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Coordinated Governance of Small Watershed Environments: An Empirical Analysis of Resource Management and Human Settlement Improvement in Ningde City

Qin Ma

Abstract

Small watershed governance sits at the nexus of environmental stewardship, resource coordination, and rural development within China's ecological civilization framework. This study investigates coordinated governance mechanisms across Ningde City's small watersheds through the combined lens of time ladder theory and the tragedy of the anti-commons. Drawing on field surveys, semi-structured interviews (n=156), and institutional analysis spanning 12 representative watersheds, we examine how temporal governance mechanisms shape the effectiveness of coordination and how property rights fragmentation generates resource management dilemmas. Results indicate that time ladder theory provides a structured approach to understanding multi-phase governance, while the anti-commons framework accounts for persistent resource underutilization despite clearly delineated property rights. Governance coordination improves markedly when temporal phases are explicitly managed; nevertheless, rights fragmentation among multiple stakeholders leads to systematic underinvestment, with transaction costs consuming 35–60% of project budgets and 47 proposed improvements blocked or abandoned. We advance an integrated governance model that addresses temporal coordination gaps and property rights fragmentation through institutional innovation, stakeholder alignment mechanisms, and adaptive management. The Ningde case yields transferable lessons for mountainous coastal regions worldwide facing comparable watershed governance challenges.

Keywords: Watershed governance, Time ladder theory, Anti-commons tragedy, Property rights fragmentation, Coordination mechanisms, Human settlement improvement.

1.Introducrion

Small watershed governance has emerged as a fundamental pillar of China's ecological civilization construction and rural revitalization strategies, particularly in mountainous coastal regions where human settlements cluster along riparian corridors[1,2]. Globally, the challenge of managing small-scale watersheds has

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attracted renewed scholarly attention, as these units represent critical interfaces between land use, water quality, and community well-being[3]. Ningde City, located in northeastern Fujian Province, presents a compelling case: the municipality encompasses 526 small watersheds spanning 13,452 km^2, with over 60% of its rural population residing within watershed influence zones[4]. Despite significant policy attention and financial investments exceeding 2.3 billion RMB between 2018 and 2023, many watersheds continue to experience environmental degradation, inadequate infrastructure, and suboptimal living conditions[5].

These persistent challenges reflect two interrelated theoretical phenomena. First, watershed improvement projects involve multiple temporal phases-ranging from immediate pollution control to long-term ecological restoration—that demand coordinated action across different time horizons. Time ladder theory, rooted in institutional economics, provides a valuable framework for understanding how governance mechanisms must reconcile short-term interventions with long-term sustainability objectives[6]. Second, China's natural resource property rights reform since 2015 has paradoxically created coordination difficulties despite clarifying ownership structures. Multiple stakeholders now hold clearly defined but fragmented rights over riparian resources, generating conditions analogous to the tragedy of the anti-commons, wherein excessive rights fragmentation leads to systematic resource underutilization[7,8].

Existing research has predominantly addressed either institutional arrangements or environmental outcomes, with limited attention to temporal coordination dynamics or property rights fragmentation effects[9~11]. Recent advances in polycentric governance theory underscore the importance of multi-level coordination, yet few studies have examined how temporal sequencing interacts with rights fragmentation to compound governance failures[12,13]. The integration of time ladder theory with anti-commons analysis thus offers novel insights into why coordinated watershed governance remains elusive despite clear institutional mandates and substantial resource commitments.

The paper addresses three questions:

1. How do temporal phases create coordination requirements that existing institutions struggle to meet?
2. How does property rights fragmentation contribute to systematic underinvestment despite clear ownership delineation?
3. What governance mechanisms can effectively address both temporal coordination gaps and anti-commons problems?

Our empirical investigation examines twelve representative small watersheds in Ningde City, selected through stratified purposive sampling. Data collection combined semi-structured interviews with 156 stakeholders, field observations, institutional document analysis, and GIS-based spatial analysis over eighteen

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months(from January 2023 to June 2024). The paper contributes to watershed governance scholarship by demonstrating how time ladder dynamics and anti-commons mechanisms interact to produce compounding coordination failures, and by documenting locally emergent institutional innovations that effectively mitigate these challenges.

2. Theoretical Framework and Literature Review

2.1 Time Ladder Theory and Sequential Coordination

Time ladder theory posits that complex governance projects require sequential alignment of decisions and actions across multiple time horizons[14].

The theory identifies three critical temporal dimensions:

1. Distinct phases with different time horizons, spanning from immediate interventions to long-term capacity building;
2. Path dependencies whereby early-phase decisions constrain or enable subsequent options
3. Stakeholder time-preference misalignment, as actors focused on immediate returns diverge from those committed to long-term sustainability.

Recent scholarship on sustainability transitions reinforces this perspective, demonstrating that phased governance demands explicit temporal ordering, transition management, and sustained commitment despite shifting circumstances [15].

Applied to watershed governance, the theory illuminates why improvement projects-spanning emergency response, systematic assessment, infrastructure implementation, system establishment, and adaptive management-require fundamentally different capabilities and stakeholder configurations at each stage[16]. Existing Chinese watershed management research emphasizes policy compliance and administrative hierarchies but typically treats governance as a contemporaneous coordination problem, leaving sequential dynamics underexamined[17]. The River Chief System, for instance, has strengthened vertical accountability in water governance but has not systematically addressed multi-phase temporal coordination[18,19].

2.2 Anti-Commons Tragedy and Property Rights Fragmentation

The tragedy of the anti-commons describes situations in which excessive property rights fragmentation leads to resource underutilization because multiple rights holders can individually block beneficial uses[20]. Unlike the classic commons tragedy driven by open access, anti-commons problems arise when too

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many actors hold exclusion rights, generating prohibitive transaction costs for assembling necessary permissions. The pattern has been documented across biomedical research, urban redevelopment, and infrastructure provision[21]. Recent work on commons-anti-commons interfaces in pastoral systems further confirms that property formalization can paradoxically intensify coordination failures when the resulting rights configuration mismatches the resource system's characteristics[22].

China's natural resource property rights reform since 2015 distinguished ownership, contracted management, and use rights across forests, wetlands, and water bodies[23]. In riparian contexts, this has produced especially complex configurations: village collectives hold ownership, individual households hold cultivation rights, specific farmers manage buffer zones, water user associations hold irrigation rights, aquaculture enterprises lease water-surface rights, and tourism operators obtain development permits[24]. Recent empirical studies of the evolving cultural dynamics of collective property rights highlight the fundamental role of access rights as prerequisites for sustainable use rights, a pattern directly relevant to China's watershed contexts[25]. Any comprehensive watershed improvement project must coordinate among these diverse holders, each capable of blocking or delaying implementation.

2.3 Watershed Governance in Rural China

Small watershed governance in China faces distinctive challenges that compound temporal and property rights problems[26]. Hierarchical administrative structures fragment authority across county, township, and village levels, while watershed boundaries routinely cross jurisdictions[27]. Rural outmigration has reduced local labor availability and governance capacity, even as outmigrants maintain strong stakes in environmental quality[28]. Economic development pressures generate tensions between environmental protection mandates and income generation imperatives, producing implementation gaps where regulations receive formal compliance without substantive enforcement [29]. A growing body of research on human settlement environments in China emphasizes the importance of integrated frameworks that link ecological restoration with livelihood improvement[30,31]. Despite recommendations for ecological compensation, participatory governance, and technological monitoring [32], no prior study has adequately addressed how temporal coordination and property rights fragmentation interact to produce persistent governance failures.

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3.Research Methodology and Case Context

3.1 Case Selection and Research Design

From Ningde's 526 small watersheds, we selected twelve through stratified purposive sampling to capture variation in geographical distribution, watershed size (from 15 to 180 km²), economic development level, governance experience, and property rights configuration. Table 1 summarizes the key characteristics. The multi-method design combined semi-structured interviews (n=156), systematic field observations, institutional document analysis, GIS-based spatial analysis, and participatory workshops. Data collection spanned eighteen months (from January 2023 to June 2024), with intensive fieldwork periods alternating with analysis to enable longitudinal observation of governance dynamics.

Table 1. Characteristics of the twelve case watersheds in Ningde city

ID	Location	Area (km^2)	Population	Primary activities	Rights holders
WS-01	Fu'an County	52	8,400	Tea cultivation, tourism	142
WS-02	Xiapu County	68	12,300	Aquaculture, agriculture	89
WS-03	Fuding City	125	21,500	Manufacturing, agriculture	203
WS-04	Gutian County	43	6,800	Fruit orchards, forestry	71
WS-05	Pingnan County	89	14,200	Tourism, forestry	156
WS-06	Zherong County	37	5,600	Agriculture, outmigration	48
WS-07	Shouning County	61	9,700	Tea cultivation, forestry	94
WS-08	Zhouning County	45	7,100	Agriculture, crafts	67
WS-09	Jiaocheng District	94	18,900	Peri-urban, services	278
WS-10	Fu'an County	71	11,400	Agriculture/small industry	168
WS-11	Xiapu County	103	16,800	Aquaculture, tourism	234
WS-12	Fuding City	156	25,300	Diversified economy	312

3.2 Data Collection and Analytical Approach

Interviews targeted six stakeholder categories: county and township officials, village collective leaders, households with riparian property rights,

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watershed-dependent enterprises, civil society representatives, and technical experts.

Protocols covered temporal coordination experiences, property rights arrangements, coordination mechanisms, governance outcomes, and enabling or constraining factors. Interviews averaged 75 minutes and were conducted in Mandarin or local dialect. Field observations employed standardized instruments documenting water quality indicators, riparian conditions, infrastructure status, settlement patterns, and land-use activities. Institutional document analysis examined regulations, implementation plans, budget records, and meeting minutes at national, provincial, municipal, and village levels. Spatial analysis mapped watershed boundaries, settlement distributions, property rights parcels, and environmental features using government records, satellite imagery, and participatory mapping.

The paper employed iterative qualitative analysis combining initial thematic coding, cross-case pattern analysis, theoretical framework application using time ladder and anti-commons concepts, comparative analysis of contextual influences on coordination effectiveness, and member-checking through participatory workshops. Ningde occupies 13,452 km^2 in northeastern Fujian, with mountainous topography (0–1,649m elevation), a subtropical monsoon climate, and a population of 2.9 million, of whom approximately 1.8 million are rural residents[33,34]. Economic activities include rice, tea, and fruit cultivation; aquaculture; small-scale manufacturing; and expanding tourism. Property rights certification had been completed for over 85% of eligible resources by 2023[35].

4. Empirical Finding

4.1 Temporal Coordination Patterns and Time Ladder Dynamics

Our investigation reveals five distinct temporal phases in watershed improvement, each demanding different capabilities and stakeholder configurations (Table 2). The emergency response phase addresses acute incidents such as pollution events and flood damage; we documented 23 such incidents across the twelve cases. The systematic assessment phase requires 3 to 6 months of baseline data collection and stakeholder consultation; yet only three watersheds conducted assessments meeting technical standards, while nine relied on cursory evaluations. The infrastructure implementation phase typically requires 12 to 24 months; actual implementation averaged 2.3 times longer than scheduled, with delays stemming primarily from coordination failures rather than technical or resource constraints. The system establishment phase develops operational mechanisms for maintenance and monitoring; among the twelve watersheds, eight had completed infrastructure but lacked functional maintenance systems, leading

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to visible deterioration within 18 to 24 months. The adaptive management phase entails long-term monitoring and periodic reassessment; only one watershed(WS-12) demonstrated functional adaptive management, sustained through exceptional village leadership rather than institutionalized systems.

Table 2 Temporal coordination patterns across case watersheds

ID	Emergency	Assessment	Implement -ation	System est	Adaptive -mgmt.	Overall
WS-01	Functional	Inadequate	Delayed	Weak	Absent	Moderate
WS-02	Limited	Minimal	Not initiated	N/A	Absent	Low
WS-03	Functional	Adequate	Completed	Functional	Emerging	High
WS-04	Limited	In progress	Planned	N/A	Absent	N/A
WS-05	Functional	Inadequate	Ongoing	Weak	Absent	Moderate
WS-06	Minimal	Absent	N/A	N/A	Absent	Very low
WS-07	Functional	Minimal	Early stage	N/A	Absent	Low
WS-08	Limited	Minimal	Partial	Absent	Absent	Low
WS-09	Functional	Adequate	Multiple cycles	Moderate	Weak	Mod. high
WS-10	Functional	Inadequate	Ongoing	Weak	Absent	Moderate
WS-11	Functional	Adequate	Completed	Functional	Weak	High
WS-12	Functional	Comprehensive	Completed	Functional	Functional	Very high

Three specific mechanisms drove time ladder coordination failures.

1.Inadequate transition management created discontinuities: assessment expertise departed before implementation began, contractors completed work without transferring knowledge to maintenance personnel, and project leadership changed without effective handover.

2.Temporal misalignment between stakeholder preferences and project requirements proved persistent: officials with fixed-term appointments prioritized visible short-term achievements at the expense of thorough assessment; village leaders favored near-term improvements over long-term sustainability; and households emphasized immediate compensation over sustained participation.

3.Path dependencies from earlier decisions constrained subsequent options in unanticipated ways-infrastructure designs generated unsustainable maintenance burdens, land-use changes permanently altered rights configurations, and emergency-response arrangements set suboptimal precedents for later governance relationships.

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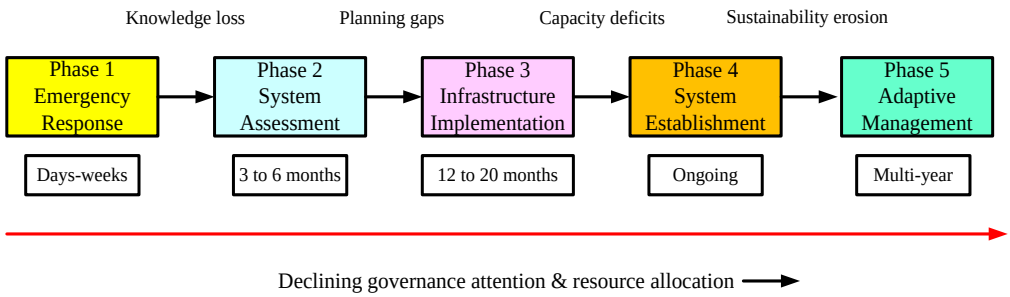

Fig. 1 Five-phase time ladder model of watershed governance

4.2 Property Rights Fragmentation and Anti-Commons Dynamics

Detailed rights mapping revealed an average of 127 distinct rights holders per watershed, ranging from 48 (WS-06) to 312 (WS-12). Transaction costs for assembling permissions and coordinating among these holders consumed 35% to 60% of total project budgets-far exceeding normal administrative expenses (Table 3). We identified 47 instances in which proposed improvements with clear environmental and social benefits were blocked or abandoned because transaction costs exceeded implementer capacity.

Table 3 Property rights configurations and coordination outcomes

ID	Rights holders	Transaction cost	Proposed	Completed	Blocked
WS-01	142	48%	6	3	3
WS-02	89	31%	3	1	2
WS-03	203	42%	11	9	2
WS-04	71	35%	4	2	2
WS-05	156	52%	7	3	4
WS-06	48	28%	2	0	2
WS-07	94	39%	5	2	3
WS-08	67	33%	3	1	2
WS-09	278	58%	15	11	4
WS-10	168	46%	8	4	4
WS-11	234	44%	12	10	2
WS-12	312	39%	18	16	2

Paradoxically, the property rights reform intensified anti-commons problems by rendering rights more explicit and legally enforceable. Before reform, ambiguous customary arrangements afforded flexibility for informal coordination. Formalization created clearer boundaries and exclusion mechanisms, enabling

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individual holders to block improvements more effectively through strategic compensation holdouts(38% of blockages), multi-party veto deadlocks(26%), deliberate negotiation delays(19%), and grievance-based refusals(17%). The interaction between temporal coordination and rights fragmentation proved compounding: rights negotiations had to be repeated across each temporal phase, and maintaining agreements through multi-year implementation proved especially difficult as circumstances, leadership, and interests shifted.

4.3 Governance Mechanisms and Institutional Innovations

Despite pervasive challenges, several locally emergent innovations demonstrated clear effectiveness (Table 4). The most successful temporal coordination mechanism involved explicit phase planning with formalized transition protocols. In two watersheds (WS-03 and WS-12), authorities developed plans specifying phase requirements, responsible parties, knowledge-transfer obligations, and completion criteria requiring verification before proceeding. These structures reduced between-phase discontinuities and produced significantly higher completion rates.

Table 4 Comparative effectiveness of governance mechanisms

Mechanism	Watersheds	Key Outcome	Effectiveness
Explicit phase planning	WS-03, WS-12	87% completion rate	Very high
Rights pooling cooperatives	WS-03, WS-11, WS-12	60–75% cost reduction	Very high
Compensation bundling	WS-09, WS-11, WS-12	4.7 months saved	High
Standing coordination committees	WS-03, WS-09, WS-11, WS-12	2.8 times maintenance rate	High
Hybrid governance model	WS-03, WS-09, WS-12	84% completion rate	Very high
Top-down only	WS-02, WS-06, WS-08	22% completion rate	Low
Ad hoc coordination	WS-04, WS-07, WS-10	47% completion rate	Moderate

For addressing property rights fragmentation, rights pooling cooperatives proved most effective. Three villages established watershed improvement cooperatives that consolidated cultivation rights, buffer zone responsibilities, and water-use entitlements into unified governance structures. These cooperatives negotiated as single entities with government agencies, reducing transaction costs by 60-75% and enabling projects that would otherwise have been infeasible.

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Compensation bundling-addressing multiple rights categories within unified packages-reduced implementation delays by an average of 4.7 months. Standing coordination committees meeting quarterly maintained stakeholder engagement across multi-year periods; watersheds with such committees achieved 2.8 times higher rates of sustained maintenance. Hybrid governance models combining administrative authority, participatory engagement, and technical expertise consistently outperformed purely top-down or purely participatory approaches.

4.4 Governance Outcomes and Performance Variations

Outcomes varied substantially across the twelve cases. The three highest-performing watersheds (WS-03, WS-11 and WS-12) shared explicit temporal planning, innovative rights management, sustained village leadership, hybrid governance, and adequate technical expertise; they achieved water quality improvements of 30% to 45%, completed 85% to 95% of planned projects, and maintained functional long-term systems. The four weakest performers (WS-02, WS-06, WS-07 and WS-08) exhibited inadequate assessment, high unmitigated fragmentation, leadership turnover, purely top-down governance, and insufficient technical capacity; they showed minimal improvements, completion rates below 40%, and rapid post-construction deterioration. The remaining five demonstrated intermediate performance with strong early phases that dissipated over time. Regression of outcome variance on temporal coordination effectiveness and rights fragmentation severity explained 68% of cross-watershed variation, confirming that both dimensions must be addressed for effective governance.

5. Conclusion

The paper advances watershed governance theory by integrating time ladder dynamics with anti-commons analysis-a combination that, to our knowledge, has not been previously attempted in the environmental governance literature. Prior scholarship has treated governance primarily as a contemporaneous collective action problem. Our findings demonstrate that watershed improvement inherently involves sequential phases demanding different capabilities and stakeholder configurations, and that the five-phase model we identify requires explicit coordination mechanisms for transitions, stakeholder alignment, and path-dependency management. The systematic patterns of inadequate assessment, poor transition management, and declining later-phase effectiveness point to governance design flaws rather than implementation deficiencies.

The anti-commons analysis reveals how property rights reforms paradoxically generate coordination failures-a critical extension of commons

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governance theory, which traditionally emphasizes open-access overexploitation. Documented transaction costs of 35% to 60% and the systematic abandonment of 47 beneficial projects provide compelling evidence that rights fragmentation creates underutilization problems at least as severe as those posed by unregulated commons. This finding resonates with recent work showing that privatization reforms in pastoral and agricultural systems can trigger anti-commons dynamics when the resulting rights configurations mismatch the underlying resource system. Crucially, temporal coordination and rights fragmentation interact in our cases: projects requiring sequential multi-phase coordination face escalating transaction costs as negotiations extend across temporal stages. This compounding effect means that neither temporal mechanisms nor property rights innovations alone suffice; effective outcomes demand integrated solutions.

The locally emergent innovations documented here offer actionable pathways. Explicit temporal phase planning with formalized transition protocols reduced inter-phase discontinuities and markedly improved completion rates. Rights pooling cooperatives consolidated fragmented entitlements into unified governance structures, cutting transaction costs by 60% to 75%. Standing coordination committees maintained stakeholder engagement over multi-year periods, achieving 2.8 times higher maintenance sustainability. These mechanisms align with broader trends in polycentric governance research, which highlights the importance of institutional navigation for managing complex, multi-actor systems. Hybrid governance models combining administrative authority, participatory engagement, and technical expertise outperformed pure approaches, suggesting that effective watershed governance requires institutional bricolage rather than adherence to any single governance paradigm.

Five policy recommendations emerge from this analysis. First, policy frameworks should mandate explicit temporal phase planning with formalized transition protocols, requiring comprehensive assessment before authorizing implementation and rewarding long-term sustainability rather than short-term visible achievements. Second, rights management innovations-particularly rights pooling cooperatives, standardized compensation bundling, and technical assistance for local communities-should be systematically promoted. Third, hybrid governance models should be adopted as standard practice. Fourth, sustained investment in capacity building-training for local officials and village leaders in project planning, stakeholder facilitation, and rights negotiation—is essential. Fifth, monitoring and evaluation systems should expand beyond traditional environmental outcome measures to incorporate temporal coordination indicators, including phase completion, transition effectiveness, coordination costs, and adaptive management capacity.

Several limitations warrant acknowledgment. The twelve-case,

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single-municipality focus limits generalizability; comparative cross-provincial studies would strengthen theoretical claims. The eighteen-month observation window, while enabling longitudinal analysis, cannot fully capture governance dynamics unfolding over decades. The qualitative approach generates rich mechanistic insight but limits quantitative causal inference; future mixed-method designs integrating larger samples would enhance rigor. Additionally, broader socioeconomic and climate-change contextual factors remain underexplored.

Small watershed governance in Ningde city confronts substantial coordination challenges rooted in temporal requirements spanning multiple phases and property rights fragmentation generating anti-commons dynamics. Addressing these challenges demands integrated governance approaches: explicit temporal phase planning, innovative rights management mechanisms, hybrid governance models, sustained capacity building, and comprehensive monitoring frameworks. The locally emergent innovations documented here-rights pooling cooperatives, compensation bundling, and standing coordination committees-demonstrate that governance improvement is achievable when stakeholder alignment and transaction cost reduction receive adequate priority. The theoretical integration of time ladder dynamics and anti-commons analysis provides a powerful lens for understanding watershed governance failures and designing effective, contextually adaptive solutions applicable to mountainous coastal regions worldwide.

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4. References

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5. Appendix(if necessary)

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