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Stronger policy required to substantially reduce deaths from $PM_{2.5}$ pollution in China

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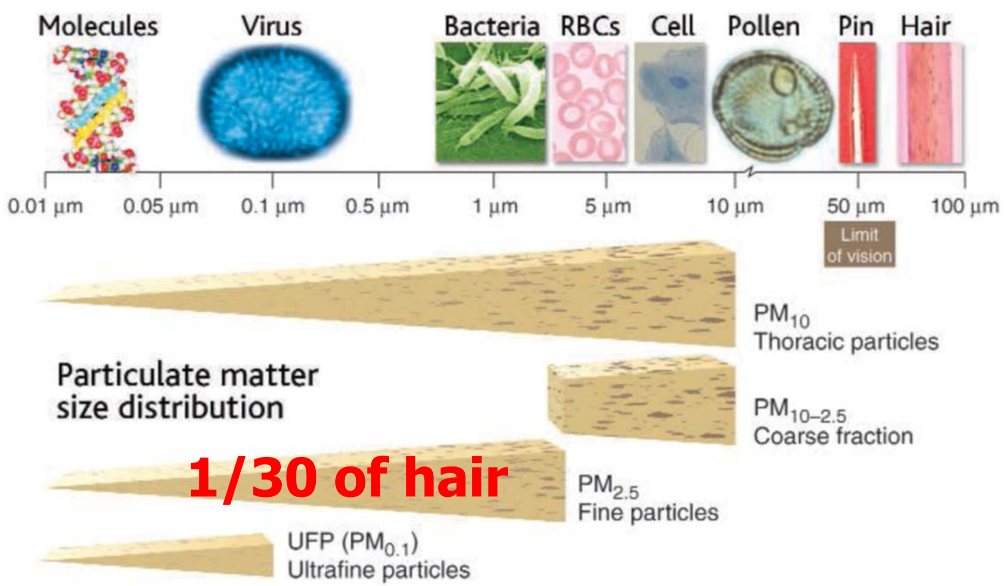
CONTENTS

1. Introduction

What's $PM_{2.5}$ pollution?

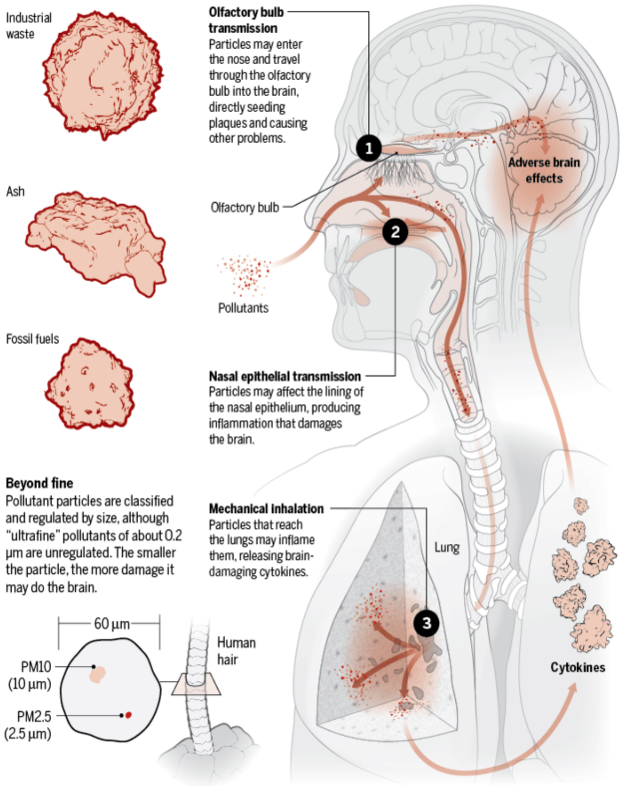
(Kaiser, 2005)



Fine-Particle Matter ($PM_{2.5}$) refers to the particulate matter less than **2.5µm** in diameter, including dust, sea salt, organic mass, black carbon, sulfate, nitrate and ammonium etc.

(WHO, 2005)

Health effects of $PM_{2.5}$



(Underwood, 2017)

Respiratory disease
Cardiovascular disease……

Deaths caused by exposure to ambient $PM_{2.5}$ pollution in a given year, termed **deaths attributable to $PM_{2.5}$ pollution (DAPP).**

According to Global Burden of Disease (GBD), the DAPP in 2017 counts about 3 million, **3 times of AIDS**!

Sustainable Development Goal (SDG) 3.9. By 2030, substantially reduce the number of **deaths and illnesses from hazardous chemicals and air**, water and soil pollution and contamination.

China's response to heavy air pollution

As the largest developing country, China is heavily affected by $PM_{2.5}$ pollution. To reduce $PM_{2.5}$ pollution, the Chinese government launched the ***Air Pollution Prevention and Control Action Plan* (APPCAP)** in 2013 which aimed to lower $PM_{2.5}$ concentration in cities by **10-25%** by 2017.

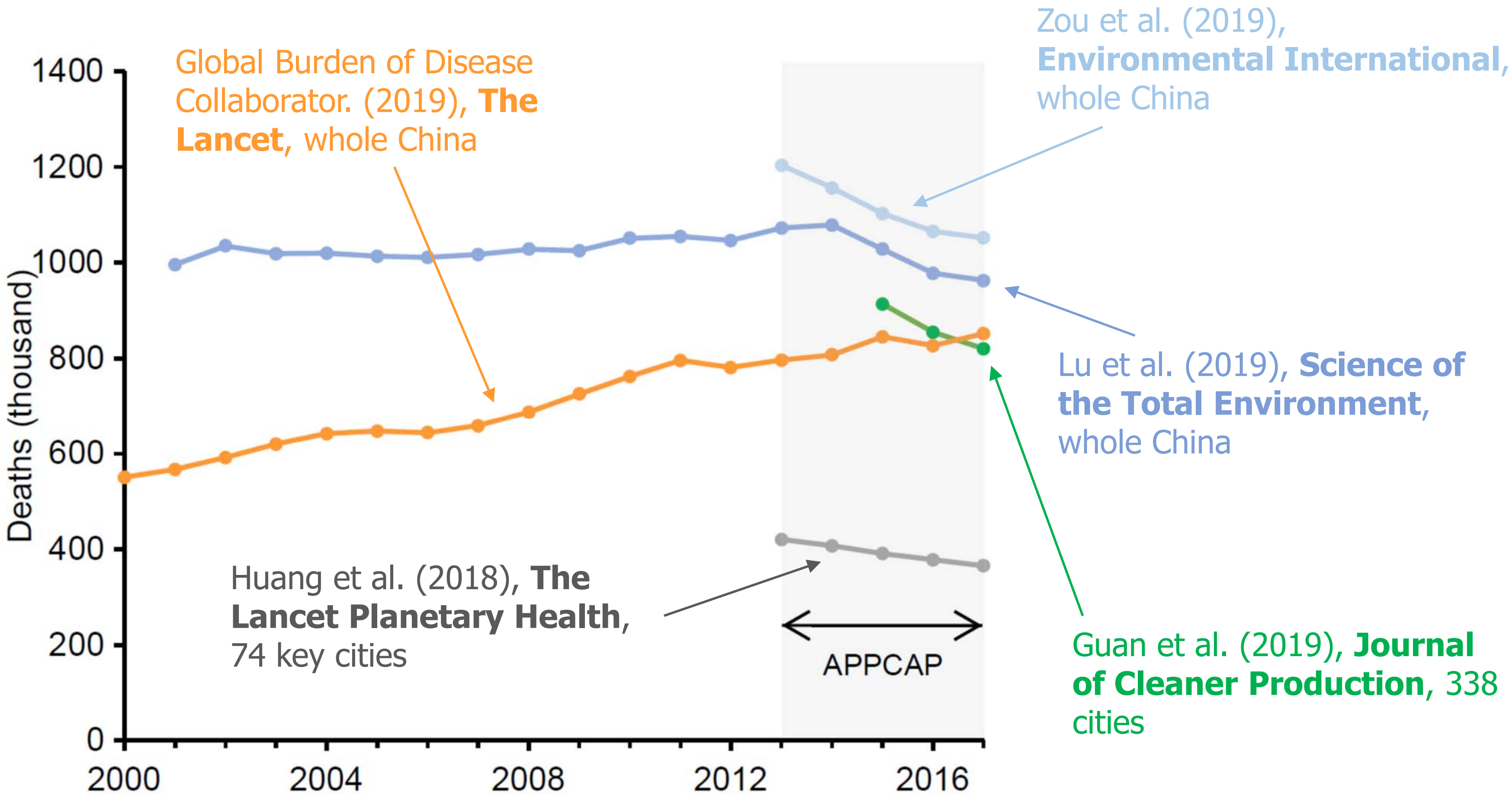
(www.chinadaily.com.cn)

1.7 trillion RMB
(**$270 billion US $**)

Largest and **most remarkable** air pollution control action ever implemented.

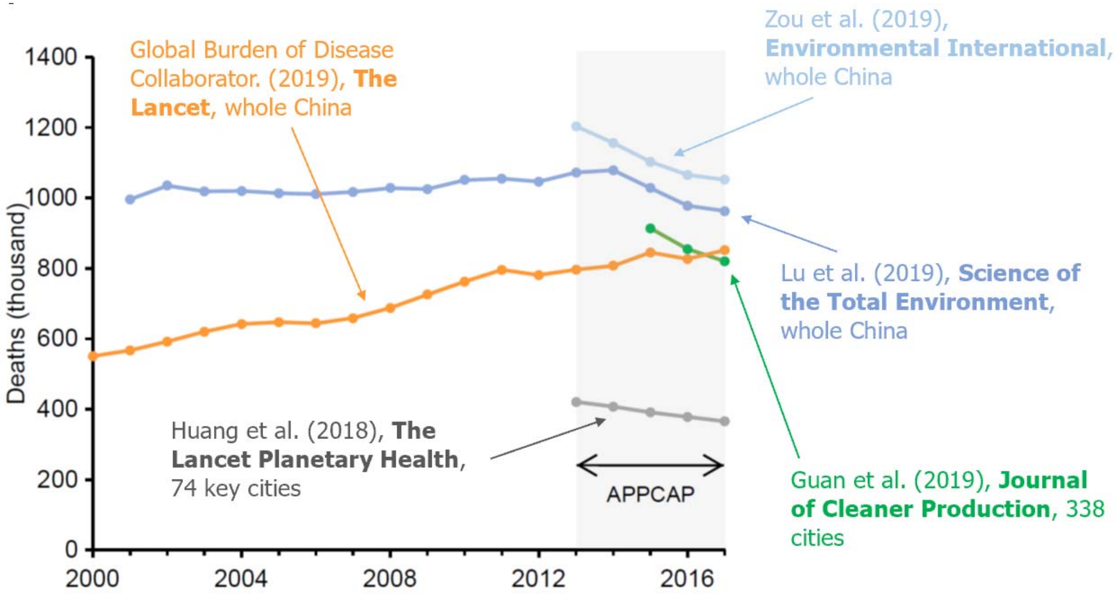
Quantifying the impact of this policy is of great significance for guiding future environmental policy needs for achieving SDG Target 3.9.

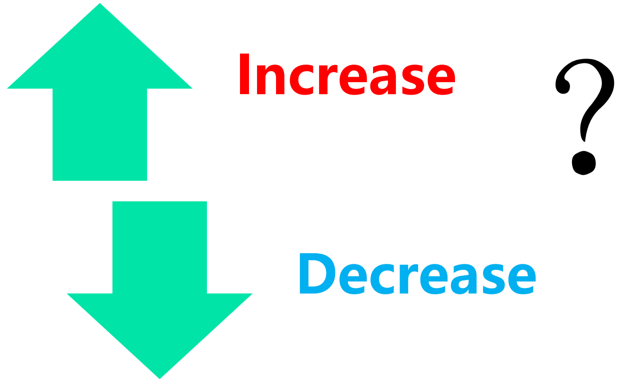
Summary of previous study



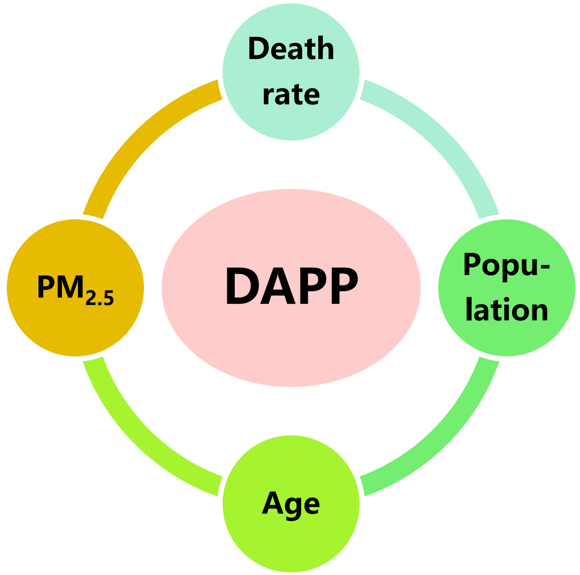
While some studies have analyzed the $PM_{2.5}$-related health benefits of the APPCAP in China, the results have **varied** and conclusions have been **conflated**.

Research gap





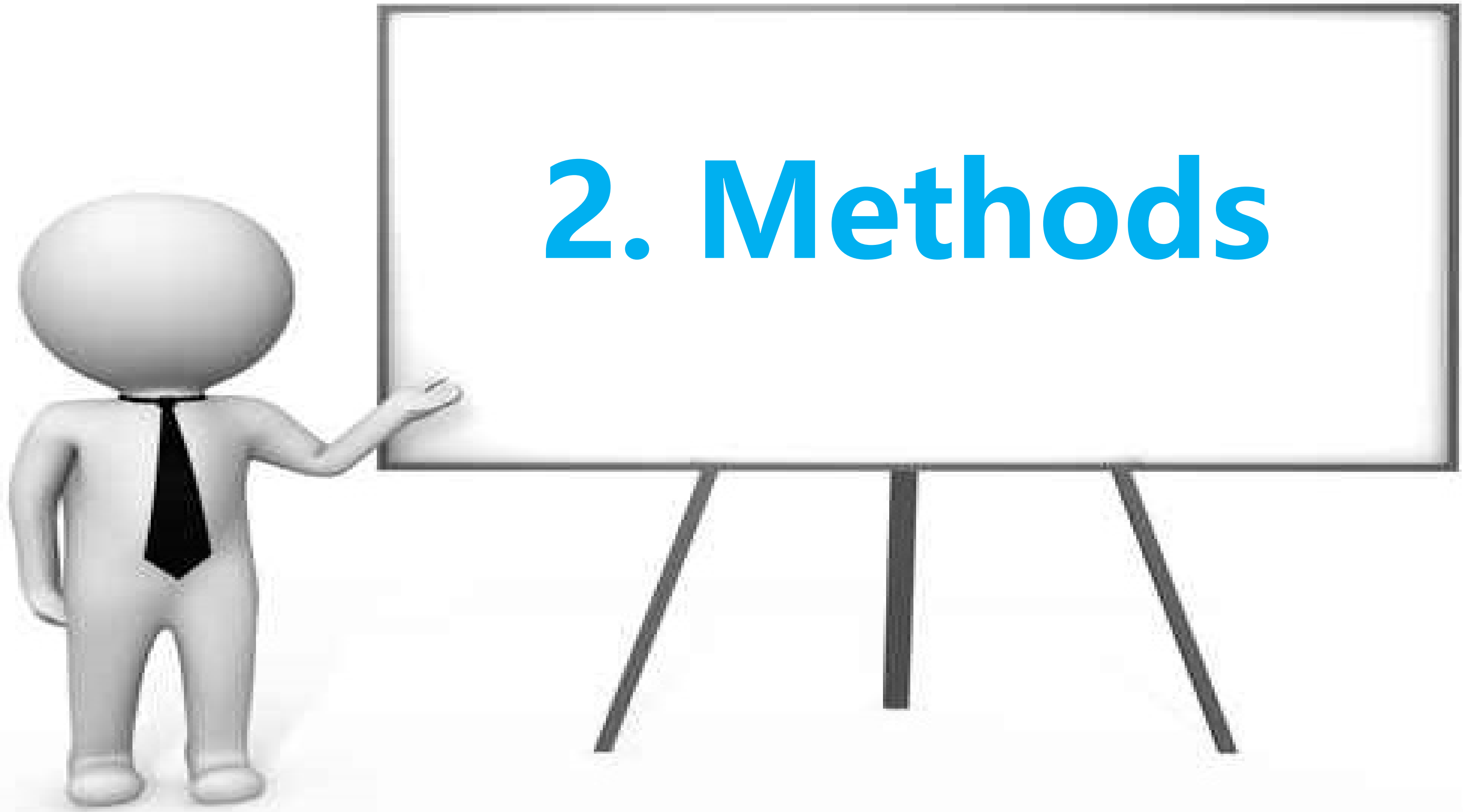
A **reliable** and **comprehensive** understanding of the spatiotemporal dynamics of DAPP and the relative contributions of the driving factors are urgently needed to **clarify the $PM_{2.5}$-related health benefits of the APPCAP**.



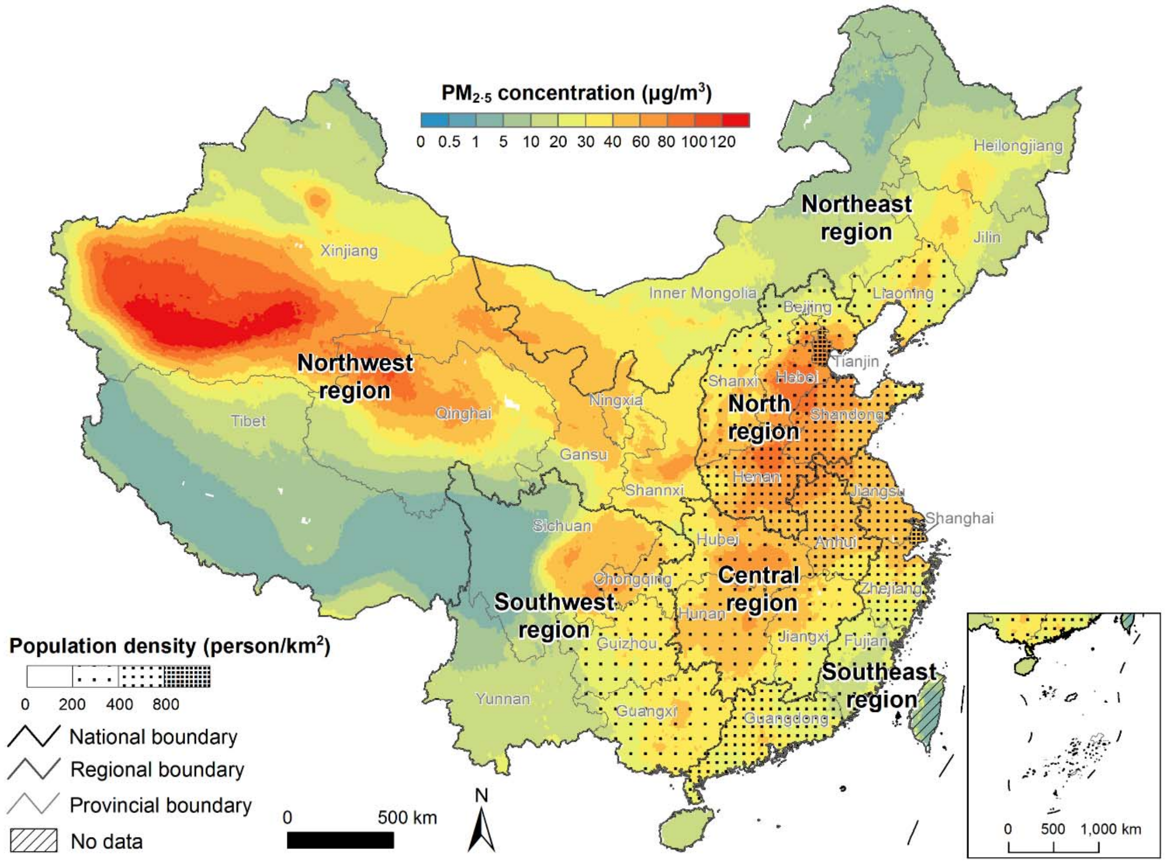
Research target

- **Research target**
  - Quantify the health benefit of APPCAP and assess the effectiveness of current air quality related policy in the future.

- **Research content**
  - Clarify the dynamics of DAPP in China from 2000 to 2017.
  - Quantify the relative contribution of different driving factors.
  - Project future DAPP using scenario analysis.


2. Methods

2.1 Study area



Large population

Total population reached 1.4 billion in 2016, which was 1/6 of global population.

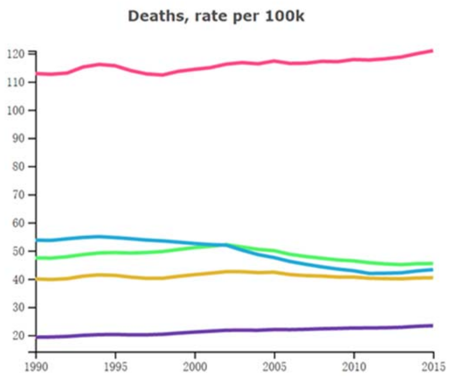
Heavy $PM_{2.5}$ pollution

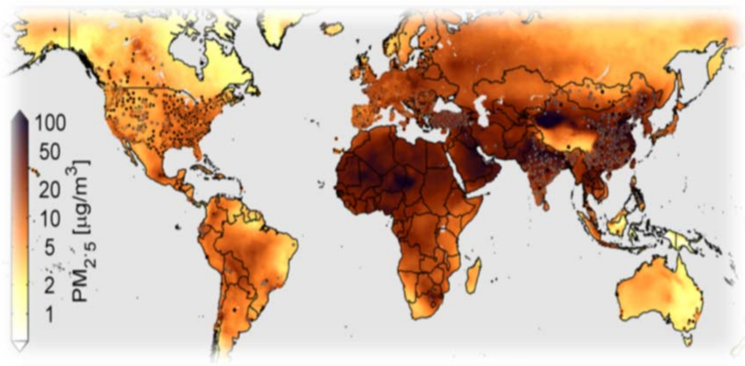
The annual average $PM_{2.5}$ concentration was about 30μg/m^3, two times higher than the air quality standard set by the World Health Organization (WHO).

Overlap of densely population and heavy pollution.

More than 70% of the population lived in the areas with annual average $PM_{2.5}$ concentration higher than 35μg/m^3.

2.2 Data





Health data
Health data was obtained from GBD 2017 dataset, including the age structure and age specific death rates of diseases.

$PM_{2.5}$ data
Gridded $PM_{2.5}$ concentration data was derived by combining global estimates of fine particulate matter dataset and $PM_{2.5}$ monitoring data in China.

Auxiliary data
Population data was obtained from the History Database of the Global Environment and calibrated by statistic data. Future national-level population and age structure data under a business as usual scenario was derived from the United Nations.

2.3 Estimating the DAPP

We estimated the annual DAPP of China using the comparative risk assessment framework from 2000 to 2017. This framework is the most commonly used method to estimate the health impacts caused by a certain risk factor (Murray et al., 2003; Cohen et al., 2017).

Basic formula

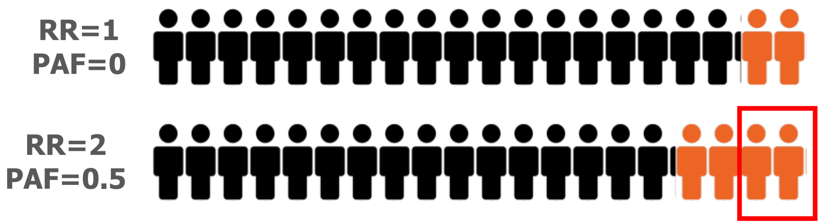
$$\text{DAPP} = \sum_{a,d} \left(PAF_{a,d} \times POP \times Rate_{a,d} \times AgeP_a \right)$$

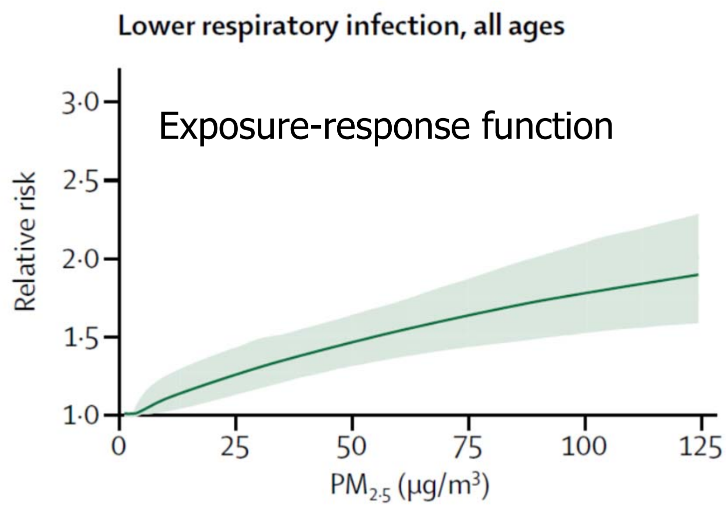
a and d refer to the different diseases and age group.

proportion of deaths attributed to $PM_{2.5}$ pollution ($PAF_{a,d}$)

Age and disease specific deaths ($POP \times Rate_{a,d} \times AgeP_a$)

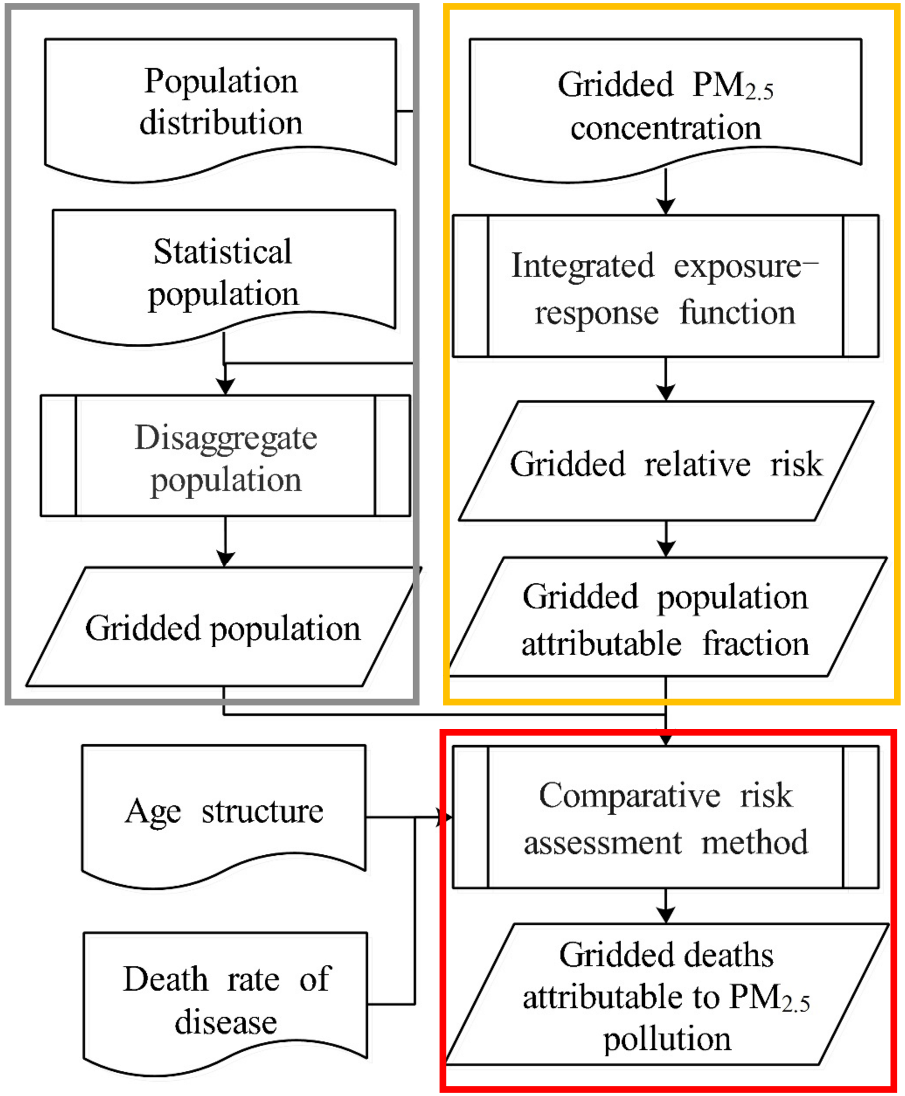
$$\text{PAF}_{a,d} = \frac{\text{RR}_{a,d} - 1}{\text{RR}_{a,d}}$$





2.3 Estimating the DAPP

Flow chart



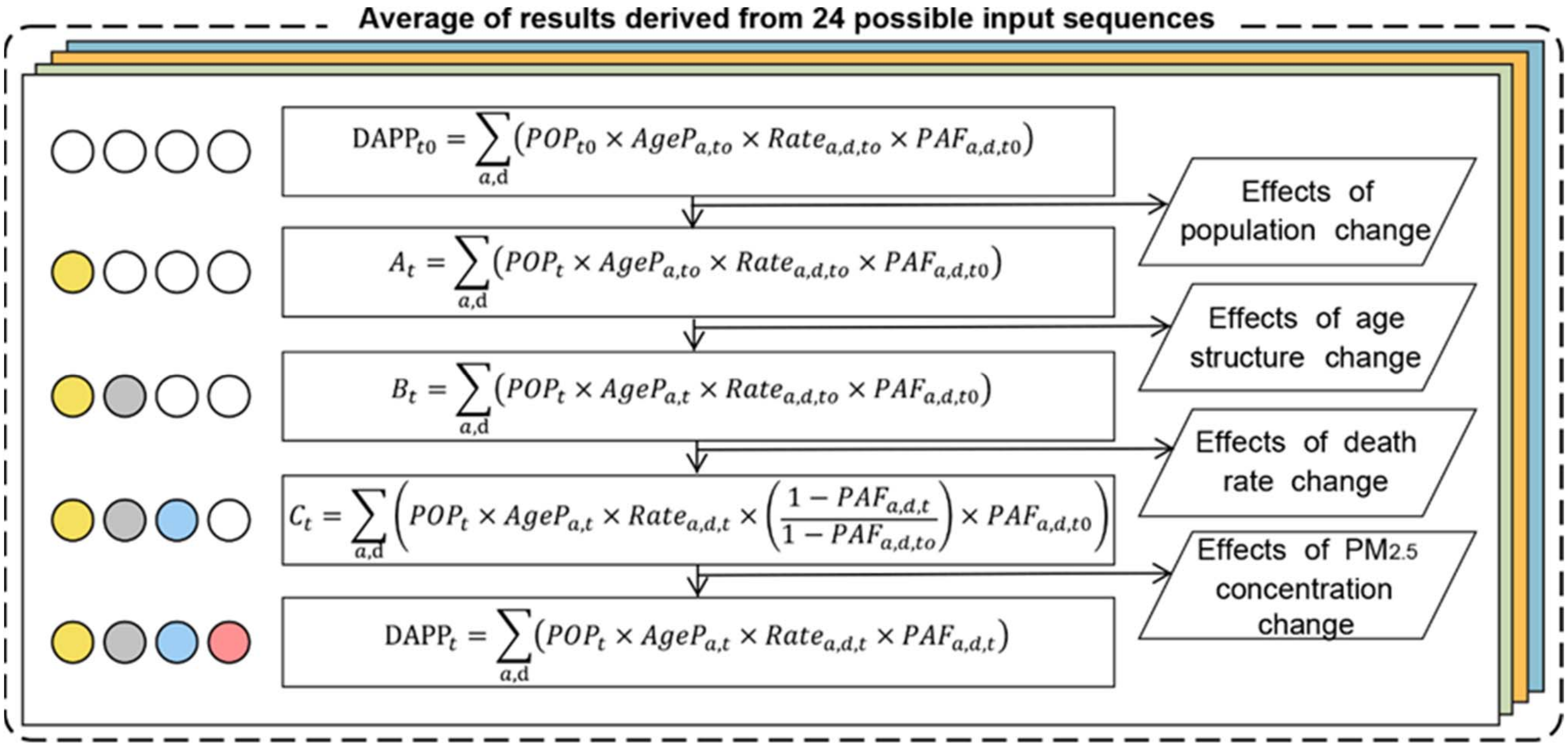
Two key indicators:

Deaths
indicates the absolute health effects

Age-standardized death rate
represents the relative health burden by excluding the impacts of demographic changes (i.e., aging and population growth)

2.4 Decomposing the changes in DAPP

We further quantified the contributions of abovementioned four factors on the changes in DAPP using the decomposition method according to GBD study (Cohen et al., 2017).



2.5 Future projection of DAPP

Policy background

Time span	Policies	Targets
2013-2017	Air Pollution Prevention and Control Action Plan	Air quality should be improved significantly until 2017, with a target of reducing the annual average $PM_{2.5}$ concentration by 10~25%.
2017-2020	Three-year action plan aims for blue skies	The $PM_{2.5}$ concentration in 2020 should decrease by 18% than that in 2015.
2015-2030	China's First Nationally Determined Contributions for Paris Agreement	Lower CO_2 emissions per unit of GDP by 60%–65% and increase the share of non-fossil fuels in primary energy consumption to around 20% by 2030 from the 2005 level. (13% in 2017)

~2030

Trend	35μg/m^3, which is World Health Organization's the Interim Target 1 of air quality, represent a achievable air quality standard for all the countries.
Ambitious	10μg/m^3, which is World Health Organization's air quality guideline, represent a relative strict standard that can avoid most health effect.

2.5 Future projection of DAPP

Scenario design

2030 policy scenario	Description	$PM_{2.5}$ concentration	Death rate of diseases	Population and age structure
Trend	$PM_{2.5}$ concentration decreases following the current trend of policy.	35μg/m^3	30% lower than in 2015, following the Healthy China 2030 Planning Outline.	Estimates from the United Nations under a business as usual trend.
Ambitious	$PM_{2.5}$ concentration decreases substantially by adopting more ambitious air pollution control policy.	10μg/m^3		

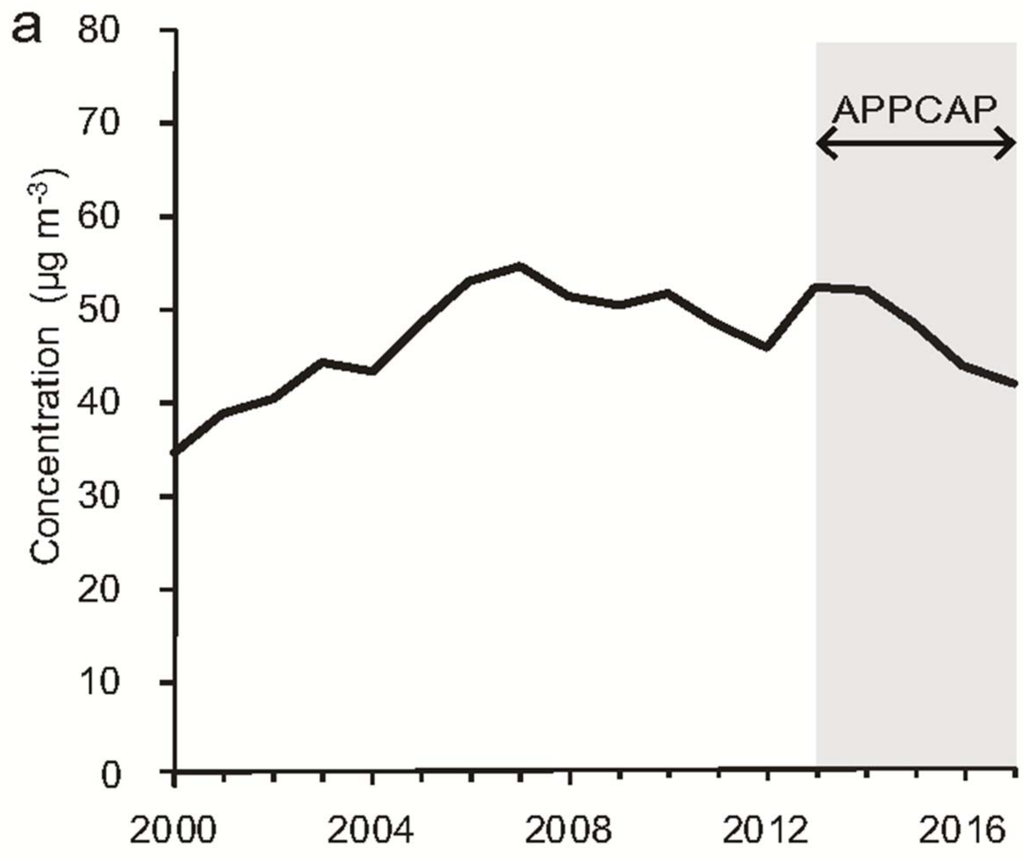
We then projected the DAPP under two different scenarios: Trend and Ambitious. With the population and age structure change as the current trends, and health care improved ideally.


3. Results

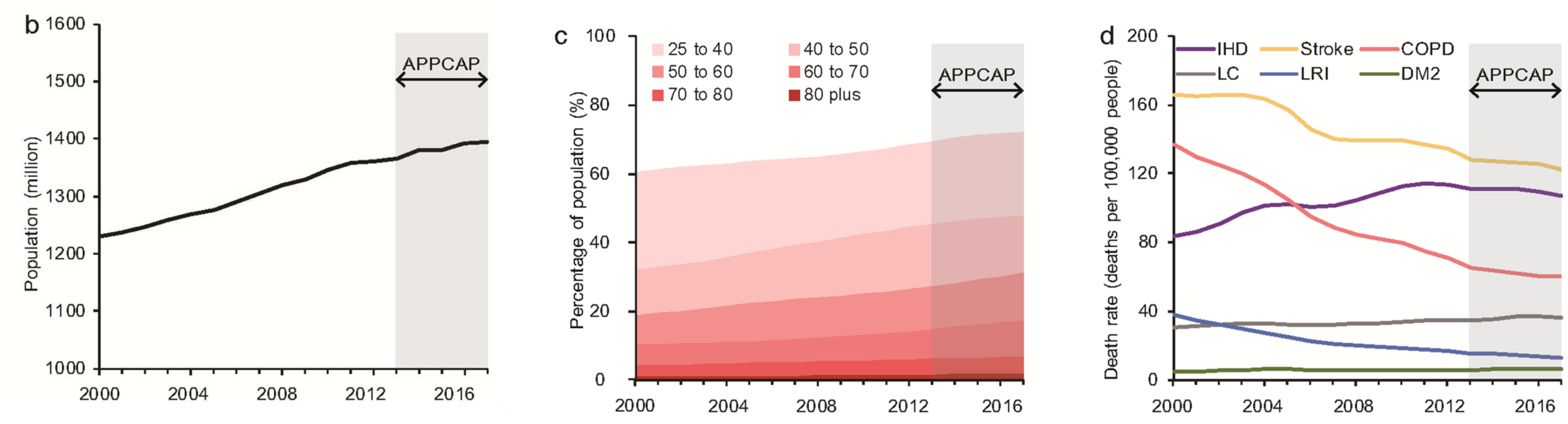
3.1 Changes of different driving factors

Population weighted $PM_{2.5}$ concentration decreased from **53μg/m³** **to** **42 μg/m³** **during APPCAP.**

$$POPWCON = \frac{\sum(POP_i \times CON_i)}{\sum POP_\mathrm{i}}$$



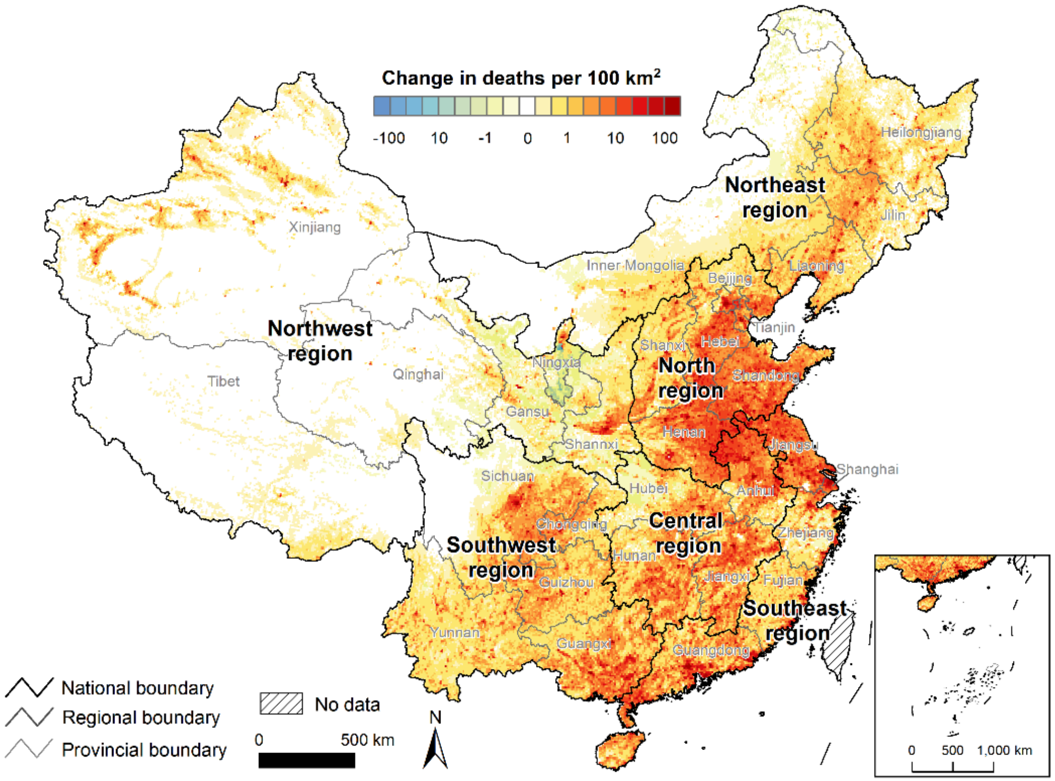
3.1 Changes of different driving factors



The population kept a growth and aging trend.

Trend of death rate varied among diseases.

3.2 Spatiotemporal dynamics of DAPP



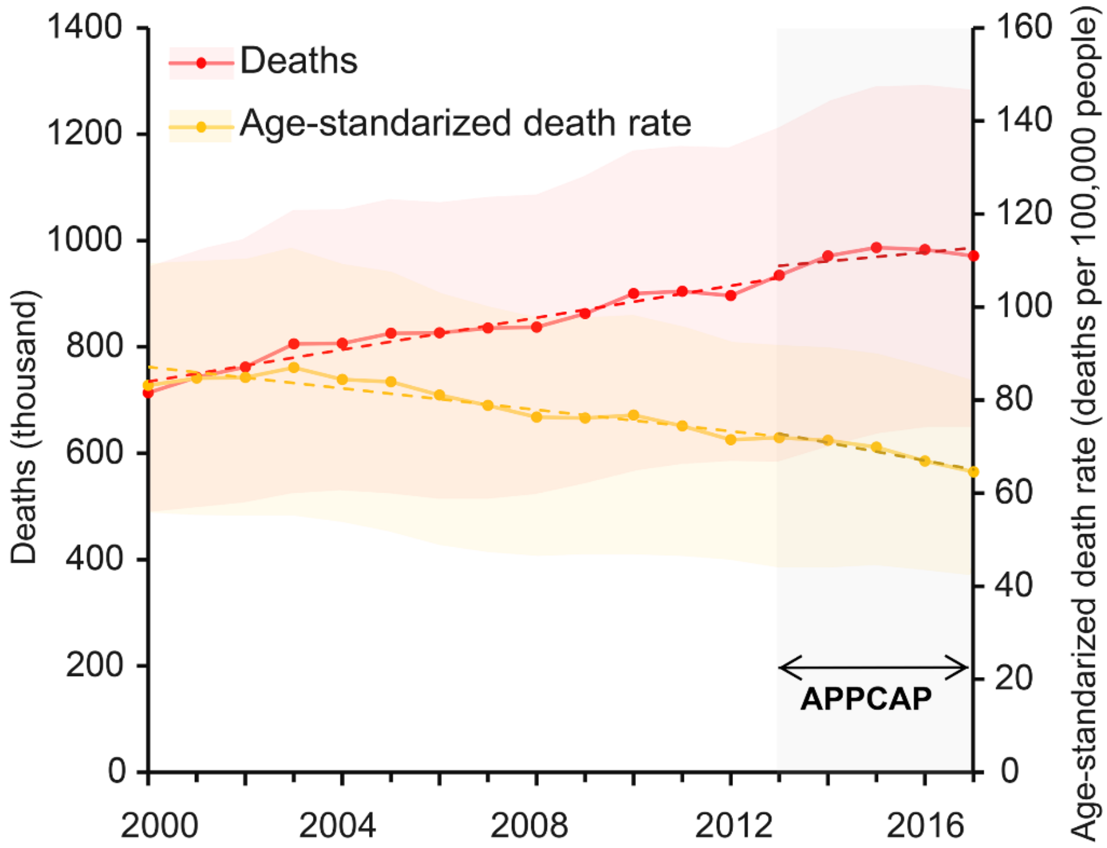
The DAPP in China increased from 714 thousand in 2000 to 971 thousand in 2017, increasing 36.1%.

The increase in DAPP was mainly concentrated in the **North region** of China, which accounted for about 30% of the total national increase.

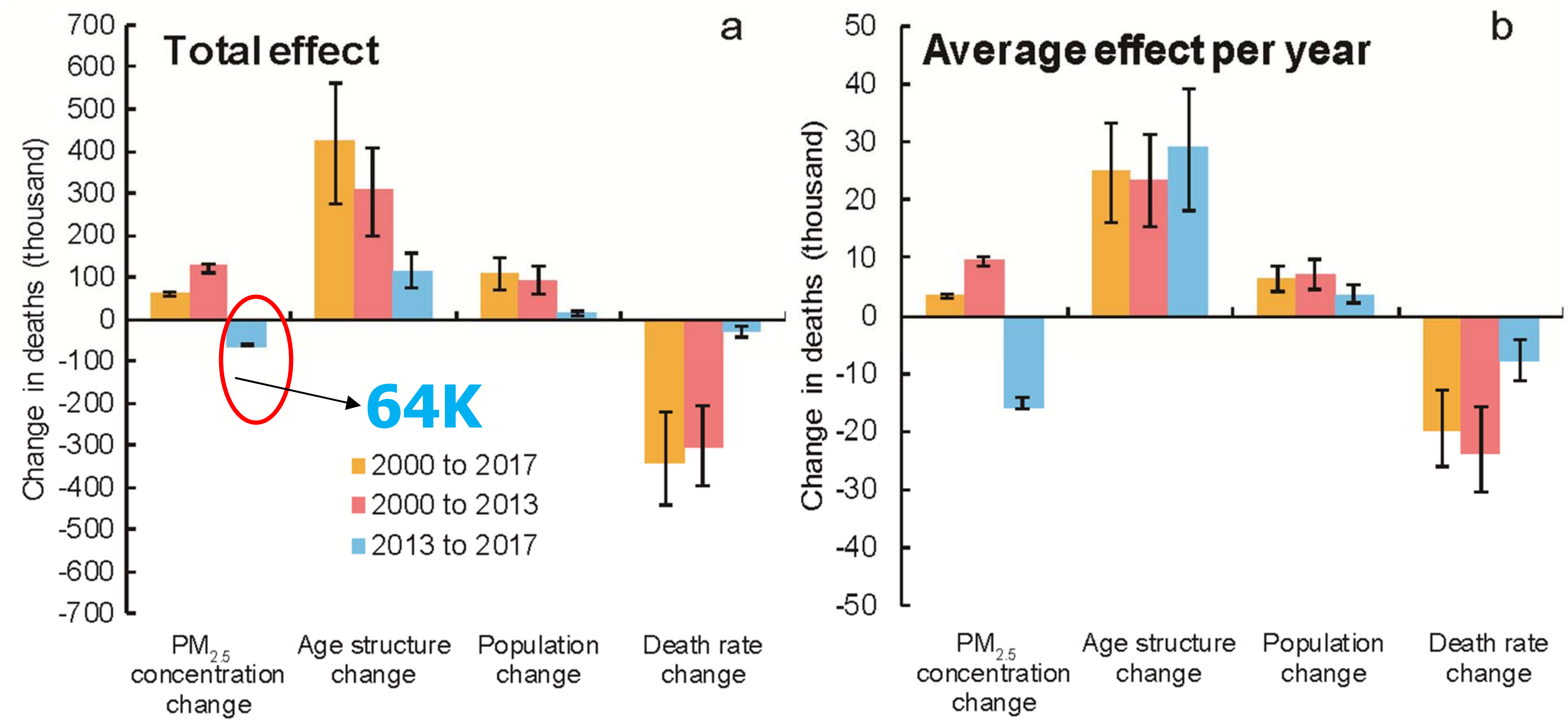
3.2 Spatiotemporal dynamics of DAPP

Although the DAPP in China shows a growth trend, the growth rate declined from 2013–2017. The average annual rate of increase in DAPP dropped from **2.1%** before APPCAP implementation (2000–2013) to **1.0%** after (2013–2017).

The age-standardized $PM_{2.5}$ attributable death rate showed a declining trend. The average annual rate of change falling from −1.1% during 2000–2013 to −2.7% during 2013–2017.



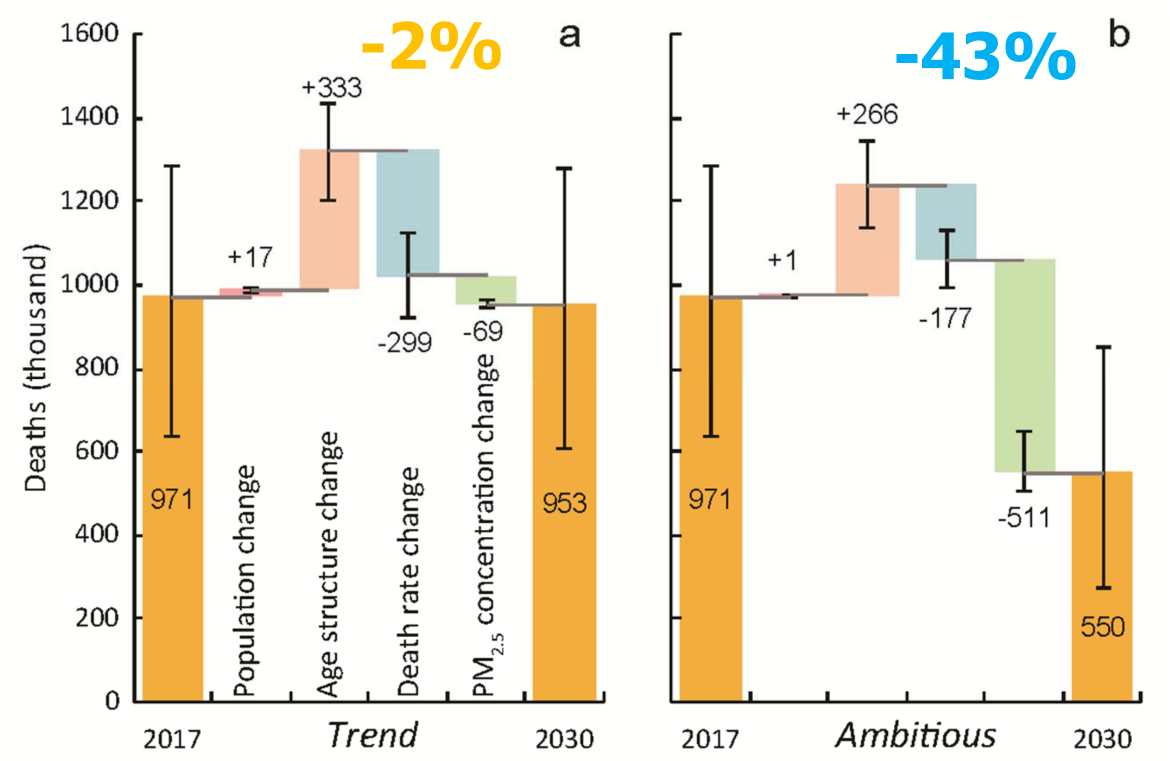
3.3 Effects of individual factors



From 2000-2013, the DAPP increased by **127 thousand** due to changes in $PM_{2.5}$ concentration. By contrast, the DAPP decreased by **64 thousand** from 2013–2017 following the decline in $PM_{2.5}$ concentration after the establishment of the APPCAP.

Regarding the average effect per year, the DAPP increased by **10 thousand per year** on average due to changes in $PM_{2.5}$ concentration before 2013. After APPCAP, the air quality improvement resulted in an annual average decrease in DAPP of **16 thousand per year**.

3.4 Future projection of DAPP



Under the Trend scenario, DAPP was estimated to be 953 thousand in 2030, 2% lower than that in 2017. In comparison, under the Ambitious scenario, the DAPP will be reduced to 550 thousand in 2030, a net reduction of 421 thousand compared to 2017.
At the same time, age structure change will play an important role, increase the DAPP by 333 thousand under the Trend scenario and 266 thousand under the Ambitious scenario.

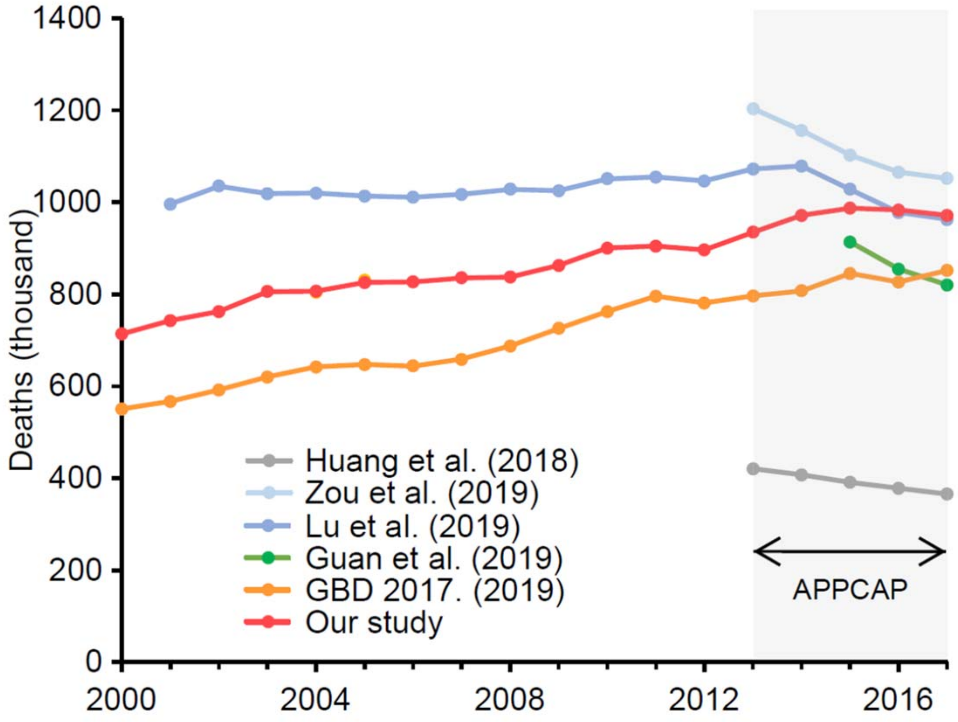

4. Discussion

4.1 Comparison with previous study

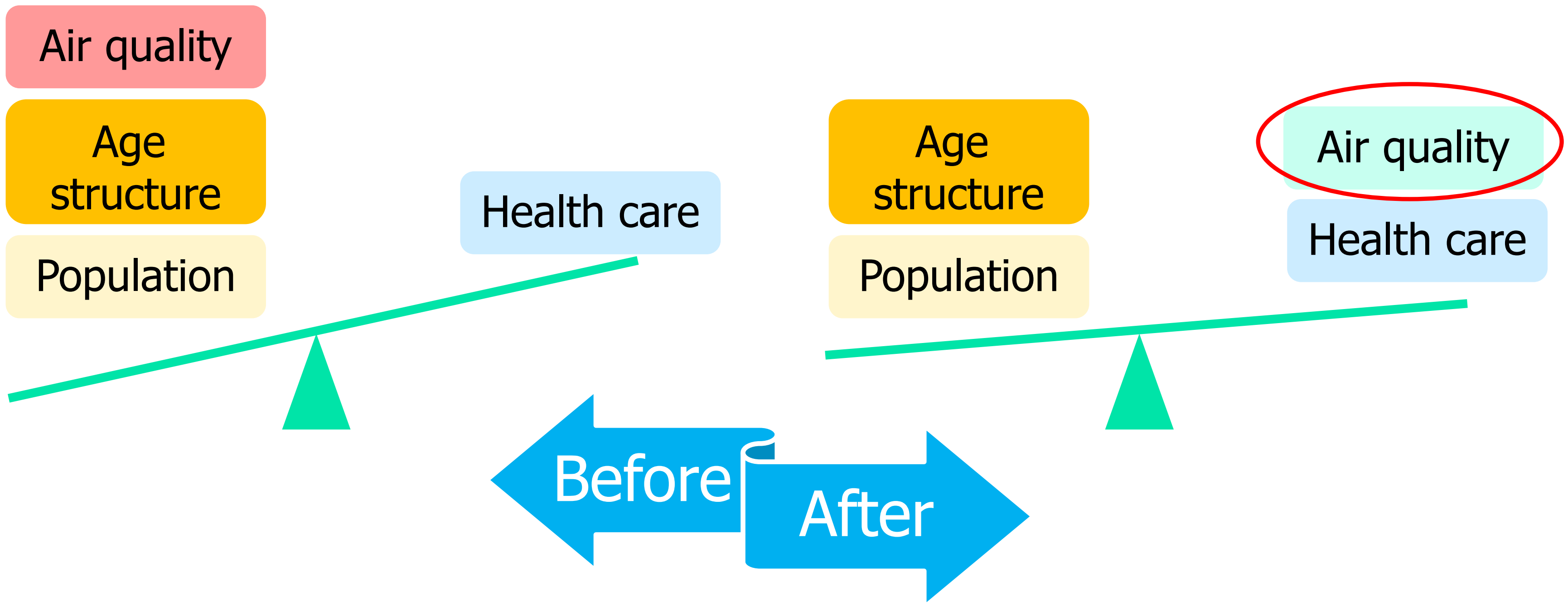
Trend and **health benefit**

Our findings indicated **DAPP in China continued the growth trend after the establishment of the APPCAP in 2013**. This result is consistent with the latest update of the authoritative GBD 2017, but contrasts with some previous studies which indicated that DAPP showed a decreasing trend.

Our study also provided **a far more reliable estimate for health benefit of APPCAP**.



4.2 The health benefit resulted by APPCAP



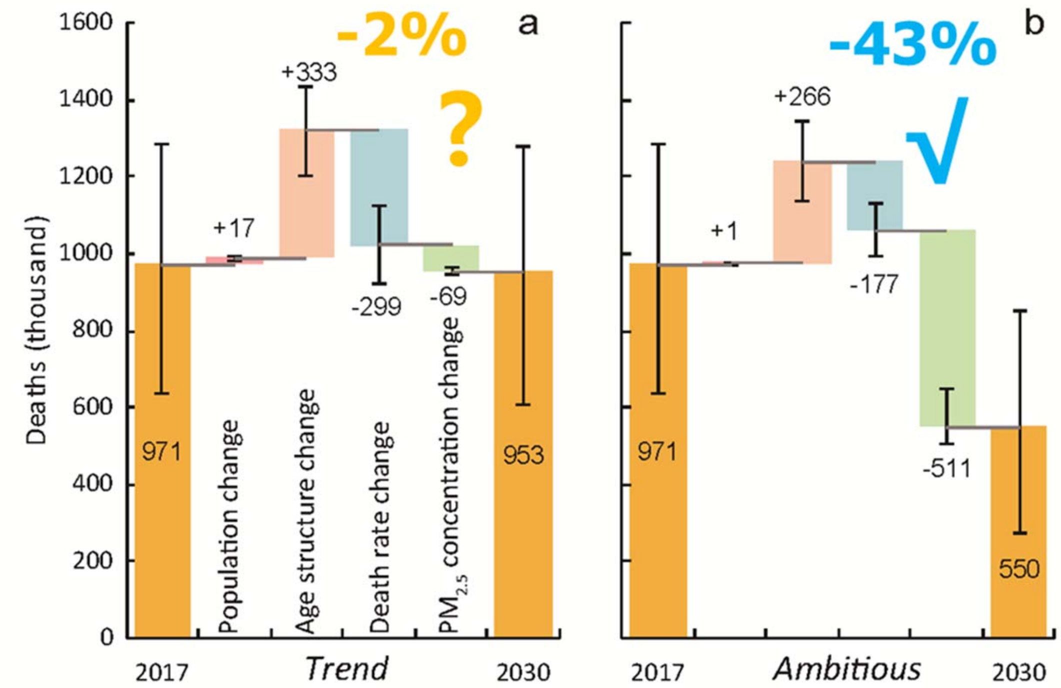
The reductions in $PM_{2.5}$ concentrations effected by the APPCAP resulted in **64 thousand fewer deaths** in DAPP in 2017 compared to 2013.

This decline is relatively minor, and the DAPP has continued to increase overall due to the overwhelming influence of other factors. Specifically, the effects of demographic factors (i.e., population and age structure) on DAPP remained positive over time.

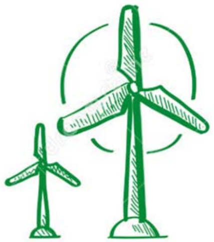
4.3 Challenges still remain in the mitigation of DAPP

Material reductions in DAPP is the great challenge that remains to be addressed in China. China needs to adopt more stringent policies to achieve the intent of SDG target 3.9.

By 2030, **substantially** reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.



4.3 Challenges still remain in the mitigation of DAPP



On the one hand, the **energy system** should be adjusted to control pollutant emissions.

On the other hand, **regulation and management** strategies should be enhanced for the main emissions sources.

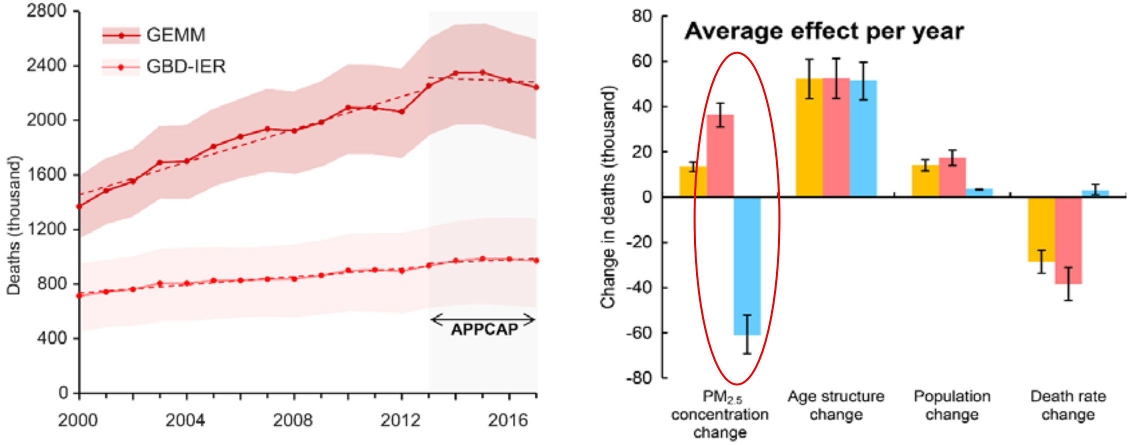
Personal behavior could also be useful for health risk reduction, such as reducing inhalation of $PM_{2.5}$.

The joint effects of air pollution control and taking climate action

The efforts of climate action are closely related to the air pollution control policies in the energy, transport and industry sectors. Hence, stronger air quality control policy is beneficial to achieving both SDG 3 ensuring healthy lives and SDG 13 combating climate change.

4.4 Uncertainty and limitation

1. Selection of exposure-response function



2. Age structure and death rate data

Due to data availability, we used national-level age structure and death rates in our estimation.

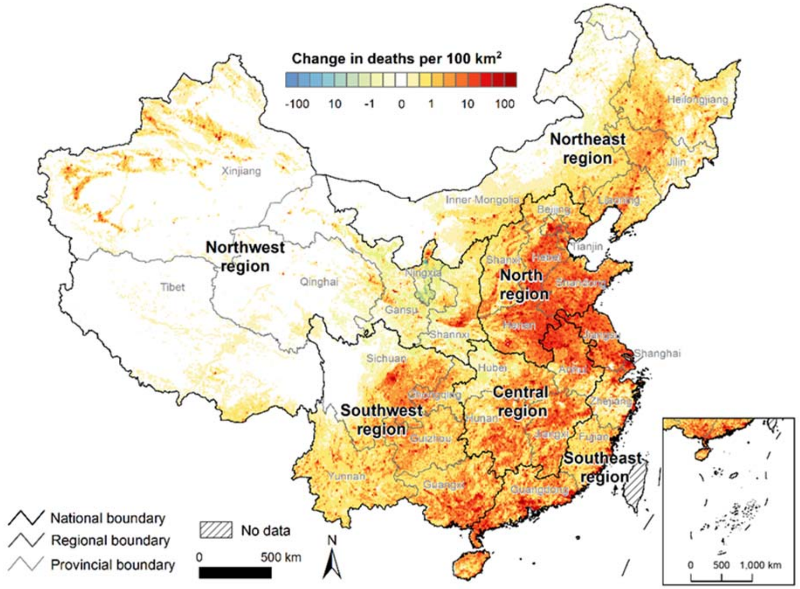
3. Driving factor analysis

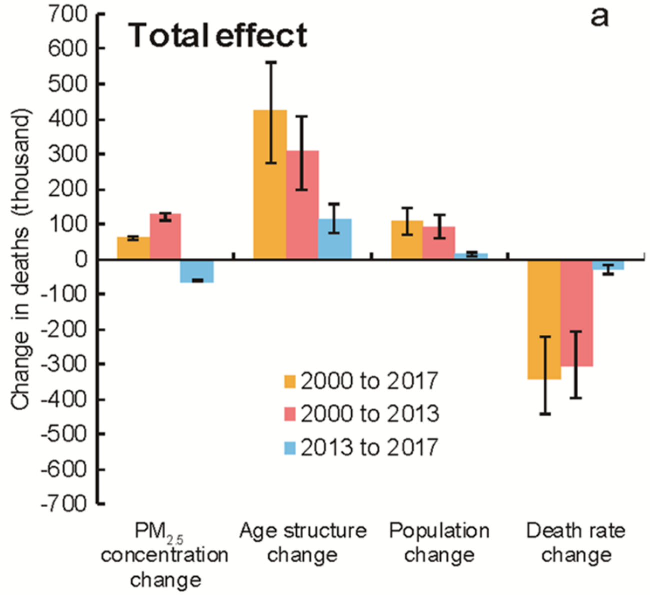
The decomposition didn't consider other underlying socioeconomic and behavioral factors.

4. Scenario design

The scenarios (i.e., Trend and Ambitious) of future air quality in our study are relatively simple.

4.5 Key novelty and contribution





Provide a more accurate estimate of DAPP from 2000 to 2017 based on an updated epidemiological model (GBD 2017). The highly resolved results can provide detailed insights to support decision making and public health management in China.

Present a comprehensive and reliable estimate of the health benefit related to the implementation of the APPCAP, which helped explain the discrepancies in previous estimates and provides new, more accurate results for robust health impact and policy assessment.

Conclusion

- During this 18-year period, growth in DAPP slowed after the establishment of the APPCAP in 2013. A decline in $PM_{2.5}$ concentration after the release of the APPCAP reduced the DAPP in 2017 by **64 thousand** compared to that in 2013.

- If China follows the current trend of policy and reduces the population-weighted $PM_{2.5}$ concentration to $35 \mu g/m^3$ by 2030, the DAPP will decline by 2% compared with that in 2017, which is unlikely to result in further major reductions in DAPP and **more ambitious policies are required** to meet the United Nation's Sustainable Development Goal 3.

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Thanks!

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