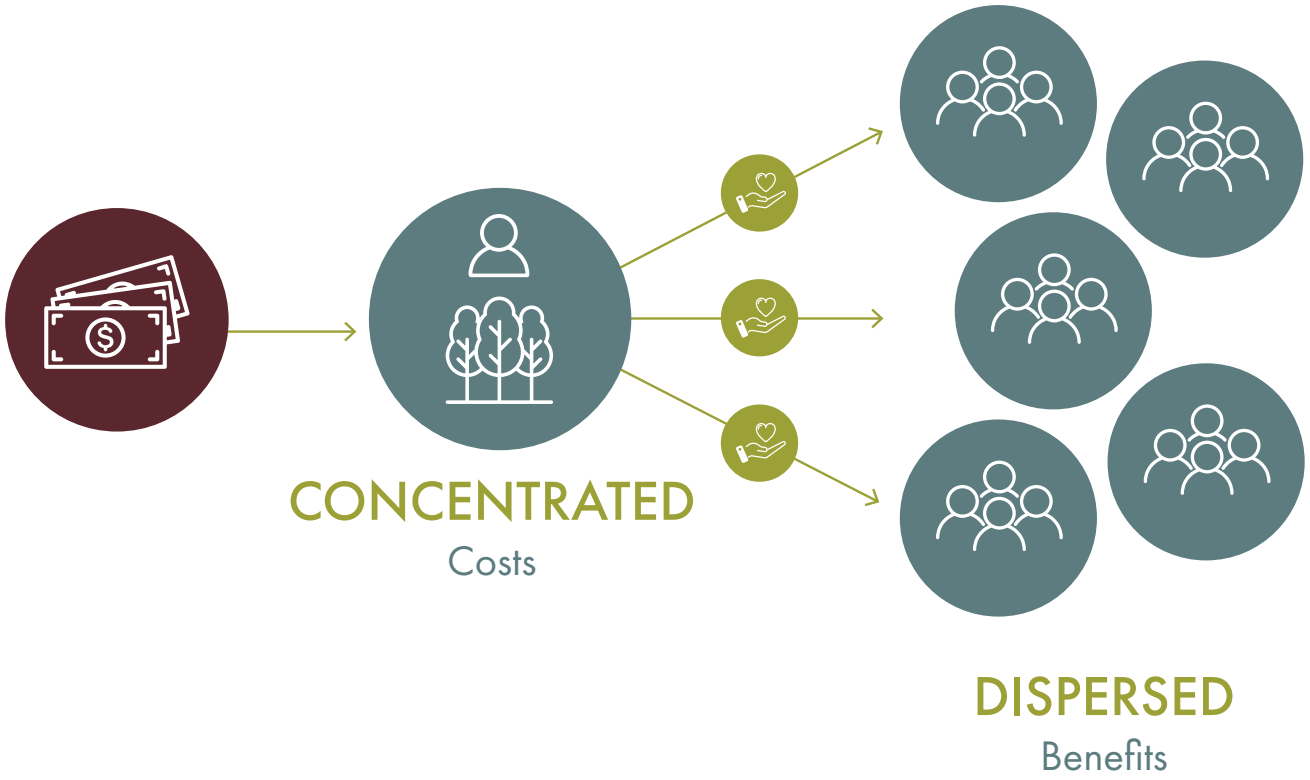


Figure 2. The decline of natural capital stems in part from a collective action problem where ecosystem service benefits are broadly dispersed but costs are concentrated on landowners and land managers.

WHY NATURAL CAPITAL INVESTMENTS

Previous approaches to incentivize the delivery of ecosystem services, such as payments for ecosystem services (PES), aim to have beneficiaries compensate landowners for specific ecological functions such as carbon sequestration, water filtration, or biodiversity preservation.[4] While these mechanisms have achieved some success, they are inherently limited by their tendency to isolate and commodify individual ecosystem services rather than addressing the integrated ecological systems that produce them. This fragmentation can lead to unintended consequences, as optimizing for a single service (such as

3 Ehrlich, P. R., Kareiva, P. M., & Daily, G. C. (2012). Securing natural capital and expanding equity to rescale civilization. *Nature*, *486*(7401), 68-73.

4 Farley, J., & Costanza, R. (2010). Payments for ecosystem services: from local to global. *Ecological economics*, *69* (11), 2060-2068.

carbon storage) may inadvertently diminish other critical functions (such as water yield or habitat provision).[5] Moreover, these narrowly-focused approaches often struggle to account for the complex, interconnected nature of ecological processes and the multiple, sometimes competing benefits they generate across different spatial and temporal scales.

Natural capital investments have emerged as an alternative strategy that recognizes the economic value of nature while embracing its inherent complexity. This framing represents a significant conceptual shift—rather than focusing on discrete ecosystem service flows during a given time period, it centers on maintaining and enhancing the underlying natural capital assets that generate these services (Figure 3).[6] By investing in the integrity and resilience of whole ecosystems, this approach provides a more holistic perspective that acknowledges the interdependence of ecological functions and better aligns with how ecosystems operate. Furthermore, while conventional financial investments seek to extract value from an asset over time, natural capital investments aim to sustain or increase the asset's capacity to generate multiple benefits,[7] often for diverse stakeholders across longer time periods.

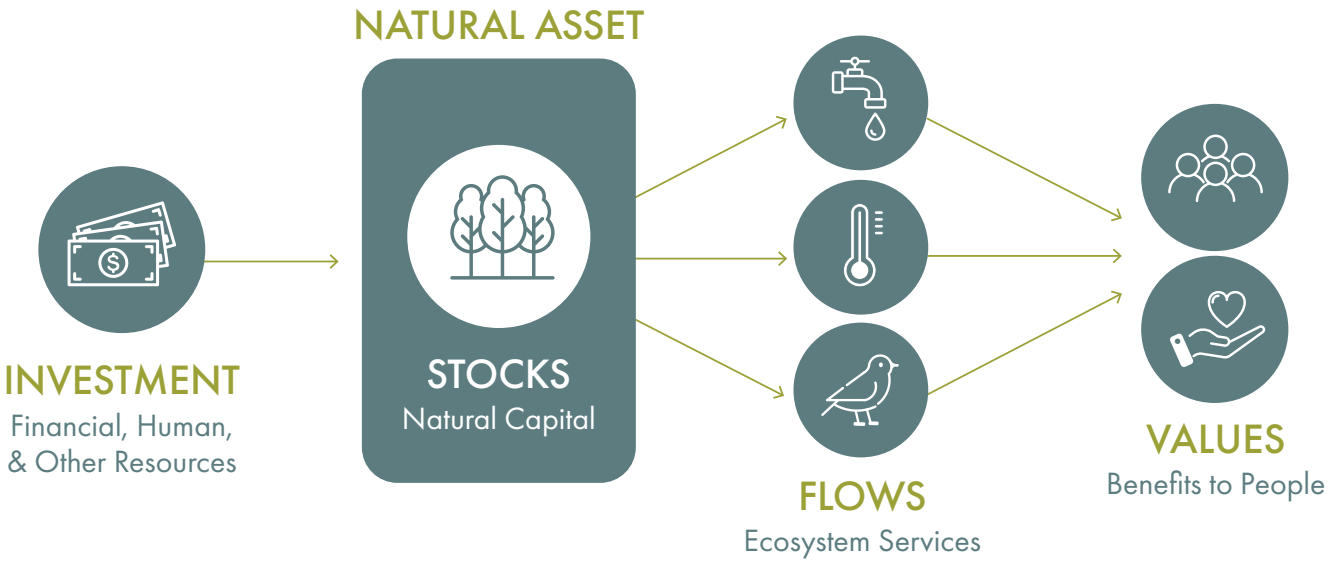


Figure 3. Basic conceptual model showing an investment of financial, human, or other resources in a natural asset to sustain or enhance its stock of natural capital.

Importantly, investments in natural capital extend beyond purely financial mechanisms. They can encompass investments of human capital—such as the development of collaborative governance structures, scientific monitoring programs, or community education initiatives; physical capital—including restoration infrastructure or equipment that enables sustainable land management; or social capital—fostering networks of trust and reciprocity among stakeholders.[8] These diverse forms of investment, when strategically coordinated, can maintain or enhance natural assets to continue providing tangible benefits to people while simultaneously preserving their intrinsic ecological value. This multidimensional understanding of investment recognizes that sustaining natural capital requires not just financial flows, but also institutional capacity, technical knowledge, and social cohesion—all working in concert toward ecological and economic resilience.

5 Börner, J., Baylis, K., Corbera, E., Ezzine-de-Blas, D., Honey-Rosés, J., Persson, U. M., & Wunder, S. (2017). The effectiveness of payments for environmental services. *World development*, *96*, 359-374.

6 Ouyang, Z., Zheng, H., Xiao, Y., Polasky, S., Liu, J., Xu, W., ... & Daily, G. C. (2016). Improvements in ecosystem services from investments in natural capital. *Science*, *352*(6292), 1455-1459.

7 Turner, R. K., & Daily, G. C. (2008). The ecosystem services framework and natural capital conservation. *Environmental and resource economics*, *39*, 25-35.

8 Reynolds, T. W., Farley, J., & Huber, C. (2010). Investing in human and natural capital: An alternative paradigm for sustainable development in Awassa, Ethiopia. *Ecological Economics*, *69*(11), 2140-2150.

QUESTIONS FOR NATURAL CAPITAL INVESTMENT APPROACHES

While investments in natural capital have emerged as a promising strategy for maintaining ecosystem integrity and function, these approaches remain in their nascent stages, with considerable questions about their long-term viability and optimal implementation. As highlighted in the World Economic Forum's 2024 report "Investing in Natural Capital: Innovations Supporting Much-Needed Financing for Nature,"[9] there is an urgent need to develop robust business models and supporting infrastructure that can attract significant capital flows to conservation at scale. Despite growing interest from investors, governments, and conservation organizations, persistent challenges around risk assessment, return measurement, transaction costs, and governance structures continue to hamper widespread adoption. The report emphasizes that, without addressing these foundational issues, natural capital investments may struggle to move beyond philanthropically-subsidized pilot projects to become mainstream financial mechanisms capable of addressing the estimated $700 billion annual funding gap[10] for nature conservation and restoration.

Without addressing foundational issues like risk, return, and governance, natural capital investments may never scale beyond pilot projects—despite growing investor interest and a $700 billion annual funding gap for nature.

This research addresses these knowledge gaps through an in-depth examination of four diverse natural capital investments across different ecosystems and institutional contexts in the American West. Using a comparative case study analysis, we explore the underlying business models, financing structures, stakeholder arrangements, and governance mechanisms that enable these investments to function. By investigating both successful approaches and those that have yet to realize their objectives, we identify critical factors that contribute to viable natural capital investments and consider the various advantages and limitations of different models in delivering long-term ecological and economic benefits.

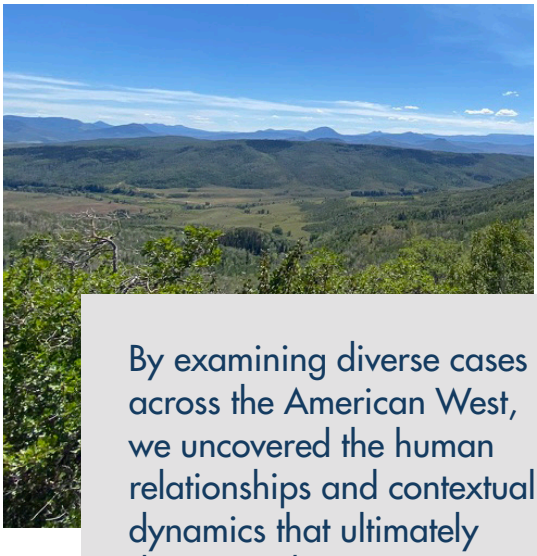
Approach

We used a comparative case study methodology for this research, focusing specifically on initiatives within the American West. This region presents a rich context for examining natural capital investments due to its diverse ecosystems, complex land ownership patterns, and pressing environmental challenges including water scarcity, wildfire risk, and habitat fragmentation. The four cases were purposively selected to represent varied ecological contexts (forests, rangelands, watersheds), different institutional arrangements (public-private partnerships, nonprofit-led initiatives, multi-stakeholder collaboratives), and a range of financing mechanisms (bonds, carbon markets, conservation easements, and water funds).

9 Investing in Natural Capital: Innovations Supporting Much-Needed Financing for Nature. (2024). In *World Economic Forum*. World Economic Forum. https://www3.weforum.org/docs/WEF_Investing_in_Natural_Capital_2024.pdf

10 Id. at 4.

We used on a qualitative approach that relied on in-depth, semi-structured interviews with key stakeholders intimately involved in each case. Respondents represented multiple perspectives within each initiative, including project developers, investors, landowners, public agency representatives, and technical experts. These interviews explored the genesis of each project, the challenges encountered during implementation, the financial and governance structures employed, and the perceived successes and limitations of each approach. This diversity of viewpoints enabled us to develop a comprehensive understanding of the multifaceted dynamics at play in each case and to identify patterns of convergence and divergence across the four initiatives. To complement and triangulate the interview data, we conducted extensive document analysis, reviewing a wide range of materials including feasibility studies, annual reports, monitoring and evaluation documents, grant applications, legal agreements, and media coverage. These sources provided valuable context, technical details, and historical information that helped validate and extend the insights gathered through interviews.



By examining diverse cases across the American West, we uncovered the human relationships and contextual dynamics that ultimately determine the success—or failure—of natural capital investments.

By integrating these complementary data sources, our approach enabled a nuanced examination of the complex socio-ecological systems in which natural capital investments operate. This methodology allowed us to move beyond superficial accounts of project structure or performance to uncover the underlying mechanisms, contextual factors, and human relationships that ultimately determine the success and limits of innovative approaches to investing in natural capital. The comparative dimension of our analysis further strengthened these insights by highlighting commonalities and distinctions across diverse contexts, thereby enhancing the practical utility of our findings.

Case Study Summaries and Key Insights

BLUE FOREST | YUBA I FOREST RESILIENCE BOND

The Yuba I Forest Resilience Bond (FRB), implemented by Blue Forest in 2018 in California on the Tahoe National Forest, represents an innovative financial instrument specifically designed to overcome the chronic underfunding of forest restoration activities in the western United States. The model secured $4 million in up-front capital from a diversified portfolio of investors, including both philanthropic organizations offering concessionary returns (1%) and commercial investors seeking market-rate returns (4%).[11] This blended capital structure enabled the National Forest Foundation to subcontract with local businesses to immediately implement forest restoration work across 15,000 acres[12] of the Tahoe

11 *The Forest Resilience Bond Case Study - Convergence Resources | Convergence*. (2024). https://www.convergence.finance/resource/the-forest-resilience-bond-case-study/view

12 Blue Forest. (2024, November 13). *Yuba I FRB | Blue Forest*. https://www.blueforest.org/our-impact/our-projects/yuba-i-frb/

National Forest within California's Yuba River watershed. The restoration activities included mechanical thinning of overcrowded forests, prescribed burns to reduce fuel loads, and meadow and aspen forest restoration to enhance water retention and habitat diversity. The Yuba I FRB operated through a "special purpose vehicle" (the FRB Yuba Project I LLC), which managed the financial flows and contracts between investors and beneficiaries. The up-front investments were repaid with interest over multiple years by two primary beneficiaries—the Yuba Water Agency and CAL FIRE—who value the resulting ecosystem services, including reduced wildfire severity, improved water quality and quantity, carbon sequestration, and rural economic development through job creation.

Figure 4. Yuba I Forest Resilience Bond business model.

KEY INSIGHTS

The Yuba I FRB provides several informative insights for natural capital investments. First is the indispensable role of a dedicated lead partner with both technical expertise and valuable relationships with other key partners. Blue Forest served not merely as a facilitator but as the driving force behind the initiative—conceptualizing the financial model, securing diverse investors, navigating complex multi-party agreements, and coordinating implementation across public and private entities. Without this entrepreneurial leadership and persistent championing, the innovative but complex structure would likely have faltered in early development stages.

The project also powerfully illustrates how a successful pilot program can catalyze momentum for replication in other locations. By demonstrating both technical feasibility and the ability to align diverse stakeholders with competing priorities, Yuba I effectively "broke the ice" for the FRB model. Subsequent iterations of the program have required significantly less effort to attract support and funding, suggesting that innovation in natural capital markets often faces first-mover challenges that diminish once a proof of concept is established.

Notably, the FRB achieved success without relying on strict pay-for-performance metrics that might create implementation barriers. Instead of using rigid outcome-based payment triggers, the model allows each stakeholder to participate based on the specific benefits they prioritized—whether watershed resilience for the water agency or reduced fire suppression costs for state government. This flexible multi-beneficiary approach made the FRB appealing to a wider range of partners without requiring precise quantification of benefits or imposing excessive measurement costs.

Perhaps most significant is the FRB's sophisticated blended finance approach, which strategically combines philanthropic capital, government funds, and private investment across different components of the project and business model. This layered structure effectively de-risks participation for more conservative capital providers and encourages public agencies to engage in multi-stakeholder collaboration they might otherwise avoid due to institutional constraints. The result is a financing model that distributes financial burden according to risk tolerance and time horizon, broadens impact beyond what any single funding source could achieve, and fosters long-term institutional relationships that can support future conservation finance initiatives.

By breaking first-mover barriers with a flexible, multi-beneficiary model and blended finance, the FRB showed how one successful pilot can unlock broader momentum for natural capital investment.

MAY RANCH | CONSERVATION EASEMENT AND RANGELAND CARBON CREDIT PROJECT

The May Ranch project represents a sophisticated integration of a conservation easement transaction with an avoided grassland conversion carbon market project on a 15,000-acre family-owned cattle ranch in southeastern Colorado.[13] The Colorado Cattlemen's Agricultural Land Trust holds a permanent conservation easement on the property, which restricts future development and certain land-use practices while allowing sustainable ranching operations to continue. The easement was purchased through coordinated fundraising efforts led primarily by The Conservation Fund, which secured sufficient funding to compensate the May family for voluntarily limiting their development rights. Simultaneously, Ducks Unlimited developed and implemented a carbon credit project on the property, registering the ranch with an established carbon registry and engaging a third-party verification body to validate carbon sequestration claims. An anonymous impact investor financed the up-front transaction costs through a five-year offtake agreement that made the carbon project financially possible. Initially offering funding at 0% return due to commitment to the conservation mission, this investor eventually took repayment in the form of carbon credits for personal use. The dual conservation easement and carbon credit structure allows the May family to maintain their ranching livelihood while receiving income from both the easement purchase and ongoing carbon credit sales, creating a financially viable path to preserve native grasslands that might otherwise have been converted to more intensive uses.

13 Malotky, B. (2023, August 22). *Free-Range Carbon*. Western Confluence. https://westernconfluence.org/free-range-carbon-2/

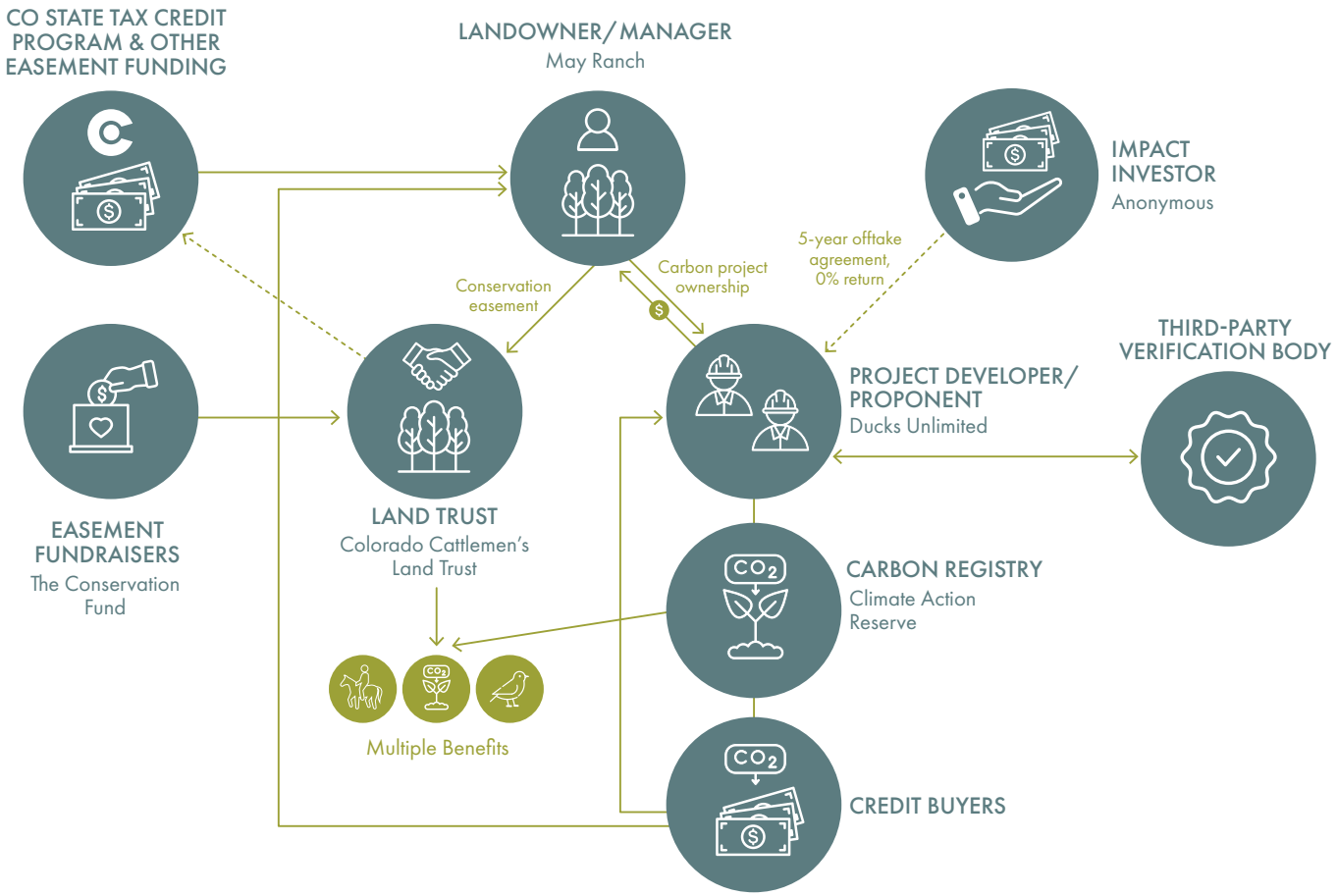


Figure 5. May Ranch Conservation Easement and Rangeland Carbon Project business model.

KEY INSIGHTS

The May Ranch project succeeded partly because the property faced genuine development pressure from solar developers, with a contract already in hand when the conservation alternative was proposed. This established a credible and relatively high baseline value that justified both the easement purchase price and the carbon credit creation through avoided conversion. The presence of real alternative land uses added legitimacy to the claim that conservation represented a meaningful choice rather than an inevitable outcome, strengthening both the financial case and the carbon accounting methodology.

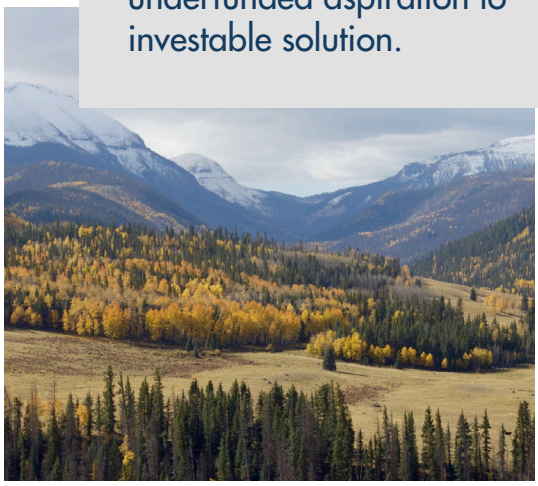
The project demonstrates the strategic power of investing in whole ecosystems rather than isolated services. By pairing carbon credits with an easement containing a no-sod-busting clause that preserves native vegetation, the initiative protects the entire grassland ecosystem including its wildlife habitat, water filtration capacity, and cultural heritage values, while simultaneously maintaining carbon stocks. This holistic approach avoids the pitfalls of commodifying specific services in isolation, which can lead to fragmented interventions that optimize for a single outcome at the expense of overall ecosystem integrity. The carbon credits derive direct value from these carbon stocks, but their true worth is intertwined with the preservation of the functioning ecosystem protected by the easement.

The project's success also hinged on the participation of influential partners with specialized expertise and financial capacity. The anonymous impact investor played a critical role in de-risking the early years of credit issuance by providing bridge financing that enabled Ducks Unlimited to cover project costs while developing the market for credits. Equally important were the established conservation organizations who led various aspects of the project—Ducks Unlimited in particular leveraged their technical expertise in carbon protocols and market relationships to overcome the complexities of credit certification and marketing. A strong foundation of trust between the May family, Ducks Unlimited, and the Colorado Cattlemen's Agricultural Land Trust enabled a shared commitment that helped navigate the risks and uncertainties of developing one of the first grassland carbon projects in the region. The collaborative expertise across these organizations created a project infrastructure that no single entity could have provided, demonstrating how social and institutional capital can be just as important as financial capital in natural capital investments.

QUANTIFIED VENTURES | ENVIRONMENTAL IMPACT FUND FOR WILDFIRE MITIGATION

Quantified Ventures' Environmental Impact Fund (EIF) proposed an ambitious pay-for-success financing model for landscape-scale wildfire mitigation in Southwest Colorado that ultimately did not launch. The approximately $44 million initiative would have funded forest health treatments across 64,871 acres spanning multiple jurisdictions, using a revolving loan fund structure to provide sustained capital for both initial treatments and long-term maintenance.[14] The financing strategy was designed to distribute costs among multiple stakeholders: biomass operators would contribute over $10 million in exchange for harvesting approximately 288,000 green tons of material for energy and product use; private landowners would provide a 35% cost-share totaling more than $10 million; federal contributions were projected at just under $2 million; and the remaining $21.6 million would be disbursed through the EIF's revolving impact loans. These loans would be repaid over 20-year cycles by a coalition of beneficiaries including local governments, utilities, and tribal organizations, with annual debt service ranging between $1.3 and $1.6 million depending on performance outcomes. The initial seed capital for the fund would come from a bond issued by the Colorado Water Resources and Power Development Authority, supplemented by grants and other credit enhancements. Quantified Ventures developed a sophisticated financial model to simulate treatment outcomes, stakeholder contributions, repayment structures, and variable performance scenarios, positioning the EIF as an innovative solution to the chronic underfunding of forest health initiatives.

> ...the EIF's ambitious $44 million model showed how shared costs, revolving loans, and pay-for-success financing could transform wildfire mitigation from underfunded aspiration to investable solution.



14 The SW Colorado Wildfire Mitigation Environmental Impact Fund (EIF). (2019). In *Quantified Ventures*. Quantified Ventures. https://www.quantifiedventures.com/wildfire-mitigation-environmental-impact-fund

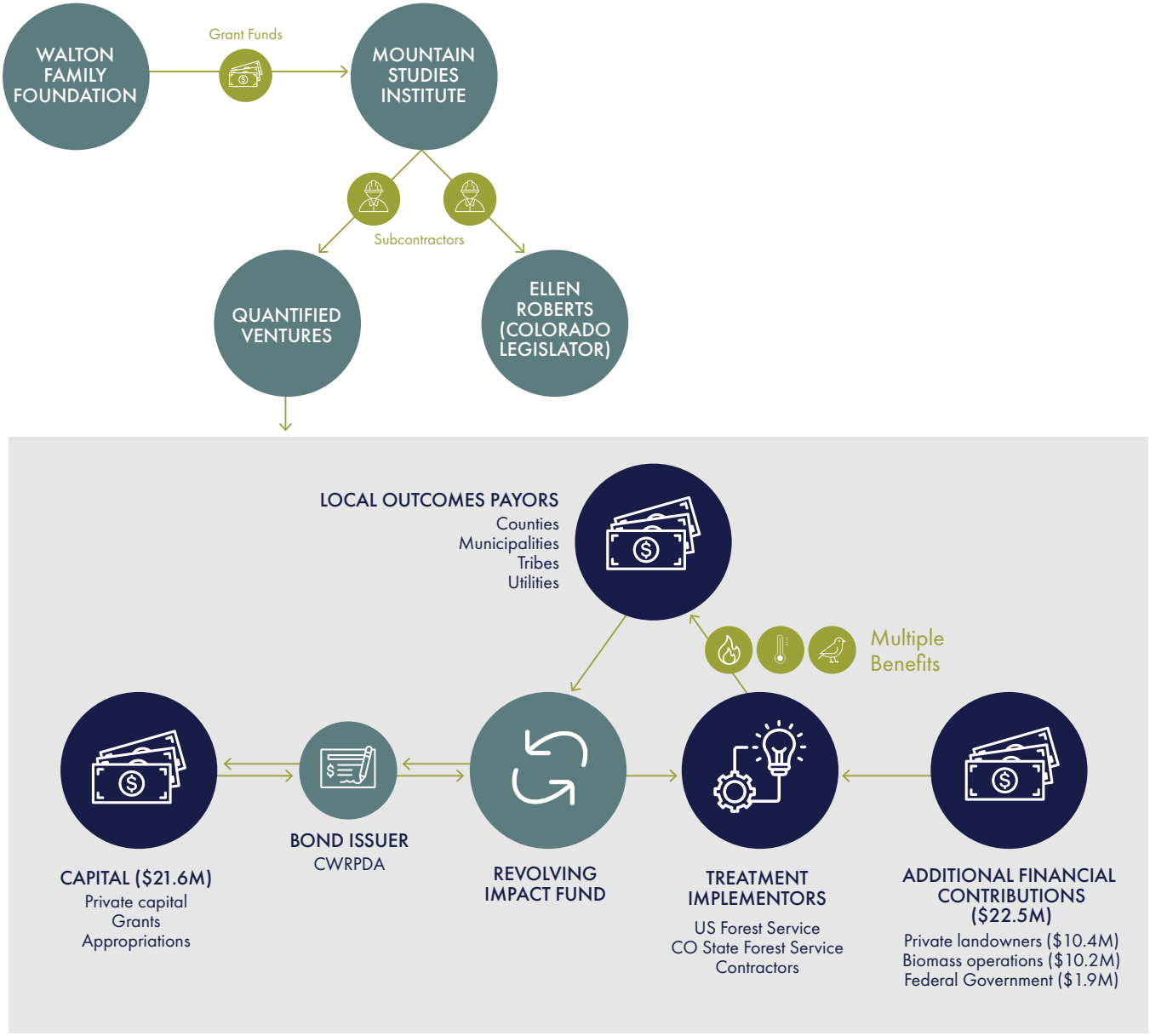


Figure 6. Quantified Venture's Environmental Impact Fund for Wildfire Mitigation business model.

KEY INSIGHTS

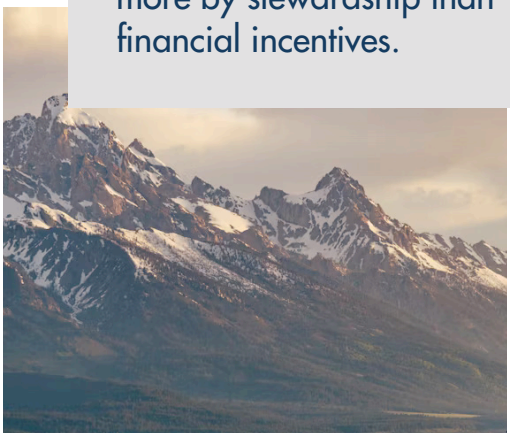
Despite its innovative design and technical sophistication, the EIF failed to launch due to three critical and ultimately insurmountable barriers. First, the initiative suffered from insufficient up-front capital to jumpstart the project. Although the Walton Family Foundation funded the feasibility assessment, applications for additional grants from the USDA, USFS, and other sources were unsuccessful. This revealed a crucial gap in the project's development sequence: without seed funding to establish the revolving fund, the entire financing structure remained theoretical. The experience highlights the challenge of securing initial capital for novel environmental finance mechanisms, particularly when competing against established models with proven track records. Second, the EIF encountered a fundamental market failure in its attempt to monetize biomass as a key revenue stream. The financial model projected that biomass

operators would contribute substantially to the project through both in-kind labor and by purchasing material generated from thinning treatments. However, this assumption proved unrealistic; biomass lacked sufficient market value in southwest Colorado to be commercially viable at the scale required. Third, and perhaps most significantly, the EIF faced institutional resistance from local governments who were unwilling to issue debt or participate in the bond process. The proposed 20-year repayment period exceeded the comfort zone for many public entities, while the outcomes-based structure introduced perceived uncertainty that many risk-averse government agencies found unacceptable. This resistance reveals the importance of thoroughly understanding institutional constraints and risk tolerances when designing multi-stakeholder financing mechanisms.

The EIF's failure to launch illustrates a broader lesson about the limitations of focusing on a single ecosystem service rather than bundling multiple benefits. By structuring the model primarily around wildfire mitigation through biomass removal, the project became vulnerable to market fluctuations in a single resource value. Had the model marketed a wider range of ecosystem co-benefits—such as water quality improvement, habitat enhancement, or recreational value—it might have attracted a more diverse pool of beneficiaries and created greater financial resilience. The case powerfully demonstrates that technical sophistication and financial engineering cannot overcome fundamental gaps in resource availability, market conditions, or institutional alignment.

TETON BASIN WATER USERS ASSOCIATION | AQUIFER RECHARGE PROJECT

By turning spring runoff into banked groundwater for dry summer months, TBWUA's community-led effort blends tradition with innovation—driven more by stewardship than financial incentives.



The Teton Basin Water Users Association (TBWUA), established in 2018, developed a community-based approach to water resource management in Idaho's Teton Valley, addressing declining aquifer levels caused by climate change and increasing agricultural demand. The organization comprises a diverse coalition of stakeholders including agricultural and livestock producers, conservation nonprofits, local government leaders, and hydrology experts united by concern about declining water availability in the Teton Valley. The program encourages upstream irrigators to flood-irrigate their fields during abundant spring runoff periods, effectively banking groundwater that gradually seeps into streams later in the summer when water is scarce and more economically and environmentally valuable. This approach leverages existing irrigation infrastructure and traditional agricultural practices while attempting to transform low-cost spring water into high-value late-season water. Initially designed as a local water market where downstream junior water rights holders would compensate upstream irrigators for recharge services, this market exchange never materialized due to the complex water rights and hydrological systems. Under this water rights system, when water becomes scarce, junior users face complete curtailment rather than gradual reduction, meaning that modest increases in streamflow from recharge provide insufficient benefit to justify compensation from downstream users. Canal companies that initially participated were compensated with grant funding, but as this support has ended, the program now relies primarily on voluntary participation motivated by community goodwill and stewardship norms rather than financial incentives. TBWUA continues to explore alternative compensation models while Idaho's mandated formation of new groundwater districts may offer a potential pathway forward—if managed recharge can be recognized as a compliance tool for groundwater users facing regulatory obligations.

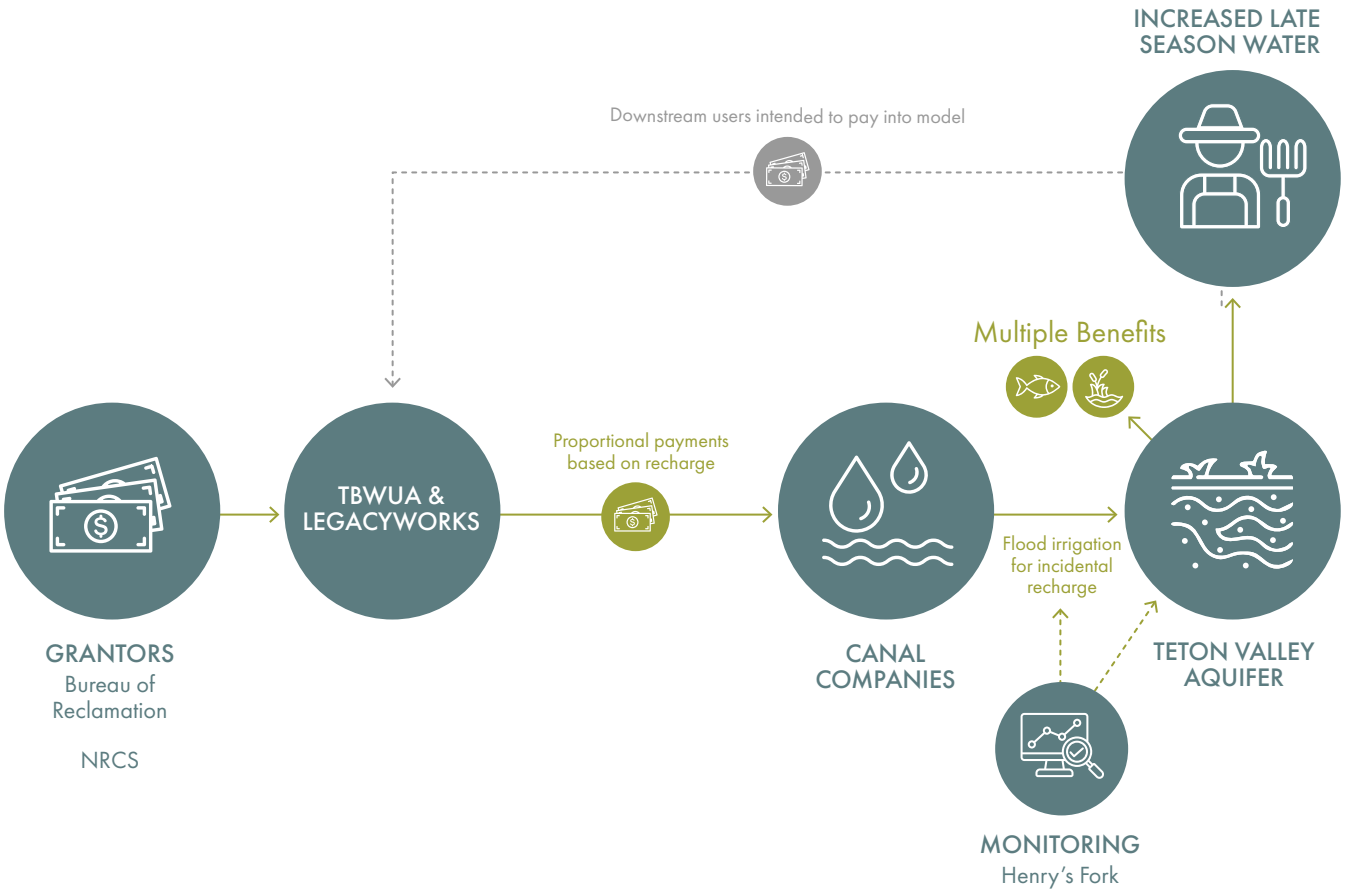


Figure 7. Teton Basin Water Users Association Aquifer Recharge Program business model.

KEY INSIGHTS

TBWUA's experience highlights how deep community trust and collaborative governance can enable collective action even in the absence of formal market structures or consistent financial incentives. The meaningful inclusion of diverse stakeholders in decision-making, implementation, and monitoring has fostered a shared commitment to water security that transcends immediate economic calculations. This social capital has sustained limited voluntary participation despite the collapse of the envisioned market mechanism and the end of grant funding. The case demonstrates how investments in relationship-building and inclusive governance can generate resilience in natural resource management initiatives when financial models falter.

However, this strength in community cohesion also reveals a fundamental limitation: without sustained financial backing or regulatory requirements to support recharge activities, the model lacks both economic sustainability and replicability. The program's continued operation at reduced scale depends heavily on goodwill and in-kind contributions from participants who share conservation values, making it vulnerable to changing priorities or economic pressures. This dependency highlights the challenge of scaling community-based solutions without durable funding mechanisms or formal institutional support.

The TBWUA experience also underscores the critical importance of robust monitoring systems in natural capital investments. Even during periods of reduced financial support, the program has maintained scientific monitoring of hydrologic outcomes to validate recharge volumes and communicate benefits to stakeholders. This commitment to measurement not only builds credibility with potential funders and regulatory authorities but also enables adaptive management as conditions change. Without such monitoring, the program would risk becoming a symbolic effort with no demonstrable outcomes—a particularly important consideration if recharge eventually becomes integrated into formal groundwater district mitigation strategies.

TBWUA shows that lasting impact may lie at the intersection of community initiative and regulatory alignment—where voluntary action meets formal compliance.

Perhaps the most significant insight from the TBWUA case is that innovative community-based solutions may ultimately depend on alignment with existing regulatory frameworks to achieve financial viability and institutional durability. In Idaho, new mandates require the formation of groundwater districts responsible for offsetting the impacts of groundwater pumping. Within this context, managed aquifer recharge—originally spearheaded by TBWUA—could become a formal compliance mechanism. If adopted as a recognized mitigation strategy, managed recharge would enable groundwater users to meet legal obligations while avoiding curtailment, creating a regulatory incentive for sustained investment in groundwater recharge. The ongoing evolution of TBWUA illustrates how natural capital investments may need to navigate between voluntary market-based approaches and regulatory frameworks, sometimes finding their most sustainable expression at the intersection of community initiative and formal governance systems.

Key Cross-Cutting Themes

Our analysis across these four diverse case studies reveals several fundamental principles that influence the success or failure of natural capital investments. These insights transcend specific ecological contexts or financing mechanisms to illuminate broader patterns in how these investments function, the conditions that enable them to thrive, and the barriers that limit their effectiveness or scalability.

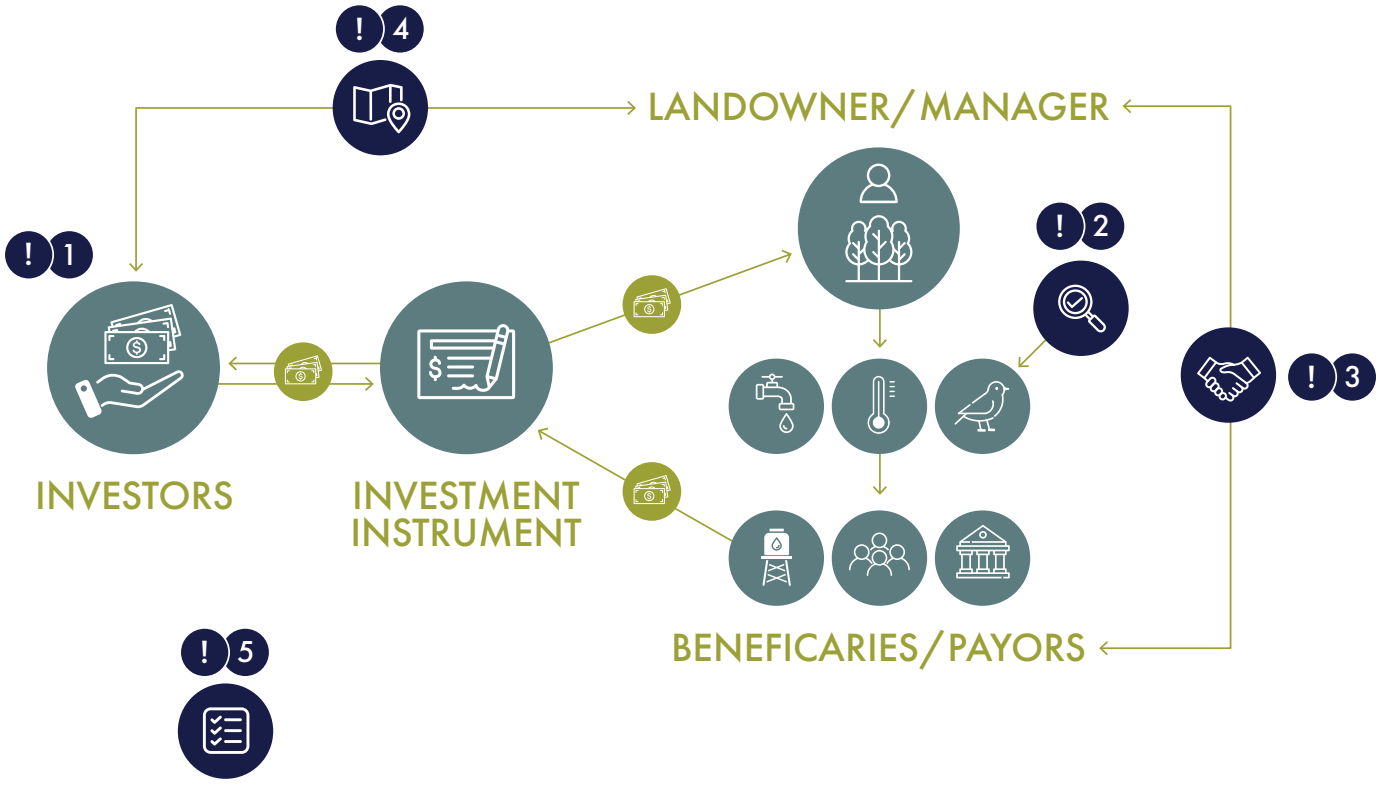


Figure 8. A general business model for a natural capital investment showing key insights from this research: (1) the "flavor" of money matters and determines its flexibility in an investment; (2) investments need "sufficient science" to inform investment decisions yet what is sufficient is highly variable depending on the social and ecological context; (3) social capital is an essential yet often underappreciated asset in facilitating novel investments; (4) investments must work at an adequate economic and ecological scale to cross critical thresholds that can make investments viable; and (5) there are important enabling conditions that make some investments viable that may not be present in many other situations.

Strategic Deployment of Capital Types

The "flavor of money"—its source, flexibility, risk tolerance, and conditions—profoundly shapes investment outcomes. Different funding sources carry distinct characteristics that determine their suitability for various stages and functions within natural capital investments. Our case studies demonstrate that understanding these nuances and strategically deploying the right type of capital at the right moment can be as important as the total amount of funding secured.

Philanthropic capital emerged as particularly powerful when deployed as "catalytic capital"—funding that absorbs disproportionate risk or accepts below-market returns to enable projects that wouldn't otherwise materialize. In the Yuba I FRB, philanthropic investors accepting 1% returns created a blended finance structure that made 4% returns possible for commercial investors, effectively de-risking the novel financing mechanism. Similarly, in the May Ranch case, the anonymous impact investor's willingness to provide up-front capital with zero return expectations and eventually convert the investment to personal carbon offsets was instrumental in overcoming the initial transaction costs that presented a real market barrier for the landowner in developing a rangeland carbon project. Notably, in both cases, philanthropic dollars represented a minority of the total capital involved in the overall initiative, yet their strategic positioning magnified

their impact dramatically. This catalytic function proved especially critical during early project phases characterized by high uncertainty, unproven methodologies, or complex stakeholder dynamics. Philanthropic funding often served another crucial role by supporting capacity building, stakeholder engagement, and technical assistance that public funding streams typically restrict or exclude altogether.

Public capital contributed essential scale, stability, and legitimacy to several projects, but came with significant constraints in flexibility and timing. The Yuba I FRB's repayment structure relied on commitments from the Yuba Water Agency and the California state government, providing reliable cash flows needed to satisfy investors. Importantly, Yuba Water Agency's funding, which was structured as a fee-for-service contract, could be used to pay interest on the investment. This capability contrasted with that of the CAL FIRE grant, which was restricted to reimbursable expenses and could not cover financing costs. Considering this distinction, Yuba Water Agency's contribution was especially valuable as it enabled the bond to offer reasonable returns and attract private capital. As the Yuba I FRB case illustrates, public dollars can be slow to materialize and are typically restricted in their allowable uses, which may require creative financial structuring to bridge timing gaps as part of a broader natural capital investment approach. This pattern underscores the complementary relationship between philanthropic and public capital—the former providing flexibility and risk absorption, the latter offering durability and scale.

Philanthropic capital, when used catalytically, can unlock larger investments by absorbing risk—proving that small, flexible dollars can have outsized impact in natural capital finance.

Private capital demonstrated the greatest variation in terms and expectations across our cases. In the May Ranch project, impact-oriented private capital proved willing to accept unconventional terms to support conservation outcomes, while in the QV EIF case, the assumed commercial participation of biomass operators never materialized due to insufficient market returns. This variance highlights the importance of realistic market analysis when projecting private sector participation in natural capital investments.

"Sufficient Science" and Decision-Making Under Uncertainty

Across all four cases, stakeholders faced significant scientific uncertainty regarding the precise ecological outcomes and economic benefits their investments would generate. Yet successful projects did not allow this uncertainty to paralyze decision-making. Instead, they embraced the concept of "sufficient science"—knowledge that, while imperfect, provides enough confidence to justify action while acknowledging and managing remaining uncertainties.

The Yuba I FRB relied on hydrological and fire modeling that established plausible connections between forest restoration activities and reduced wildfire severity, improved water quality, and enhanced landscape resilience. These models did not

produce precise dollar-value predictions for every acre treated, but they created enough confidence among stakeholders that meaningful benefits would accrue to multiple parties. Blue Forest and their key partner, the World Resources Institute, effectively communicated these scientific foundations while acknowledging inherent limitations, building trust through transparency rather than overpromising specific outcomes.

Similarly, the May Ranch carbon project required rigorous soil carbon sampling and modeling to satisfy verification standards, yet these protocols balanced scientific rigor with practical feasibility. The carbon accounting methodologies were designed to be credible enough for market participation without imposing prohibitive monitoring costs that would have rendered the project financially unviable. This pragmatic approach recognized that perfect measurement was less important than consistent, defensible methods that allowed the conservation activity to proceed.

In natural capital investments, 'sufficient science' is contextual—success depends not on perfect precision, but on credible, defensible methods matched to stakeholder needs and financial realities.

By contrast, the TBWUA initially struggled to establish sufficient scientific evidence that its recharge activities delivered meaningful benefits to downstream water users. The complex hydrology of the aquifer system, combined with the abrupt administrative mechanism of water curtailment, meant that modest increases in streamflow did not translate into tangible economic value for potential payors. This scientific challenge, coupled with institutional constraints in Idaho water law, ultimately prevented the formation of a functional water market.

These experiences suggest that "sufficient science" is contextual—what constitutes adequate evidence depends on the audience, the stakes, and the financial structure. Regulatory compliance mechanisms typically demand higher levels of scientific precision than voluntary agreements based on shared values. The key insight is not that science can or should be compromised, but rather that natural capital investments must strategically match their level of scientific rigor to the specific needs of their stakeholders and financial structures, avoiding both paralysis from excessive demands for certainty and failures from inadequate technical foundations.

Social Capital as a Foundational Asset

Perhaps the most consistent finding across all four cases is the fundamental importance of social capital—the networks of relationships, trust, and reciprocity that enable collective action. This intangible but powerful asset functioned as both an enabler of successful investments and, in some cases, a partial substitute for financial capital or perfect information.

Blue Forest's success with the Yuba I FRB depended heavily on its institutional credibility and pre-existing relationships with federal agencies, water utilities, and conservation organizations. These connections allowed the organization to align diverse stakeholders despite the novelty and complexity of the financial instrument. The FRB's innovative structure

required significant trust among participants—investors needed confidence that public entities would fulfill long-term payment obligations, while public agencies needed assurance that restoration activities would deliver promised benefits. This trust was built through Blue Forest's reputation as an honest broker with technical expertise and mission alignment with all parties.

The May Ranch project similarly leveraged deep relationships within Colorado's ranching and conservation communities. The May family's standing among local landowners, combined with the institutional credibility of organizations like Ducks Unlimited and the Colorado Cattlemen's Agricultural Land Trust, created a foundation of trust that facilitated both the easement purchase and carbon credit development. These relationships reduced transaction costs, accelerated decision-making, and helped navigate the inevitable complications of implementing novel conservation finance mechanisms.

> Social capital isn't just a facilitator—it's a form of capital itself. The most successful natural capital projects invested as much in relationships as in finance.

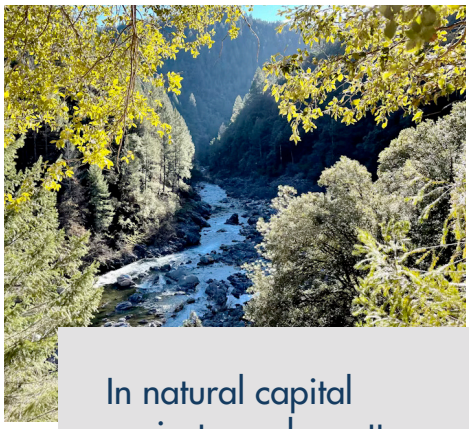
The TBWUA case demonstrates how social capital can sustain collective action even when financial incentives falter. The strong community bonds and shared concern for water security among Teton Valley stakeholders enabled continued voluntary participation in recharge activities despite the fact that the envisioned market mechanism has yet to materialize. While this social cohesion could not entirely compensate for the absence of sustainable funding, it maintained momentum and created space for evolving the model toward more durable institutional arrangements.

Quantified Ventures' EIF faced challenges in part because it was a newer entrant to the regional landscape, without the benefit of long-standing relationships with key local stakeholders. The model itself was technically sound and grounded in strong financial logic, but the absence of pre-existing institutional connections made it more difficult to secure early commitments from local governments and other beneficiaries. It is possible that these relational gaps, not design flaws inherent to the model, limited the EIF's ability to adapt to the specific constraints and market conditions present in the region. These contrasting experiences reveal social capital as not merely a facilitator of natural capital investments but as a form of capital itself—one that requires intentional development, maintenance, and deployment alongside financial resources. The most successful projects invested significantly in relationship-building and collaborative governance, recognizing that technical and financial innovation alone cannot overcome the complex coordination challenges inherent in ecosystem management.

Scale Thresholds and Minimum Viable Investments

Several cases illustrated the critical importance of achieving sufficient scale to cross ecological thresholds and generate meaningful benefits. Natural systems often exhibit non-linear responses to interventions, with benefits emerging only when actions reach a minimum scale or intensity. Successful natural capital investments recognized these thresholds and designed their approaches accordingly.

The Yuba I FRB deliberately targeted a 15,000-acre treatment area based on hydrological modeling that indicated this scale was necessary to meaningfully reduce catastrophic wildfire risk and improve watershed function. A smaller intervention might have produced limited or undetectable benefits, undermining the value proposition for investors and beneficiaries alike. This scale requirement influenced both the financial structure and the implementation strategy, as it necessitated sufficient up-front capital to treat a large landscape in a relatively short timeframe rather than a piecemeal approach.



Similarly, the TBWUA recognized that aquifer recharge efforts would only translate into meaningful downstream benefits if conducted at sufficient scale across multiple irrigation systems. Individual irrigators acting alone could not generate the cumulative hydrological impact needed to affect streamflow patterns. This scale requirement highlighted the collective action challenge at the heart of the initiative—despite understanding the need for coordinated action, the project struggled to develop financial mechanisms that could support participation at the necessary scale once grant funding ended.

> In natural capital projects, scale matters—investments must match ecological thresholds or risk delivering too little, too late despite substantial effort.

The recognition of these scale thresholds has significant implications for natural capital investment design. Interventions must be sized appropriately to ecological realities, which often means securing larger capital commitments, coordinating across multiple landowners or jurisdictions, and developing governance systems capable of managing landscape-scale efforts. Undersized investments risk delivering negligible ecological returns despite significant financial and institutional investments, while properly scaled interventions can unlock disproportionate benefits once critical thresholds are crossed.

Structural Limitations and Enabling Conditions

Despite their innovations and successes, the case studies revealed important structural limitations that constrain the potential of natural capital investments to address ecosystem degradation at the scale and pace required. Understanding these barriers is essential for realistic assessment of where and how these approaches can be most effectively deployed.

A consistent challenge across multiple cases was the limited generation of new cash flows from ecosystem services. While the Yuba I FRB raised some additional funding for forest management from the Yuba Water Agency, it also relied heavily on existing sources of funding for forest restoration work. Similarly, the May Ranch project depended on existing conservation easement funding to make the model work and concessionary capital from an impact investor, suggesting that even with established voluntary carbon markets, rangeland conservation may not generate fully commercial returns. The TBWUA's inability to establish a financially self-sustaining model further illustrates the difficulty of generating sufficient new revenue to drive conservation at scale. These experiences highlight a sobering reality: many natural capital investments continue to rely significantly on philanthropic support, public funding, or regulatory compliance obligations rather than purely market-driven demand for ecosystem services. While blended finance approaches can leverage these traditional funding sources more effectively, they cannot entirely overcome the fundamental challenge that many ecosystem services remain externalities in the current economic system.

The case studies also revealed that successful natural capital investments often depend on particular enabling conditions that may not be widely replicable. The May Ranch project benefited from credible alternative land uses that established a high baseline value for avoided conversion. Blue Forest's FRB model worked in part because the Yuba Water Agency had both the legal authority and financial capacity to invest in upper watershed management—conditions that may not exist in many other jurisdictions. The TBWUA operated in a watershed with particular hydrology and within Idaho's specific water rights framework, which created both constraints and opportunities that would differ substantially in other contexts. These contextual dependencies suggest that while natural capital investments offer promising approaches in certain scenarios, they are not universal solutions applicable across all ecosystems or institutional settings. Their effectiveness depends on careful alignment with local ecological, economic, legal, and social conditions—requiring customization that may limit rapid scaling or simple replication.

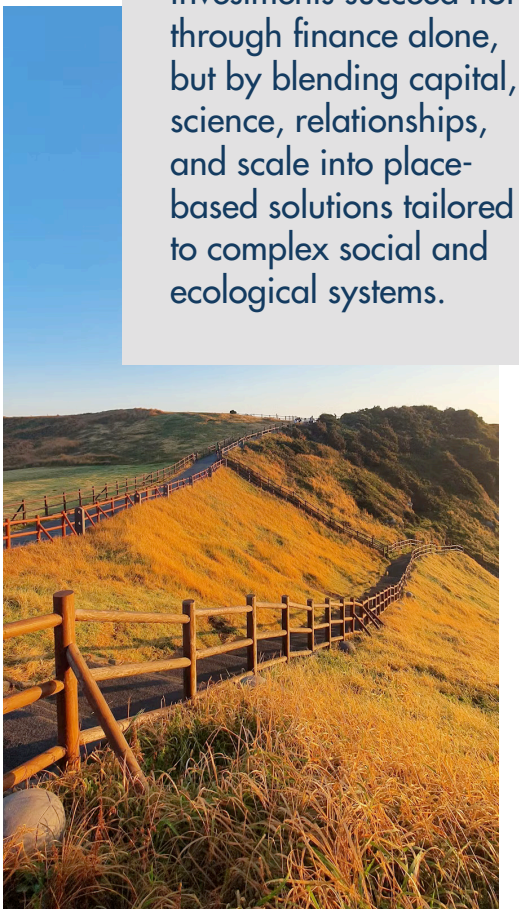
Despite these limitations, the case studies demonstrate that well-designed natural capital investments can achieve meaningful conservation outcomes while delivering economic returns and community benefits. The key lies in recognizing where enabling conditions exist, strategically deploying different forms of capital, building necessary social infrastructure, and designing interventions at ecologically relevant scales. By acknowledging both the potential and the constraints of these approaches, practitioners can more effectively target their efforts toward contexts where natural capital investments are most likely to succeed.

Conclusion

Natural capital investments represent a promising evolution in strategies to advance conservation, offering innovative approaches to align economic incentives with ecological challenges. As our comparative case study analysis reveals, successful models share several key characteristics: they strategically deploy different "flavors" of capital based on risk profiles and timing requirements, with philanthropic funding playing a particularly catalytic role; they embrace "sufficient science" that balances rigor with feasibility; they invest heavily in social capital and collaborative governance; and they design interventions at scales sufficient to cross ecological thresholds. The Forest Resilience Bond, May Ranch carbon project, Teton Basin Water Users Association, and Quantified Ventures' Environmental Impact Fund—with their varying degrees of success—highlight the potential and limitations of these emerging approaches.

These insights suggest that natural capital investments work best when viewed not as stand-alone financial mechanisms but as integrated socio-ecological initiatives that blend financial innovation with institutional capacity-building and community engagement. While these approaches cannot entirely overcome the fundamental challenge that many ecosystem services remain economic externalities, they demonstrate promising pathways to channel more resources toward conservation and restoration.

Natural capital investments succeed not through finance alone, but by blending capital, science, relationships, and scale into place-based solutions tailored to complex social and ecological systems.



Their effectiveness ultimately depends on thoughtful alignment with local ecological, economic, legal, and social contexts—requiring customization rather than one-size-fits-all replication.

As climate change and other anthropogenic pressures continue to degrade ecosystems worldwide, natural capital investments offer valuable tools to protect and enhance the ecological foundations of human well-being. By recognizing both the transformative potential and inherent constraints of these approaches, practitioners can more strategically deploy them in contexts where enabling conditions exist, while simultaneously working toward the broader systems changes needed to fully value nature's contributions. The future of conservation finance likely lies not in any single model but in a diverse portfolio of approaches that collectively shift how societies value, protect, and invest in the natural capital upon which all prosperity ultimately depends.

References

Blue Forest. (2024, November 13). *Yuba I FRB | Blue Forest*. https://www.blueforest.org/our-impact/our-projects/yuba-i-frb/

Börner, J., Baylis, K., Corbera, E., Ezzine-de-Blas, D., Honey-Rosés, J., Persson, U. M., & Wunder, S. (2017). The effectiveness of payments for environmental services. *World development*, *96*, 359-374.

Convergence. *The Forest Resilience Bond Case Study - Convergence Resources*. Convergence. (2024). https://www.convergence.finance/resource/the-forest-resilience-bond-case-study/view

Costanza, R., D'Arge, R., De Groot, R., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*(6630), 253–260.

Ehrlich, P. R., Kareiva, P. M., & Daily, G. C. (2012). Securing natural capital and expanding equity to rescale civilization. *Nature*, *486*(7401), 68-73.

Farley, J., & Costanza, R. (2010). Payments for ecosystem services: from local to global. *Ecological economics*, *69* (11), 2060-2068.

Investing in Natural Capital: Innovations Supporting Much-Needed Financing for Nature. (2024). In *World Economic Forum*. World Economic Forum. https://www3.weforum.org/docs/WEF_Investing_in_Natural_Capital_2024.pdf

Malotky, B. (2023, August 22). *Free-Range Carbon*. Western Confluence. https://westernconfluence.org/free-range-carbon-2/

Ouyang, Z., Zheng, H., Xiao, Y., Polasky, S., Liu, J., Xu, W., ... & Daily, G. C. (2016). Improvements in ecosystem services from investments in natural capital. *Science*, *352*(6292), 1455-1459.

Quantified Ventures. *The SW Colorado Wildfire Mitigation Environmental Impact Fund (EIF)*. (2019). Quantified Ventures. https://www.quantifiedventures.com/wildfire-mitigation-environmental-impact-fund

Reynolds, T. W., Farley, J., & Huber, C. (2010). Investing in human and natural capital: An alternative paradigm for sustainable development in Awassa, Ethiopia. *Ecological Economics*, *69*(11), 2140-2150.

Teton Basin Water Users Association. *Teton Basin Water Users Association*. (n.d.). Teton Water Users Association. https://www.tetonwaterusersassociation.org/

Turner, R. K., & Daily, G. C. (2008). The ecosystem services framework and natural capital conservation. *Environmental and resource economics*, *39*, 25-35.