Comprehensive Assessment of the Inflection Point of China's Ecological Environment Quality: Post-Print

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Abstract

Since the Third Plenary Session of the 18th Central Committee, the intensification of ecological and environmental protection efforts in China has curbed the trend of ecological and environmental deterioration to a certain extent, thereby raising questions among policymakers regarding when China will reach the turning point in ecological and environmental quality. The question of "when the turning point will be reached" is directly related to the strategic deployment of ecological and environmental protection for the "century-strong nation" vision. Based on a redefinition of the connotation of the ecological and environmental quality turning point, this article establishes a measurement indicator system and predictive analysis framework for the ecological and environmental quality turning point, and assesses the timing of its emergence across different domains in China. The results indicate that around 2025, China can basically achieve the ecological and environmental quality turning point as measured by conventional monitoring indicators; however, the turning point as perceived by the public will not be realized until around 2035, and the turning point that accounts for new factors such as emerging pollutants will not be achieved until around 2050. The ecological and environmental protection strategy for the "century-strong nation" vision must not only address prominent current ecological and environmental problems and plan for the decisive battle against pollution and for ecological protection, but also make forward-looking arrangements for currently difficult-to-solve and future potential new ecological and environmental risks, preparing for the protracted campaign of pollution prevention and ecological protection. In this process, in addition to further improving the institutional system of ecological civilization, it is also essential to leverage the important role of science and technology in addressing the "bottlenecks" and "difficulties" in China's ecological and environmental challenges.

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Full Text

Comprehensive Research and Judgment on China's Eco-environmental Turning Points

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Abstract

Since the Third Plenary Session of the 18th Central Committee of the CPC, intensified ecological and environmental protection efforts have curbed the deterioration of China's eco-environment to a certain extent, prompting policymakers to ask when China will reach its eco-environmental quality turning point. The timing of this turning point is directly related to strategic planning for ecological and environmental protection toward the "Centenary Goals." This article redefines the connotation of the eco-environmental quality turning point, establishes an indicator system and predictive analysis framework for measuring it, and assesses when turning points will occur across different environmental domains in China. The results indicate that around 2025, China will basically achieve the turning point measured by conventional monitoring indicators. However, the turning point based on public perception will not occur until around 2035, and the turning point considering new factors such as emerging pollutants will be delayed until around 2050. To develop eco-environmental protection strategies for the "Centenary Goals," China must both address current prominent eco-environmental problems through targeted pollution prevention and ecological protection campaigns, and make forward-looking arrangements for currently intractable issues and potential future eco-environmental risks, preparing for protracted battles in pollution prevention and ecological protection. In this process, besides further improving the ecological civilization institutional system, it is essential to leverage the important role of science and technology in solving China's eco-environmental "bottlenecks" and "difficulties."

Keywords: eco-environmental quality, evolution, turning point, prediction, indicator system

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Introduction

Over the 40 years since reform and opening up, China's economy has achieved unprecedented development, greatly enhancing national comprehensive strength and people's living standards, but at the cost of high ecological and environmental degradation. Severe environmental pollution and ecological damage pose serious threats to residents' health and well-being. Improving eco-environmental quality has become an urgent public demand and an essential requirement for building a moderately prosperous society in all respects and creating a "Beautiful China." Since the 18th National Congress of the CPC, ecological civilization construction has been elevated to the height of the "Five-in-One" overall layout for developing socialism with Chinese characteristics. The Third Plenary

Session of the 18th Central Committee proposed accelerating the establishment of a systematic and complete ecological civilization institutional system to protect the eco-environment with institutions. In September 2015, the CPC Central Committee and the State Council issued the "Overall Plan for Ecological Civilization System Reform," forming the top-level design for ecological civilization reform in China. With increased ecological and environmental protection efforts, the deterioration trend of China's eco-environment has been curbed to some extent, prompting decision-makers to question when China will reach its eco-environmental quality turning point. The judgment of "when to reach the turning point" is directly related to the strategic deployment of ecological and environmental protection for the "Centenary Goals" and the 19th National Congress.

Although existing studies have assessed China's eco-environmental quality turning point, they have not clearly defined its connotation and often rely on a few conventional indicators from a single domain as the basis for measuring the "eco-environmental quality turning point." This approach overlooks the comprehensive, complex, and severe nature of China's eco-environmental problems, often leading to overly optimistic conclusions that are not conducive to formulating realistic ecological and environmental protection strategies and targets. Based on this, this study clearly defines the connotation of the eco-environmental quality turning point, establishes an indicator system and predictive analysis framework for measuring it, and assesses when turning points will occur across different environmental domains in China, aiming to provide support for formulating scientifically sound and development-stage-appropriate ecological and environmental protection strategies.

Connotation of Eco-environmental Quality Turning Point

Definition of Eco-environment

There are significant differences in understanding the concept of "eco-environment" among academia, government, and the public. This study combines scientific connotation, policy value, and public perception to define "eco-environment" as: natural elements and processes that directly affect human survival and development and have changed mainly due to human activities. This includes not only the narrowly defined "atmosphere, water, and soil" that are widely recognized, but also increasingly concerning yet still controversial ecological issues such as "urban heat island intensification, rural ecological landscape degradation, and eutrophication of oceans and lakes," as well as resource and disaster issues with strong social repercussions but not conforming to narrow ecological and environmental definitions, such as "declining groundwater levels and frequent flood disasters."

Connotation of Eco-environmental Quality Turning Point

The judgment of eco-environmental quality turning points is directly related to understanding their connotation. For eco-environmental management decision-making, the turning point can be understood from three aspects [Figure 1: see original paper]:

1. **Turning point based on conventional monitoring indicators (Point A in Figure 1).** This refers to the threshold point where eco-environmental quality measured by conventional monitoring indicators shifts from continuous deterioration to gradual improvement. China's annual environmental status bulletins and coastal marine environmental quality bulletins assess environmental quality status and evolution trends based on conventional monitoring indicators. Existing studies on China's eco-environmental quality turning point typically use conventional monitoring indicators as the measurement standard [1,2].
2. **Turning point based on public perception (Point B in Figure 1).** This refers to the threshold point of eco-environmental quality that is generally accepted by the public and can meet people's needs for a good eco-environment. In China, due to the lag in eco-environmental assessment system construction, government-released eco-environmental information often lacks some important indicators, making it difficult to comprehensively reflect actual conditions, and assessment results do not match public perception. Before establishing a systematic and complete monitoring and evaluation system, public perception should serve as an important standard for eco-environmental quality assessment. Considering that it often takes a long time from the peak of eco-environmental deterioration to achieving public-satisfactory quality, the public-perceived quality turning point requires higher standards and will arrive later than that based on conventional monitoring indicators.
3. **Turning point considering new factors (Point C in Figure 1).** This refers to the threshold point where eco-environmental quality can meet human health and survival development needs after considering factors such as unobserved indicators, regional differences, and recovery cycles. Regarding unobserved indicators, some emerging pollutants have attracted widespread academic attention but have not been incorporated into current environmental monitoring and management systems. By the time their potential hazards are discovered, they have already entered the environment through various channels in large quantities, posing significant environmental health risks. Incorporating these emerging pollutants into the monitoring and evaluation system will delay the arrival of the true eco-environmental quality turning point. Regarding regional differences, China's high eco-environmental impact industries are gradually transferring to central and western regions, meaning that while eastern regions see eco-environmental improvement, central and western regions

face deterioration risks. Meanwhile, western regions have more fragile and sensitive eco-environments with longer recovery cycles for ecological damage, making turning points more likely to be delayed. Regarding recovery cycles, different media have different recovery speeds after pollution reduction; some pollution can be quickly self-repaired by nature once emissions decrease, but others, such as river sediment contamination and soil heavy metal pollution, require longer recovery cycles, delaying the eco-environmental quality turning point.

Research Framework for Assessing Eco-environmental Quality Turning Points

Indicator Framework

Since different environmental media and ecosystems are affected by socioeconomic development to varying degrees, face different problems and governance difficulties, their turning points will occur at significantly different times, necessitating domain-specific assessments. Based on the understanding of the eco-environmental quality turning point connotation, this study establishes an indicator framework for assessing China's eco-environmental quality turning points , considering conventional monitoring indicators as well as new factors such as emerging pollutants, historical legacy issues, and climate change impacts.

Methodological Framework

Combining the Pressure-State-Response (PSR) model and the IPAT equation for environmental impact, this study establishes an analytical framework for factors influencing China's future eco-environmental evolution [Figure 2: see original paper]. The PSR model, proposed by the Organisation for Economic Co-operation and Development (OECD), is a causal framework for analyzing eco-environmental problems. It posits that human activities exert pressure (P) on the environment, changing eco-environmental quality states (S), and society responds (R) through environmental and economic policies [3]. The IPAT equation conveniently describes eco-environmental impacts from human activities, suggesting that a region's eco-environmental pressure is mainly influenced by three factors: population, per capita consumption (affluence), and resource intensity per unit of consumption (technology) [4]. Combining these two models provides a systematic and comprehensive analytical framework for eco-environmental quality evolution. Within this framework, the study predicts the timing of crossing eco-environmental quality turning points in different domains by combining scenario simulation, trend extrapolation, international experience comparison, and expert consultation.

Analysis of Factors Influencing China's Future Eco-environmental Evolution

Population Factors

Impact of Population Size. Considering the two-child policy, China's total population will reach approximately 1.45 billion by 2030. With population growth, demand for energy, water, and land resources, as well as urban domestic pollutant emissions, will increase significantly, intensifying pollution control pressure [5].

Impact of Urbanization. By 2030, China's permanent urbanization rate will increase from 58.5% in 2017 to about 70.0%, adding over 200 million new urban residents. This will further increase consumption and demand for water and land resources, as well as construction materials like sand, stone, cement, and steel, bringing sustained eco-environmental pressure.

Impact of Population Migration. From 2000 to 2010, China's interprovincial migration totaled about 105 million people. Additionally, China has a massive floating population of 244 million in 2017, whose distribution directly affects the spatial pattern of future eco-environmental pressure. The overall trend is that population will further concentrate in key economic zones and urban agglomerations [6], bringing significant eco-environmental pressure to these areas.

Economic Factors

According to World Bank predictions, China will become the world's largest economy and enter the ranks of high-income countries by 2030 [7]. During this process, whether the economy can successfully transform and upgrade will determine the eco-environmental pressure China faces. Fortunately, promoting transformation and upgrading has received high-level attention from the Party Central Committee and the State Council. The Fifth Plenary Session of the 18th Central Committee proposed the five development concepts of "innovation, coordination, green, openness, and sharing," whose implementation will help mitigate eco-environmental pressure from socioeconomic development.

China's economy is gradually shifting from an investment- and industry-dominated structure that relies heavily on external demand to one dominated by consumption and services that relies more on domestic demand. The tertiary industry's share of GDP will continue to rise, gradually becoming a pillar industry [8]. Industrialization has entered its later stage, and the high-speed development period of heavy chemical industry is nearing its end, with output from some high-energy-consuming and high-polluting industries approaching its peak [9]. Meanwhile, a new round of industrial revolution characterized by green, intelligent, and shared features is gaining momentum, and China is an ideal location for this revolution [10,11]. Overall, the economic structure will shift in a direction conducive to mitigating eco-environmental pressure.

However, the eco-environmental pressure from consumption will increase. According to Global Footprint Network (GFN) accounting, China's per capita ecological footprint rose from 1.95 global hectares in 2000 to 3.71 global hectares in 2014. Although still below the average level of developed countries, this is 1.87 times China's per capita ecological carrying capacity in 2014. Moreover, GFN accounting shows that most developed countries' per capita ecological footprint entered a relatively slow growth or stable stage only after exceeding at least 5.0 global hectares [12]. If China's ecological footprint evolution follows this pattern, it will face more severe ecological deficits as income rises.

The eco-environmental impact of international trade cannot be ignored. Since 2013, China has become the world's largest trading nation. Behind the huge trade surplus lies a net export of large amounts of environmental pollutants and ecological products and services [13]. By 2030, China's share in world trade may double [7], and the hidden import and export of ecological products and services will continue to grow. On the one hand, as the export structure moves up the value chain, the proportion of high eco-impact products in China's exports is expected to decrease. On the other hand, with stricter domestic ecological protection policies and growing household consumption, China's dependence on imported foreign ecological products and services will increase, while facing increasingly serious green trade barriers.

Technology Factors

The current new round of scientific and technological revolution and industrial transformation is emerging [14], which is expected to accelerate China's industrial green transformation. While promoting the transformation and upgrading of traditional industries, the new technological revolution will form several emerging industries that substitute traditional ones, making future industrial development dematerialized and significantly reducing the eco-environmental impact per unit of value creation.

Historical Legacy Issues

For some time to come, China's eco-environmental quality evolution will also be affected by historical legacy issues, such as large amounts of mining tailings [15], accumulated heavy metal and chemical pollution [16-18], and some irreversible ecological degradation and biodiversity loss. These historical legacy issues, accumulated over long periods, may cause eco-environmental risks to erupt successively in the future, delaying the arrival of China's eco-environmental quality turning point.

Climate Change

China's eco-environment is extremely sensitive to global climate change [19]. Future climate warming trends will further intensify, extreme weather and climate events may increase in frequency, precipitation distribution will become more uneven, and drought areas may expand. Such strong climate change will significantly impact natural ecosystems, changing ecosystem patterns, quality, and service functions, and increasing the risk of biodiversity loss.

Public Awareness

A survey shows that Chinese youth have significantly higher environmental awareness levels than other groups. However, their recognition of their own role in environmental protection is relatively lacking, and their willingness to pay for environmental protection is still weak [20]. Therefore, the improvement of public eco-environmental awareness in China will be more reflected in the demand for a good eco-environment, but there is still a large gap from true environmental awareness awakening and universal participation in eco-environmental protection.

Institutional and Policy Factors

Institutional and policy factors have crucial impacts on eco-environmental changes, determining how quickly China crosses the eco-environmental quality turning point. With the implementation of the national ecological civilization construction strategy and innovation-driven development strategy, and the construction and improvement of the ecological civilization "four beams and eight columns" institutional system, production methods will be forced to transform and production technology to advance. New energy technologies and green production methods are expected to accelerate the reversal of China's eco-environmental deterioration trend and promote early crossing of the eco-environmental quality turning point.

Engineering and Technology Factors

Since 2000, major ecological projects such as the Natural Forest Protection Program and the Grain for Green Program have been implemented successively, playing important roles in improving China's ecosystem quality and service functions [21]. During the 13th Five-Year Plan period, China will expand the Grain for Green Program, strengthen grassland protection, improve the natural forest protection system, completely stop commercial logging of natural forests, and implement ecological protection and restoration projects for mountains, waters, forests, farmlands, and lakes to build a solid ecological security barrier. The implementation of these major ecological projects will contribute to further improvement of China's ecological quality.

Turning Point Predictions by Environmental Domain

Atmospheric Environment Quality

China's sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and fine particulate matter (PM2.5) monitoring indicators are gradually improving. However, due to the long-term lack of effective control measures, volatile organic compound (VOC) pollution has not shown significant improvement, and ozone (O_3) pollution is still intensifying. VOCs include over 100 common compounds involving hundreds of industries, with numerous and dispersed emission sources, serious fugitive emissions, and difficulty in centralized collection and treatment, posing enormous challenges for emission reduction [22]. O_3 has become another secondary pollutant troubling urban air quality after PM2.5. From 2013 to 2017, O_3 pollution in 74 cities implementing the new standard's first-phase monitoring significantly intensified. O_3 generation is complex and highly correlated with other air pollutants like NOx and VOCs, making prevention and control difficult [23], with further deterioration risks in the coming period.

Considering current atmospheric environmental quality status, trends, and various influencing factors, the turning point based on conventional monitoring indicators is expected around 2020-2025. However, achieving good atmospheric environmental quality that satisfies the public will take until 2030-2035, while the turning point considering new factors such as VOCs, O_3 pollution, and climate change will be delayed to around 2040.

Water Environment Quality

China's chemical oxygen demand (COD) and ammonia nitrogen (NH_3-N) emissions have entered a continuous decline channel, accompanied by a steady increase in the percentage of river sections with water quality better than Class III. However, lake and wetland water environmental quality has not shown sustained and obvious improvement trends due to long water exchange cycles and accumulated pollutants in sediments and along lake shores. If emerging pollutants not currently monitored or managed, such as persistent organic pollutants, antibiotics, microplastics, and endocrine disruptors, are considered, China's water environmental quality will further deteriorate in the coming period. This judgment is based on four reasons: (1) some watersheds in China are already severely polluted by these emerging pollutants [24,25]; (2) research on these pollutants is insufficient, lacking necessary basic data and cost-controllable reduction and treatment technologies; (3) these pollutants have not received government attention and lack effective control measures; and (4) these pollutants are difficult to degrade and accumulate in the environment.

Considering all factors, the water environment quality turning points based on conventional monitoring indicators, public perception, and new factors are expected around 2025-2030, 2035-2040, and 2050, respectively. Achieving a fundamental transformation of water environmental quality by 2035 and the goal of building a "Beautiful China" by 2050 will require significant additional effort.

Soil Environment Quality

According to the 2014 national soil pollution survey, China's soil environment is generally not optimistic, with concerning quality of cultivated land soil and prominent environmental issues at industrial and mining abandoned sites [26]. With rapid socioeconomic development, various pollutants including heavy metals, phthalates, antibiotics, radionuclides, and pathogenic bacteria continue to enter the soil environment in multiple forms, ways, and pathways, expanding the area, increasing the degree, and intensifying the harm of soil pollution. Soil environmental problems are becoming diverse and complex, making risk control more difficult [27,28]. Meanwhile, climate warming may cause some pollutants adsorbed in soil to shift from fixed to free states, intensifying soil environmental risks. Therefore, China's soil environmental quality faces further deterioration risks in the coming period.

Compared with atmospheric and water environments, achieving the soil environment quality turning point is more difficult. The turning points based on conventional monitoring indicators, public perception, and new factors are expected around 2040, around 2050, and after 2050, respectively. Soil pollution will become a major bottleneck for building a "Centenary Strong Nation" and a "Beautiful China," requiring medium- and long-term pollution prevention and control deployment.

Rural Environment Quality

China's rural areas currently face severe environmental pollution problems. With rural economic development, per capita waste generation and composition are increasingly approaching urban levels. Meanwhile, rapid development of planting and breeding industries has dramatically increased the production of human, livestock, and poultry manure and crop straw. The rural environment faces a coexistence of point and non-point sources, domestic and production, and exogenous and endogenous pollution [29]. Due to the dispersed nature of rural production and living, centralized treatment of various pollutants is difficult and costly. Although China has strengthened rural environmental remediation in recent years, treatment capacity cannot keep pace with destruction speed, and the environment continues to deteriorate. However, with rural population reduction and increased pollution prevention efforts, the rural environmental deterioration trend is expected to ease in the coming period.

Considering all factors, the rural environment quality turning points based on conventional monitoring indicators, public perception, and new factors are expected around 2025-2030, 2030-2035, and around 2050, respectively.

Coastal Marine Environment Quality

China's annual marine environmental status bulletins show that in recent years, the coastal marine environmental quality measured by conventional indicators has remained basically stable and generally good. However, pollution in nearshore local sea areas, especially estuaries and bays, caused by land-based pollution discharge remains severe. As land-based pollution discharge decreases, conventional pollution will ease. However, due to the lack of effective control measures, pollution from some emerging pollutants will intensify. Studies show that concentrations of organochlorine pesticides, polychlorinated biphenyls, and antibiotics in China's coastal waters are significantly higher than in other countries and regions; endocrine disruptor concentrations and microplastic content are equal to or lower than other regions, but concentrations in rivers entering the sea are high, and future pollution will further intensify [30,31].

With reduced land-based emissions, the coastal marine environment quality turning point based on conventional monitoring indicators is expected around 2020-2025. The public-perceived turning point will arrive around 2035-2040, while the turning point considering numerous emerging pollutants is expected around 2050.

Terrestrial Ecosystem Quality

The National Ecological Environment Ten-Year Change Remote Sensing Survey and Assessment show that from 2000 to 2010, China's terrestrial ecosystem quality generally improved, with significantly enhanced service functions [21]. With optimized territorial development patterns and industrial structure, as well as implementation of ecological protection and restoration projects, China's terrestrial ecosystem quality will further improve. However, considering China's poor ecological quality baseline and still prominent ecological problems, ecological quality improvement must follow natural laws and cannot achieve qualitative leaps in the short term. For a long time to come, China will face problems of poor ecological quality, prominent ecological issues, and insufficient supply of high-quality ecological products. Meanwhile, driven by population concentration and development activities, ecological quality in central and western emerging urban agglomeration areas and "Belt and Road" node cities faces further deterioration risks.

Terrestrial ecosystem quality is expected to achieve a turning point from overall improvement with local deterioration to comprehensive improvement around 2020-2025. However, reaching the public-perceived turning point that meets public demand for high-quality ecological products will take until around 2050.

Wetland Ecosystem Quality

For a long time, large-scale agricultural reclamation, drainage channel construction around wetlands, excessive reclamation for aquaculture, fishing, and grazing—especially in the past 20-30 years with large-scale development along rivers, lakes, and coasts—have brought enormous pressure to wetland ecosystems. China's natural wetlands have continued to decrease while artificial wetlands have increased, causing their functions as refuges for rare species and as environmental and hydrological regulators to decline. This has led to continuous biodiversity loss, severe environmental pollution, river cutoff, wetland drying, and frequent floods in surrounding areas [32-34]. Although China has strengthened wetland protection and restoration in recent years, threats from socioeconomic development to wetlands are difficult to alleviate in the short term. Climate change also brings potential negative impacts to wetland ecosystems by affecting water temperature, soil temperature, and hydrological regimes, and wetland self-recovery requires long cycles. Therefore, China's terrestrial wetland ecosystem quality faces further deterioration risks in the coming period.

Compared with terrestrial ecosystems, degraded wetland ecosystems are more difficult to restore, and their quality turning point will arrive later. The turning point from continuous deterioration to gradual improvement is expected around 2025-2030, while the public-perceived turning point meeting public demand for high-quality ecological products will be achieved around 2050.

Coastal Marine Ecosystem Quality

For a long time, influenced by factors such as coastal reclamation, land-based pollutant discharge, overfishing, invasive alien species, and climate change, China's coastal marine ecosystem quality has continued to deteriorate. Artificial coastlines have grown disorderly, natural coastlines have continuously decreased, coastal wetlands have shrunk dramatically, and survival habitats for important resource organisms such as coral reefs, mangroves, and estuary areas have been lost on a large scale [35,36], damaging ecosystem health. China's annual marine environmental status bulletins show that typical ecosystems in China's coastal estuaries, bays, tidal flats, coral reefs, mangroves, and seagrass beds are mostly in sub-healthy or unhealthy conditions. Although the recorded number of red tides in China shows a declining trend, the proportion of toxic and harmful algal red tides is rising, and their scale is increasing. In the coming period, China's coastal marine ecosystem quality will continue to be affected by long-term impacts from intensive human activities and climate change, making it difficult to reverse the continuous deterioration trend in the short term.

Compared with terrestrial wetland ecosystems, coastal marine ecosystems are influenced by more factors, so the turning point for ecosystem quality improvement will be later. The turning point from continuous deterioration to gradual improvement is expected around 2030-2035, while the public-perceived turning point will take at least until around 2050.

Overall Assessment of Eco-environmental Quality Turning Points

The next 5-10 years are an important strategic opportunity period for China's socioeconomic development and also a period when resource, environmental, and ecological constraints intensify and contradictions become prominent. Medium-to-high-speed economic growth, large-scale urbanization, path dependence on traditional industrialization, and growing household consumption will bring continuously increasing pressure on China's eco-environment, posing risks of continued deterioration. Meanwhile, some historically accumulated environmental pollution and ecological damage problems may erupt 集中 ly, and pollution from emerging pollutants may intensify. Without active protection measures, some key economic zones, urban agglomerations, and ecologically fragile areas will face extremely severe resource constraints, eco-environmental deterioration, and intensified ecological problems, seriously endangering China's sustainable development.

The next 5-10 years are also a crucial period when ecological civilization construction is fully integrated into China's "Five-in-One" overall layout for developing socialism, eco-environmental system reform is deeply advanced, and socioeconomic development enters a new normal. Improvements in science and technology, transformation of economic development concepts and modes, construction and improvement of ecological protection institutions, increased ecological protection investment, and awakening of public ecological awareness will help enhance society's response to eco-environmental protection, optimize response modes, and mitigate eco-environmental pressure and risks.

Different environmental media and ecosystems bear different eco-environmental pressures, face different problems and governance difficulties, and will reach their turning points at significantly different times . Atmospheric pollution control is relatively easy—once pollutant emissions are controlled, environmental quality can improve quickly—so it will be the first to cross various turning points. In contrast, due to long recovery cycles of lakes, wetlands, and coastal marine environments and the influence of numerous emerging pollutants, various terrestrial and coastal water environment quality turning points will lag corresponding atmospheric environment turning points by about 5-10 years. Soil pollution control faces greater challenges, and its turning points will be substantially delayed compared to terrestrial atmospheric and water environment turning points, becoming a key bottleneck for achieving fundamental eco-environmental quality transformation and basically building a "Beautiful China" by 2035. Regarding ecosystems, terrestrial ecosystems will be the first to cross various turning points; wetland ecosystems require longer recovery cycles after damage, so their turning points will be 5-10 years later; coastal marine ecosystem quality will also be affected by long-term impacts from fishery and aquaculture, overfishing, and climate change, making its turning points even later.

Overall, in the coming period, China will be in a stage where eco-environmental quality improvement and deterioration coexist, characterized by overall improvement with local deterioration, improvement in some domains and deterioration in others, and gradual improvement in conventional monitoring indicators while emerging unconventional indicators continue to deteriorate. Around 2025, China will basically achieve the shift from gradual deterioration to gradual improvement based on conventional monitoring indicators, but there remains a large gap from achieving public-perceived satisfaction and turning points considering new factors. Achieving the goals proposed in the 19th CPC National Congress Report—basically building a "Beautiful China" by 2035 and fully building it by 2050—will still require arduous efforts.

Recommendations for Accelerating China's Crossing of Eco-environmental Quality Turning Points

The timing of eco-environmental quality turning points is influenced by various factors with considerable complexity and uncertainty. The degree of socioeconomic development transformation and eco-environmental protection efforts play crucial roles. If China accelerates green transformation of socioeconomic development, improves the scientific and rational ecological civilization institutional system, increases environmental protection investment, and fosters broad participation from all society and market entities in eco-environmental protection, it can hopefully achieve the "Beautiful China" goals proposed in the 19th CPC National Congress Report ahead of schedule. However, promoting green transformation and eco-environmental improvement must follow socioeconomic and natural evolution laws to avoid excessively aggressive strategies that cause high socioeconomic costs. Therefore, transformation and protection strategies for the "Centenary Strong Nation" must both demonstrate determination to fight decisive battles addressing current prominent problems and prepare for protracted battles solving currently intractable or future potential risks.

1. **Focus on public satisfaction to fight decisive battles in pollution prevention and ecological protection, targeting current "pain points" and "weaknesses."** After crossing the turning point based on conventional monitoring indicators, further efforts are needed to achieve the public-perceived turning point. By 2035, strategic priorities should include intensifying governance of cultivated land pollution, planting and breeding industry pollution to ensure food safety; formulating more targeted regional policies and performance evaluation systems based on major function oriented zoning to strengthen regional regulation; enhancing pollution control and ecological restoration in densely populated key urban agglomerations and rural areas to create good living environments; strengthening treatment of historically accumulated mining tailings, industrial contaminated sites, and deep pits of industrial wastewater, as

well as ecological restoration in degraded areas to settle historical eco-environmental debts.

2. **Focus on comprehensively safeguarding residents' health and well-being to fight protracted battles in pollution prevention and ecological protection, addressing "bottleneck" issues for the "Centenary Strong Nation."** Improve the eco-environmental governance system with government, enterprise, and social participation to form long-term mechanisms for pollution prevention and ecological protection. After crossing the public-perceived turning point, further strengthen governance of eco-environmental problems that are difficult for the public to perceive but endanger public health and well-being, achieving comprehensive crossing of turning points considering new factors. Strengthen forward-looking arrangements in science and technology, standards, institutions, and legislation for various emerging pollutants, establish monitoring and early warning mechanisms for resource and environmental carrying capacity, and build risk prevention and pollution control systems for emerging pollutants. Simultaneously, make medium- and long-term plans for key eco-environmental bottlenecks for the "Centenary Strong Nation," such as soil pollution, to promote gradual improvement of China's eco-environmental quality in an orderly manner.

3. **Leverage the key role of scientific and technological innovation in solving eco-environmental problems.** For emerging pollutants, make forward-looking arrangements for basic research, such as toxicological and environmental health risk assessments of various chemicals, environmental criteria for emerging pollutants based on human and ecological health, investigation of sources, sinks, distribution characteristics, and environmental health risk assessments of emerging pollutants, environmental quality and emission standards, and pollution control technologies, providing scientific and technological support for China to cross the turning point considering new factors and fully build a "Beautiful China."

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Note: Figure translations are in progress. See original paper for figures.