Report

Current Biology

Hidden Loss of Wetlands in China

Highlights

- We examine the sufficiency of the "no net loss" goal for managing China's wetlands
- China's wetlands showed a net increase of 1,548 km^2 between 2000 and 2015
- Conservation efforts to restore wetlands did not offset human-caused wetland losses
- The "no net loss" goal should be used carefully as a target for wetland conservation

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In Brief

Xu et al. examine the sufficiency of the "no net loss" goal for managing wetlands. China's wetlands had a net increase of 1,548 km^2 between 2000 and 2015. This number hides considerable complexities of wetland changes such as those in composition and ecological functions. The "no net loss" goal should not be used alone for wetland conservation.

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Report

Hidden Loss of Wetlands in China

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SUMMARY

To counter their widespread loss, global aspirations are for no net loss of remaining wetlands [1]. We examine whether this goal alone is sufficient for managing China's wetlands, for they constitute 10% of the world's total. Analyzing wetland changes between 2000 and 2015 using 30-m-resolution satellite images, we show that China's wetlands expanded by 27,614 km^2 but lost 26,066 km^2—a net increase of 1,548 km^2 (or 0.4%). This net change hides considerable complexities in the types of wetlands created and destroyed. The area of open water surface increased by 9,110 km^2, but natural wetlands—henceforth "marshes"—decreased by 7,562 km^2. Of the expanded wetlands, restoration policies contributed 24.5% and dam construction contributed 20.8%. Climate change accounted for 23.6% but is likely to involve a transient increase due to melting glaciers. Of the lost wetlands, agricultural and urban expansion contributed 47.7% and 13.8%, respectively. The increase in wetlands from conservation efforts (6,765 km^2) did not offset human-caused wetland losses (16,032 km^2). The wetland changes may harm wildlife. The wetland loss in east China threatens bird migration across eastern Asia [2]. Open water from dam construction flooded the original habitats of threatened terrestrial species and affected aquatic species by fragmenting wetland habitats [3]. Thus, the "no net loss" target measures total changes without considering changes in composition and the corresponding ecological functions. It may result in "paper offsets" and should be used carefully as a target for wetland conservation.

RESULTS

"The biosphere, upon which humanity as a whole depends, is being altered to an unparalleled degree across all spatial scales" [4], while biodiversity is declining faster than at any time in human history, nearly everywhere, and at all levels [5]. Wetlands, possessing abundant vegetation and diverse animal and plant species, play a pivotal role in global biodiversity conservation. Yet wetlands are one of the most threatened ecosystems. They are central to meeting many of the United Nations' 17 Sustainable Development Goals (SDGs), contributing directly or indirectly to 75 (out of 230) SDG indicators [6]. Alarmingly, 35% of wetlands have been lost globally since 1970. Many national policies adopt a "no net loss" target to combat this trend. For example, in 1987, the U.S. Environmental Protection Agency (EPA) convened the National Wetlands Policy Forum (NWPF), refocusing the country's wetland regulation toward a policy of no net loss [1]. Under this policy, when a proposal is made to drain or fill a wetland, the proposers must restore or construct wetlands nearby that are of the same or greater size and levels of function to offset the loss (https://www.epa.gov/wetlands/wetlands-restoration-definitions-and-distinctions). Several methods of realizing the no-net-loss target have developed since the late 1970s, including permittee-responsible mitigation and third-party mitigation (i.e., wetland mitigation banking and in-lieu fee mitigation) [7]. Overall, freshwater wetlands have experienced a slight increase in area between 2004 and 2009 [8]. Unfortunately, this policy ignores important features of wetlands and wetland changes, such as category, location, temporal scale of change, ecological functions, and the forces behind those changes (e.g., [9]), likely resulting in "paper offsets" [10].

In the context of several key ecological functions or services and especially biodiversity, we examine the suitability of no net loss as a wetland conservation target using data of wetland changes in China between 2000 and 2015. Details are in STAR Methods and Supplemental Information. We propose a framework for effective wetland analysis and conservation practice. It aims to detail changes over space and time, by category and

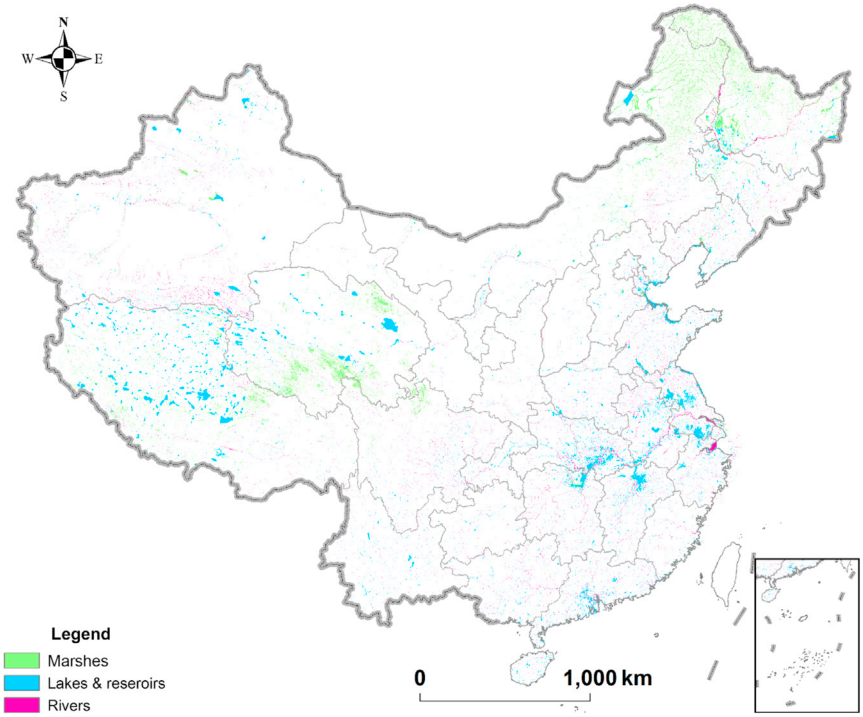

Figure 1. Spatial Pattern of Wetlands in China in 2015

ecological functions, and seek insights into their causes. Our study will contribute to fulfilling the commitments for biodiversity conservation in response to the 2020 Global Biodiversity Targets and in setting up post-2020 targets.

Changes of Wetlands by Category and in Space

Wetlands of various kinds cover 359,138 km^2 (3.8%) of mainland China's territory (Figure 1) and are unevenly distributed across it. Among the three categories, marshes had the highest proportion (41.5%), followed by lakes plus reservoirs (41.3%) and rivers (17.2%). Marshes are mainly in northeast China and the Qinghai-Tibetan Plateau, with lakes plus reservoirs in the Qinghai-Tibetan Plateau and lower reaches of the Yangtze River (Figure 1). From 2000 to 2015, wetlands in China showed a net gain of 0.4% (or 1,548 km^2). Marshes decreased by 4.8% (or 7,562 km^2). Lakes plus reservoirs showed a net gain of 5.8% (8,169 km^2). Rivers received a small net gain of 1.5% (941 km^2) (Figure 2A).

Wetlands expanded mainly in the Qinghai-Tibetan Plateau, west of the Xinjiang Autonomous Region, the Three Gorges Reservoir Area, and the middle and lower reaches of the Yangtze River (Figure 3). In total, 27,614 km^2 of wetlands was converted from other ecosystems, among which 35.8% was from agricultural land, 27.6% from grassland, and 9.5% from forest and shrubs. Of the wetlands gained, 77.3% was to open water surface (63.1% to lakes plus reservoirs and 14.2% to rivers) and 22.7% to marshes (Figure 2B).

Wetlands shrank mostly in the Song-Liao Plain in the northeast and the lower reaches of the Yangtze River in the east (Figure 3). A total of 26,066 km^2 of wetlands converted to other land cover types, with 47.7% to agricultural land, 14.5% to grassland, and 13.8% to urban areas. Of the lost wetlands, 46.2% was from marshes, 42.7% from lakes plus reservoirs, and 11.2% from rivers (Figure 2C).

Driving Forces of Wetland Changes

Agricultural Land Expansion and Urbanization

Agricultural land and urban expansion are the major factors causing wetland loss. They accounted for 47.7% (12,439 km^2) and 13.8% (3,593 km^2) of the total area of loss, respectively. Current land development policies drove these changes. Urbanization might also promote wetland loss outside urban areas. Given the magnitude of the loss of cultivated land during the rapid urbanization, China adopted the ''cultivated land balance policy'' in 1996 to retain the existing amount of cultivated land nationally for food security [11].

Additionally, the policies of direct agricultural subsidies on crops after 2004 and cancelling taxes on crops from 2006 might have also encouraged farmers to convert wetlands to cropland to get more income [12]. Unlike forest, policies consider marshes to be ''unutilized land'' and so easily marshes are converted to urbanized areas. Four major city clusters in the east (Beijing-Tianjing-Hebei, Yangtze River Delta, Pearl River Delta, and Middle Reach of the Yangtze River) were responsible for 64% of the total area converted.

Wetland restoration policy, climate change, and dam construction are the major factors for wetland expansion. They explain 24.5% (6,765 km^2), 23.6% (6,505 km^2), and 20.8% (5,731 km^2) of the total expansion, respectively. Thus, wetland loss by agricultural land and urban expansion was 2.4 times that of wetland expansion due to wetland restoration policy. The conservation efforts in wetlands did not offset wetland losses.

Climate Change

In the sparsely populated Qinghai-Tibetan Plateau that accounts for 84% of the total glacial area in China [13], the temperature increased over the past 50 years twice as much as the global rate [14] with largely stable precipitation [15]. The warming climate caused glaciers to melt and retreat and thus increased water supply to rivers, lakes, and even to pastures, causing wetland expansion. Large lakes such as Nam-Co and Siling-Co showed obvious expansion due to melting glaciers [16].

Dam and Reservoir Construction

From 2000 to 2015, China constructed more than 80 major dams, mainly in the southwest. Of them, the Three Gorges Dam flooded a large discharge area in 2003, creating a giant artificial lake of >1,000 km^2 [17]. The Danjiangkou Reservoir, a water source for the South-to-North Water Transfer Project [18], expanded water surface area with an increase in dam height. With the dam and reservoir construction, the original lands including

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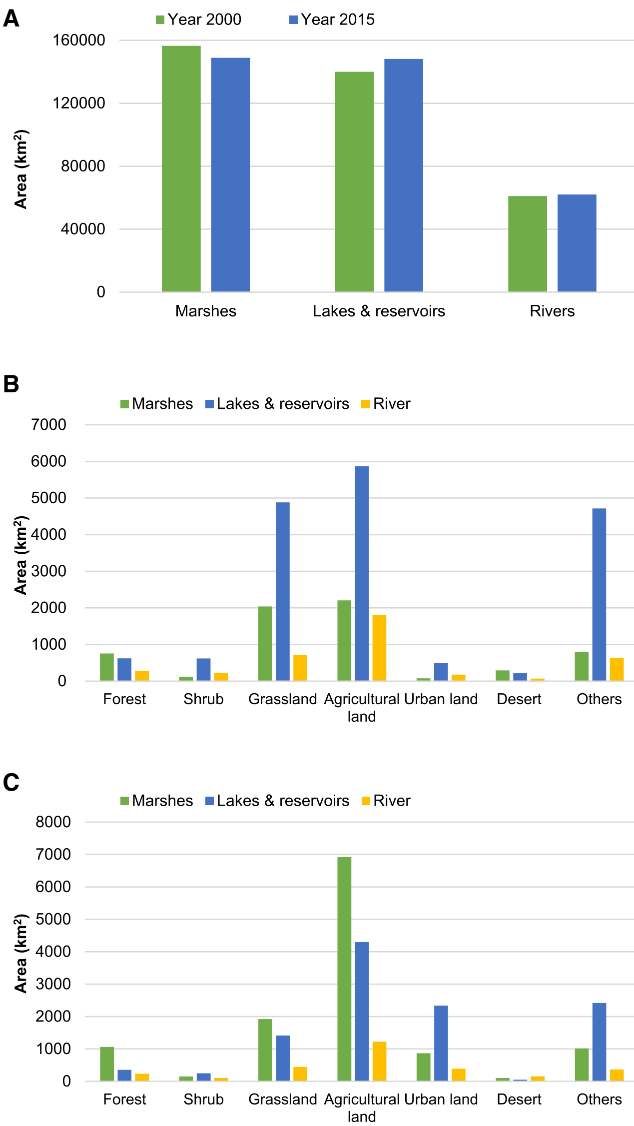

Figure 2. Wetland Area Changes and Conversion from 2000 to 2015

(A) Changes of wetland area by categories.

(B) Conversion from other land cover types to wetlands.

(C) Conversion from wetlands to other land cover types.

See Figure S1 for major reservoirs and dams constructed between 2000 and 2015.

agricultural land, forest, shrub, and urban areas became open water surface.

Wetland Conservation and Restoration Projects

After the massive flooding of the Yangtze in 1998 [19], governmental policies aiming to restore and conserve wetlands included the National Wetland Conservation Action Plan in 2000, the National Wetland Conservation Program (NWCP) (2002–2030) in 2003, and short-term NWCP implementation plans, every 5 years. China initiated several large-scale wetland restoration projects after the massive flooding in the middle and lower reaches of the Yangtze River in 1998. Since then, the central government has invested over 10 billion Yuan ($1.5 billion) converting villages and agricultural land in the flood discharge areas to lakes and marshes in four provinces of the lower reaches of the Yangtze River, to leave space for flood discharge [20]. With this policy, over 2 million people were moved from the flood discharge areas around Poyang Lake, Dongting Lake, and other places in the lower reaches of the Yangtze River. Over 2,000 km^2 of land was left for flood discharge [20]. Since 2000, the Chinese government has implemented the National Wetland Action Plan. It aims to conserve natural wetlands and convert reclaimed low-yield croplands back to wetlands [21]. In the same period, China established more than 200 new wetland nature reserves at the national and regional levels. Wetland restoration projects throughout China greatly contributed to the total wetland expansion. Other related policies, though not explicitly focusing on wetland conservation, also contributed. An example is the Pilot Functional Zoning Plan, issued in 2008, that provided financial compensation in key ecological zones. Many such zones are located within or at least partially overlapped with key wetlands in the country [22].

The above factors explain 68.8% of the total expansion and 61.5% of the total loss. A large proportion of wetlands was also subjected to two-way changes between wetland and grassland, along with those between wetland and bare land. For instance, the conversion from wetlands to grasslands was 14.5% of wetland loss. However, these types of conversions were mainly related to the hydrological processes in these regions. Changes in water use for various purposes (e.g., agricultural, industrial, and domestic purposes), climate (e.g., temperature, precipitation, and evapotranspiration), or both, caused these wetland conversions. We cannot distinguish the contributions of related driving factors due to the lack of relevant data and so do not take them into account.

DISCUSSION

Unlike the rapid shrinkage in the past decades before 2000 [23], total wetland area showed a slight increase in China between 2000 and 2015. Nonetheless, this summary statistic hides considerable risks of wetland loss and degradation. First, the increase in total area did not reflect changes among various wetland categories. It hides decreases of the most vulnerable wetland types (e.g., marshes). Second, such statistics hide the contribution of different anthropogenic and natural driving factors. After quantifying the contribution of different factors, we found restoration efforts in wetlands did not offset wetland losses by various human activities. Third, such numbers overlook the sustainability of the associated wetland expansion. The glacial meltwater in the Qinghai-Tibetan Plateau caused by climate change will increase in the near term, but likely decrease in the long term as the glaciers shrink [24, 25]. The newly formed wetlands over that region will probably dry up when there is little snowpack or glaciers left to melt [26].

According to a meta-analysis of 102 published studies worldwide on wetland ecosystem assessment, increases in water surface (due to elevated flow release) had different impacts on biodiversity for various wetland subtypes. Biodiversity declined with water surface increases in lakes, marshes, and artificial wetlands (mainly equivalent to reservoirs in this article), yet biodiversity increased with water surface increases in rivers [27]. Among all net gains in our study, the largest portion (8,169 km^2) takes

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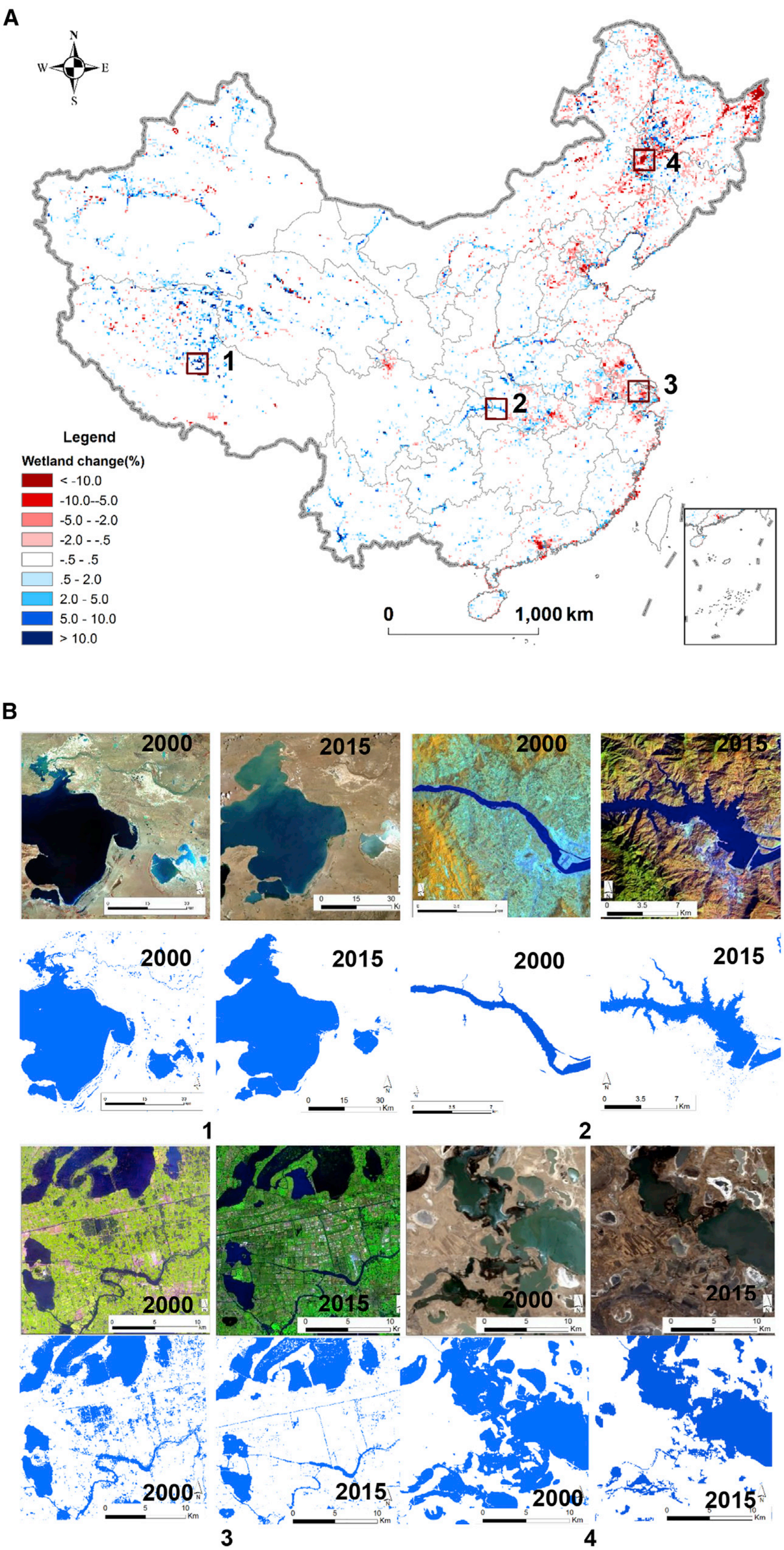

Figure 3. Spatial Distribution and Examples of Wetland Change from 2000 to 2015

(A) Spatial distribution. The fraction of wetland change within a 10-km by 10-km grid cell is shown. Red represents wetland decrease, and blue represents wetland increase.

(B) Examples of wetland change: (1) Qinghai-Tibetan Plateau, (2) Three Gorges Reservoir Area, (3) lower reaches of the Yangtze River Basin, and (4) Song-Liao Plain.

Satellite TM images (top) are from 2000 and 2015, band combination RGB 543. Below is our wetland classification of those images.

See Figure S2 for expanded wetlands and different distances to residential areas in the Qinghai-Tibetan region.

place in lakes plus reservoirs, which will likely decrease wetland biodiversity. The net gains of water surface in rivers might increase biodiversity, but their total area is small (941 km^2). Therefore, the increase in water surface, although with some degree of uncertainty, is unlikely to offset the loss in biodiversity.

Wetland changes between 2000 and 2015 are likely to jeopardize wildlife. For instance, the wetland loss in eastern China might threaten bird wintering and migration across eastern Asia [2]. Besides, although dam construction has increased the water surface area, it has caused several problems. First, the increased water surface flooded the original habitat of terrestrial species such as the endangered peafowl (*Pavo muticus*) and caused local extinction (https://tech.sina.com.cn/d/a/2019-02-13/doc-ihqfskcp4757077.shtml). Second, dam construction also caused wetland fragmentation and isolation between rivers and lakes, threatening aquatic species such as Yangtze finless porpoises (*Neophocaena asiaeorientalis*) that use these habitats upon migration across a much larger geographic region [3]. Third, dam construction also caused wetland shrinkage and degradation downstream. For instance, Poyang Lake and Dongting Lake—the largest freshwater lakes in China—have shrunk during the dry season since 2003 due to the operation of the Three Gorges Dam [28]. Such shrinkage affects their use by birds during the winter.

Simply maintaining no net loss of wetlands is insufficient: the increase in total wetland area from 2000 to 2015 does not indicate improvements in the quality of China's wetlands. Under the background of rapid urbanization and global climate change, several measures are needed urgently to complement the total area control policy.

First, natural wetlands must be classified as one land-use type (rather than as unutilized land) in the land-use classification system and set as protection targets. According to data from created or restored wetlands and five natural wetlands in central Ohio, USA [9], replacement wetlands are not functionally equivalent to original ones. Conversion of natural wetlands into restored or created wetlands could give rise to large-scale damages such as a reduced capacity for nitrate removal and carbon sequestration. Strict protection measures must be implemented to include the establishment of protected areas and ongoing ecological redlining for wetland (especially marsh) conservation. Redlines establish boundaries designed to conserve wetland areas of significant biodiversity and ecosystem services and to prevent wetland loss [29]. They could be used to prevent wetland loss from urban and agricultural land conversion. Ecological redlining and planning should be prioritized and aligned with other spatial planning, avoiding planning conflicts and the subsequent take-up of wetlands for other purposes. The new establishment of the Ministry of Natural Resources might be able to implement and promote this type of integrated land planning (http://www.mnr.gov.cn/). It administers land of ecological importance as well as urban and agricultural land that previously belonged to different ministries.

Second, wetland restoration should be strengthened once lost or degraded wetlands are known by functional trajectory, category, and spatial location. Wetland restoration—the growth of hydrologic functions, soil microbiology, floral richness, and other functions—may take different paths of growing and maturing to offset the functional losses of altered or lost wetlands over time [30, 31]. This "functional trajectories" concept largely builds on Clementsian restoration ecology, which views restoration and succession as an orderly, predictable, and deterministic process [32]. Although facing challenges, the functional trajectories concept is still useful as it directly connects restoration treatments with ecological functions and trajectories [32]. The priority areas for restoration should thus focus on the functional trajectories and categories lost recently, such as wetlands converted to agricultural land, degraded wetlands isolated from large areas, or areas surrounding important wetlands for biodiversity conservation and ecosystem services.

Third, China urgently needs integrated water allocation planning for ecological, agricultural, industrial, and domestic purposes. Water requirements for major natural wetland areas should be included in the planning process and given high priority. Other necessary measures include launching programs to turn paddy fields to dry land [33], likely increasing water yield from ecosystems and thus diminishing conflicts over water use between different purposes and different regions. This integrated allocation becomes possible when there is mechanistic knowledge about wetland loss or degradation.

Fourth, China needs wetland inventory and monitoring, including categories, locations, and quantities of wetlands at reasonable intervals, especially in areas where land use is changing quickly. Studies on financial costs or time lags associated with wetland loss and gain (e.g., via reestablishment) are few. Gutrich and Hitzhusen [34] found that it required a median of 33 and 13 years for floral and soil ecosystems, respectively, in newly established wetlands to achieve the full functional equivalency of lost wetlands in Ohio and Colorado. Their research suggests that even with the construction of wetlands that are of the same type and quantity of lost wetlands under the no-net-loss policy, society bears significant costs associated with lost wetland benefits due to the time lags inherent in site-restoration projects. Therefore, wetland monitoring must examine categories, locations, quantities, and timing of various lost and gained wetlands, and must incorporate these into performance evaluations of various levels of government.

Fifth, we must identify important areas for biodiversity conservation, where dam construction should be avoided to keep the corresponding terrestrial endangered species from disappearing because of flooding or keep aquatic life from being isolated by dams. This recommendation builds on the literature regarding the largely harmful impacts of water surface increase in aquatic biodiversity but also the direct, permanent destruction of terrestrial species in flooded areas [27].

Conclusion

Our analysis of the hidden loss of wetlands in China presents a template for global wetland analysis and conservation, pointing out the risks related to the no-net-loss policy adopted worldwide. Wetlands are threatened globally. This warrants efforts toward understanding their long-term changes for wetland management [35]. Furthermore, it is also crucially important to document and understand by what categories, at what locations, and at what magnitudes wetland changes have taken place or will likely take place. Equally important are insights about what factors drive these changes and at what temporal and spatial scales the socio-ecological impacts may unfold on the corresponding landscapes. Policymakers may seek simple statistics to monitor changes and assess policies (e.g., no net wetland loss), but the examples we present here may stand as warnings of hidden losses and risks.

In ways similar to China, many countries are facing problems due to rapid urbanization and agricultural expansion, climate change, and others [36]. Understanding compositional changes hidden in simple statistical summaries aids in identifying the factors threatening wetland ecosystems elsewhere, which turns out to be essential to proposing countermeasures for long-term wetland conservation. Therefore, it is critically important to understand wetland changes, plan conservation efforts, and spend related resources in the framework we propose. Conserving wetlands under the framework we propose will facilitate China fulfilling its commitments for biodiversity conservation in response to the 2020 Global Biodiversity Targets [37, 38]. More broadly, wetland conservation in this manner will likely accelerate the process of achieving the more ambitious goal of protecting 30% (50% by 2050) of the oceans and land by 2030, realizing China's blueprint for "ecological civilization" [39]. Furthermore, this framework will likely empower the global community to conserve wetlands and natural habitats effectively (Target 5 of the Aichi Biodiversity Targets), achieve the target of restoring at least 15% of degraded ecosystems by 2020, and set up new targets in the Convention's 15th Conference of Parties in China.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
- LEAD CONTACT AND MATERIALS AVAILABILITY
- METHOD DETAILS
  - Background
  - Landcover mapping
  - Wetland change detection and driving forces
  - Wetland assessment framework
- QUANTIFICATION AND STATISTICAL ANALYSIS
- DATA AND CODE AVAILABILITY

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.cub.2019.07.053.

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AUTHOR CONTRIBUTIONS

W.X., S.L.P., J.L., and Z.O. designed research; W.X., X.F., J.M., Y.Z., X.L., Y.X., B.W., and L.Z. performed research; W.X., X.F., J.M., L.K., and L.Z. analyzed data; and W.X., S.L.P., H.Z., J.L., L.A., X.W., and Z.O. wrote the paper.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Other		
China's landcover	[40]	N/A
Dam construction information	National Energy Administration in China	http://www.dam.com.cn/damView/list.jsp

LEAD CONTACT AND MATERIALS AVAILABILITY

Requests for further information should be directed to and will be fulfilled by the Lead Contact, Zhiyun Ouyang (zyouyang@rcees.ac.cn). This study did not generate any reagents.

METHOD DETAILS

Background

China contains 10% of the world's wetlands. These wetlands play a critical role in sustaining China's huge population by providing various vital ecosystem services such as food, water, fiber, and medicine [17]. Over the past half-century, China has lost 23.0% of its freshwater marshes, 16.1% of lakes, and 15.3% of rivers [17] due to rapid economic developments, land reclamation [17, 23, 41–43], and urbanization. On the other hand, wetland conservation and restoration efforts have generated an increase in wetland area since 2000. Climate change and dam construction — such as the Three Gorges Dam — might also contribute to these changes as we discuss [23, 28].

The Chinese government has long recognized the importance of wetland protection, particularly after joining the Ramsar Convention in 1992. To counter wetland loss and degradation, China has implemented several conservation and restoration policies that we detail below. The culmination of these government-led wetland conservation efforts is China's most recent policy of total wetland area control (i.e., no net loss) in 2016, mandating that the total area of wetlands in the country should not decrease [44].

Numerous studies have examined wetland changes in China, generating important knowledge and understanding of wetland dynamics and spatial distribution [23, 26, 42, 43]. Few of them quantified the relative contribution of different driving factors or explored the ecological effects and implications of the observed changes with sufficient detail, however. This study fills this gap, providing essential insights into global wetland conservation and restoration.

Landcover mapping

We used the broad definition of wetlands by Land Cover Classification System of the United Nations Food and Agriculture Organization. Wetlands comprise areas of open water in different depths, including deep reservoirs, and marshes. The land cover data came from The China Ecosystem Assessment projects from 2000 to 2010, and from 2010 to 2015 by the Chinese Academy of Sciences and Ministry of Ecology and Environment. Charged with assessing the current status and trends in ecosystem patterns, ecosystem quality, ecosystem services, and ecological problems, the assessment project between 2000 and 2010 involved over 3000 scientists from 2010 to 2014, with 20,355 multi-source satellite images and 114,500 field surveys [40, 45]. Following the same procedure, the assessment of ecosystem changes between 2010 and 2015 was carried out from 2016 to 2018. Based on 30 m*30 m satellite images (i.e., Landsat TM/ETM, and HuanJing A/B) of the vegetation growth seasons, we classified the entire land surface in mainland China into eight classes (i.e., forest, shrubs, grassland, wetland, agricultural land, urban land, deserts, and others such as glaciers and bare land) using the object-oriented method by the platform of eCognition 8.0. Of these classes, we further classified the wetlands into three classes of marshes, lake plus reservoirs, and rivers. Based on independent assessment using 31658 sample points throughout the entire land surface, the overall classification accuracy was over 94% for the eight classes, and 91% for wetlands [42].

Wetland change detection and driving forces

We calculated area of wetlands and detected wetland change by overlaying ecosystems maps in 2000 and 2015 by the platform of ArcGIS. The converted areas from wetlands to other landcover types, and from others to wetlands were identified. We also analyzed the contribution of different driving factors through conversion analysis. For wetland loss, we classified driving forces into urban expansion, agricultural land expansion, and others by directly calculating different proportions of wetlands converted to urban areas, to agricultural land, or to other types of ecosystems.

For wetland gain, we classified it by driving factors of climate change, dam construction, wetland restoration, and others. The final step combined the conversion matrix and locations of each driving factor (Figure S1).

(i) Climate change

The Qinghai-Tibetan plateau was a major region for wetland expansion between 2000 and 2015. Here, the temperature increased over 50 years and especially since 1980s [14]. This region has 84% of the total glacial area in China [13]. Climate warming prompted glaciers to melt, which increased the water supply for lakes and rivers. In this less human disturbed region, 94% of the expanded wetland area was at least 5 km away from urban or township areas (Figure S2). Climate change was therefore regarded as the direct and leading cause of wetland expansion [25]. Thus, we attributed wetland expansion areas in this region to climate change, by overlaying the maps of wetland expansion and Qinghai-Tibetan plateau [16].

(ii) Dam construction

Between 2000 and 2015, China undertook over 80 major dam construction projects, mainly in the south. We collected data on the distribution of dams and related them to wetland expansion. When the water surface in the upper rivers of dams expanded from 2000 to 2015, but did not change down rivers, we attributed the expanded water surface to dam construction (e.g., Figure 3B). Most of the distribution data were from Large Dam Safety Supervision Center, National Energy Administration (http://www.dam.com.cn/damView/list.jsp).

(iii) Wetland restoration projects

After massive flooding in the middle and lower reaches of the Yangtze River in 1998, China established several wetland restoration projects. In addition, the National Wetland Conservation Program established wetland restoration projects in 2003 throughout China. Since the wetland restoration projects are scattered throughout China, we only calculated the area of wetland expansion converted from agricultural land. This calculation excluded the Qinghai-Tibet region and dam construction areas where wetland expansion was not due to the wetland restoration projects.

(iv) Others

We attributed remaining wetland expansion to this category. This could be caused by climate related changes (e.g., changes in temperature, precipitation, and evapotranspiration) or changes in water utilization due to human factors (e.g., agricultural, industrial, and domestic purposes). We cannot distinguish the contributions of each factor, however.

Wetland assessment framework

We propose a framework that aims to understand wetland changes and examine the suitability of the "no net loss" target. Under this framework, it must be mechanistically aware — in the case for China's wetlands, we documented and understood what reasons have accounted for wetland changes. Furthermore, it must be temporally mindful, categorically distinct, and spatially explicit, addressing at what temporal scales, by what categories, where these changes take place, and what spill-over effects may arise. Finally, it should be quantitatively clear, answering at what magnitudes changes have taken place or will take place.

QUANTIFICATION AND STATISTICAL ANALYSIS

The areas of different landcover types were calculated in ArcGIS, which were explained in detail in Method Details.

DATA AND CODE AVAILABILITY

Landcover data are available from scientific database of the Chinese Academy of Sciences (http://www.ecosystem.csdb.cn/). Other data in this paper are publicly available or presented in this paper and Supplemental Information.

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Supplemental Information

Hidden Loss of Wetlands in China

Weihua Xu, Xinyue Fan, Jungai Ma, Stuart L. Pimm, Lingqiao Kong, Yuan Zeng, Xiaosong Li, Yi Xiao, Hua Zheng, Jianguo Liu, Bingfang Wu, Li An, Lu Zhang, Xiaoke Wang, and Zhiyun Ouyang

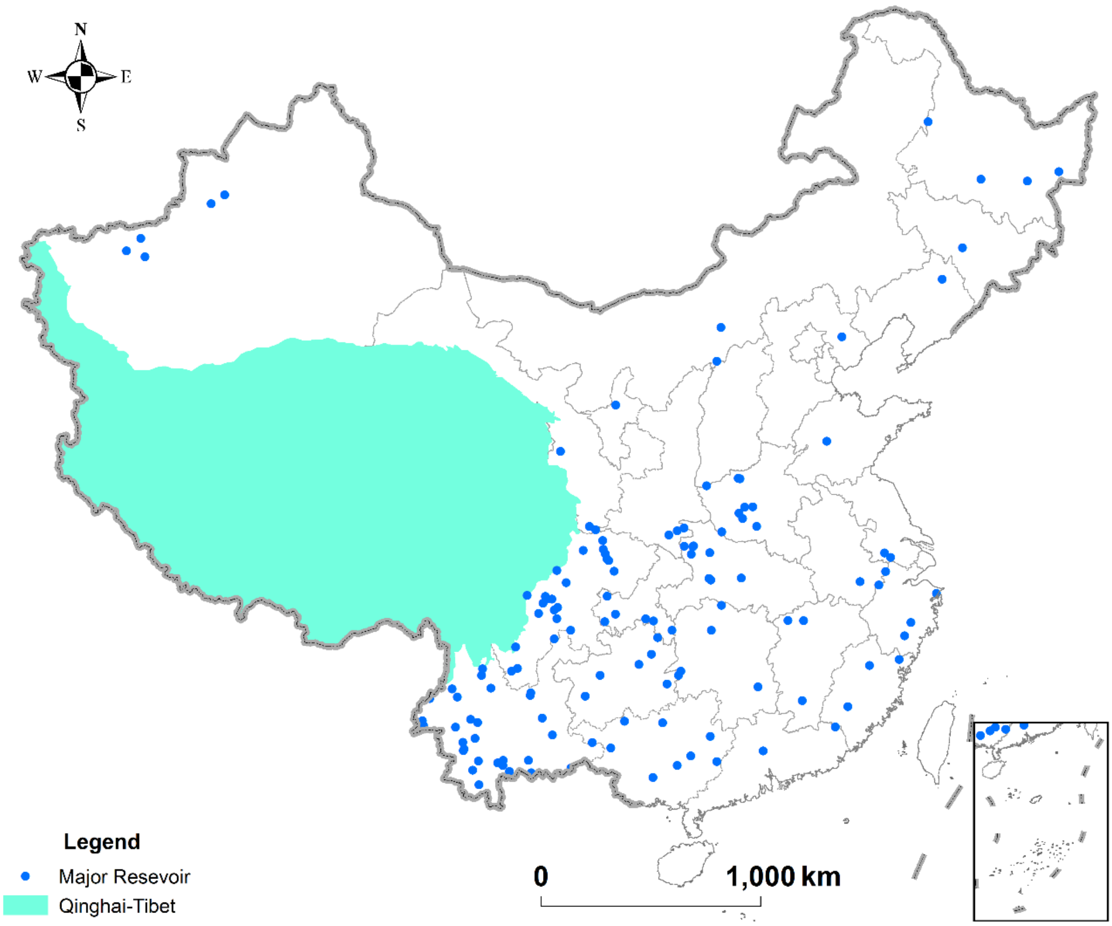

Figure S1. Locations of Qinghai-Tibet region (subject to strong impacts from climate change) and major reservoirs and dams constructed between 2000 and 2015. Related to Figure 2 and STAR Methods.

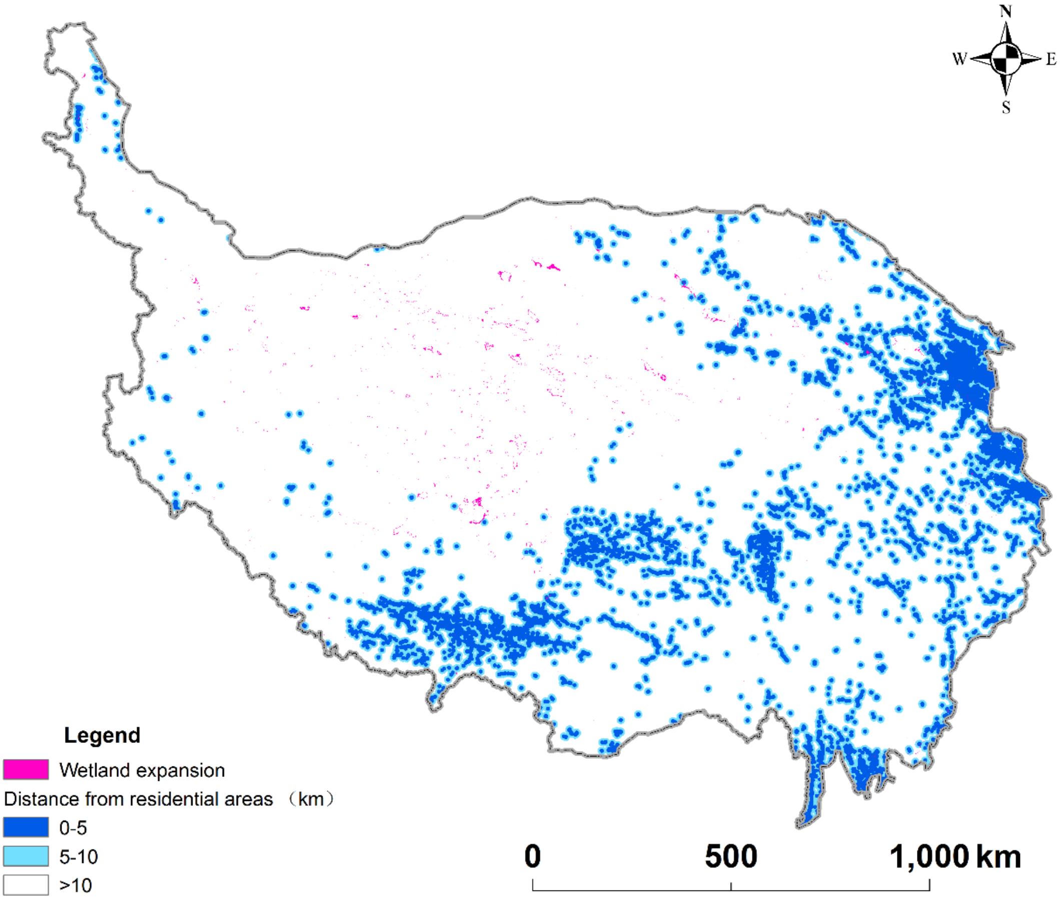

Figure S2. Locations of expanded wetlands and different distance to residential areas in Qinghai-Tibet region. Related to Figure 3 and STAR Methods.