LETTER

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Mapping changes in housing in sub-Saharan Africa from 2000 to 2015

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汇报内容

Access to adequate housing and shelter is a fundamental human right, considered central to human wellbeing through the provision of facilities that are essential to security, comfort, health and nutrition.

SUSTAINABLE DEVELOPMENT GOALS
KNOWLEDGE PLATFORM

The continent’s population is the fastest growing in the world and is predicted to increase from 1.2 billion in 2015 to 2.5 billion by 2050, which will necessitate hundreds of millions of new homes.

研究背景
研究数据
研究方法
结果与讨论

Alongside increased housing demand, the existing housing stock is steadily transforming—for example, thatch roofs are being replaced by corrugated metal roofs, and mud walls by concrete and brick walls. These changes present a powerful opportunity to improve human wellbeing, and they also demonstrate the urgent need for investment in housing infrastructure to ensure that vulnerable populations are not left behind.

目前存在的问题： existing data on African housing are limited

- The primary housing indicator

（the prevalence of urban slum housing）

  - limited to urban areas only
  - restricted to specific years
  - not standardized across the continent at any subnational scale

- Other detailed records of African housing conditions are focused on housing costs and finance

研究背景
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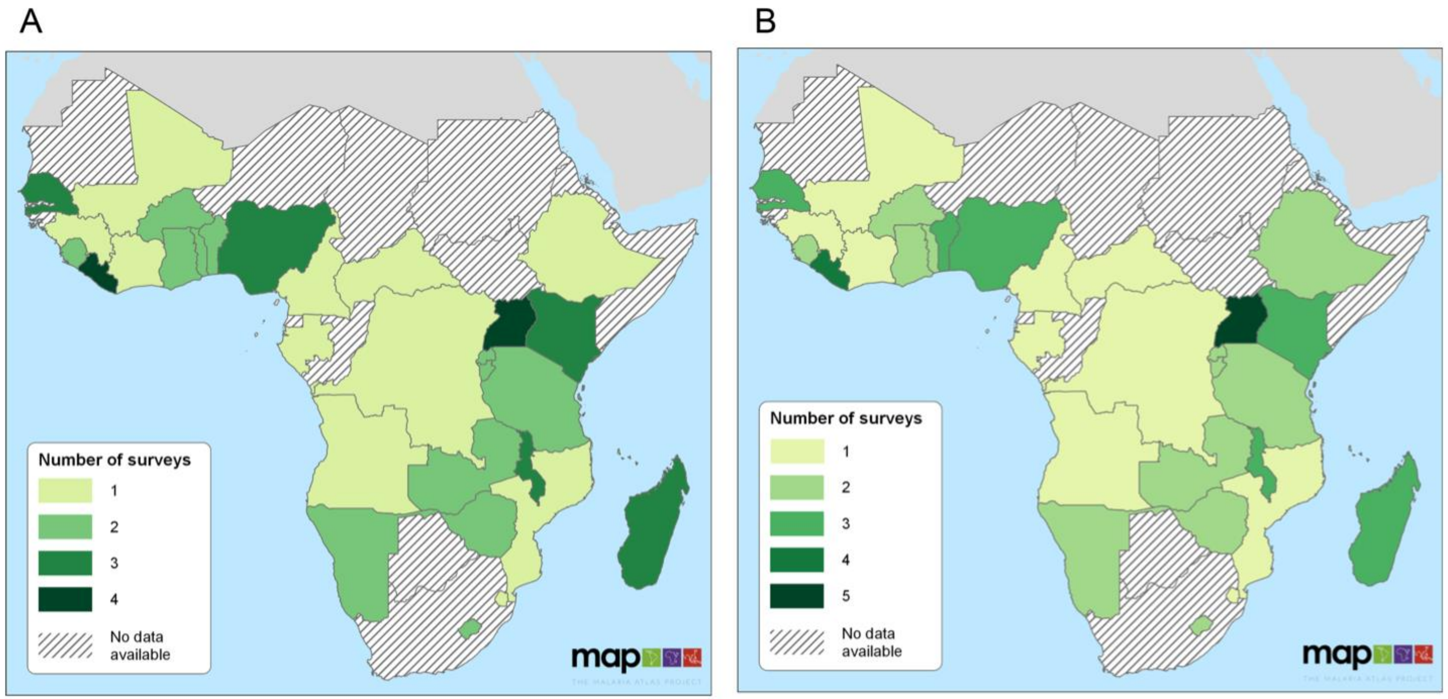
Here we **conduct a standardized analysis using a geospatial framework to quantify the changing profile of housing in urban and rural** sub-Saharan Africa during the era of the Millennium Development Goals.

✓ leveraged 62 georeferenced national household surveys, representing 661,945 unique households in 31 countries



Extended Data Fig. 1 | Availability of national survey data for the period 1990–2016 for the variables that are required to determine house construction materials and house type in sub-Saharan Africa. **a**, Availability of surveys for the determination of house construction materials. **b**, Availability of surveys for the determination of house type. Maps were produced using ArcGIS.

研究数据

✓ designed a geostatistical regression model to map house construction materials and overall house type at 5 × 5-km^2 resolution across sub-Saharan Africa

➢ categorized house construction materials into a binary variable that compared houses built from finished materials

Extended Data Table 1 | Definition of house type variables

Variable	Classification	Description
House construction materials	Natural or unfinished	Less than two out of three of the wall, roof and floor materials are finished*
	Finished	At least two out of three of the wall, roof and floor materials are finished*
House type	Unimproved house	At least one of: (1) unimproved water supply†, (2) unimproved sanitation†, (3) more than three people per bedroom, (4) made of natural or unfinished material.
	Improved house	All other houses

*Main material of the wall, roof and floor are recorded in national surveys (for example, DHS) and pre-categorized by the local investigators as 'natural', 'rudimentary' or 'finished' (Supplementary Text and Supplementary Table 5).
†Water supply and sanitation facilities were classified using World Health Organization Joint Monitoring Programme criteria (Supplementary Table 3).

研究数据

The independent variables (covariates) used in the model were:

- **aridity index**
- **degree of urbanicity**
- **accessibility to large cities**
- **travel friction surface**
- **night-time lights**
- **irrigation**

These independent variables were chosen as close proxies for factors that affect house type, such as:

- **poverty**
- **development**
- **urbanization**
- **transport access**
- **population density**

We also included spatial coordinates and time, to account for spatio-temporally autocorrelated residual effects.

Our geostatistical model utilizes **the random Fourier feature approach** for which a nonlinear, interacting function is defined through high-dimensional feature spaces computed in explicit form through a feature map. This approach approximates a kernel function through an explicit rather than implicit map.

The feature map associates a kernel function $k : \mathcal{X} \times \mathcal{X} \rightarrow \mathbb{R}$, which is defined on an input domain $\mathcal{X} \in \{x_1, \ldots, x_d\} \in \mathbb{R}^d$ such that $k\left(x_i, x_j\right) = \left(\varphi\left(x_i\right), \varphi\left(x_j\right)\right)_{\mathcal{H}}$ where $\varphi : \mathcal{X} \rightarrow \mathcal{H}$ is the feature map that associates kernel *k* with an embedding of the input space into a reproducing kernel Hilbert space $\mathcal{H}$.

On the basis of a previous study, our feature map takes the form $z(x|\omega) = [\cos(x^T\omega)\sin(x^T\omega)]^T$ such that $k\left(x_i, x_j|\theta\right) \approx \frac{\sigma^2}{N_{\text{feat}}} \sum_{r=1}^{M} z(x_i|\omega_r)^T z(x_j|\omega_r)$ with a given spectral measure ω_r.

Rather than assuming a spectral distribution in which ω_r is associated with a given kernel (for example, Student's *t* for the Matérn kernel), we obtained this distribution (empirical Lebesgue measure) directly from the data.

Given a response variable (for example, wall type), we used a beta-binomial likelihood function $p(y|x,\omega,\varphi)$ = BetaBinomial($z(x|\omega),\varphi$) to perform inference, allowing for overdispersion and sample size effects in the data.

The predictive performance of the model at the pixel level and administrative division level 1 was assessed via out-of-sample validation.

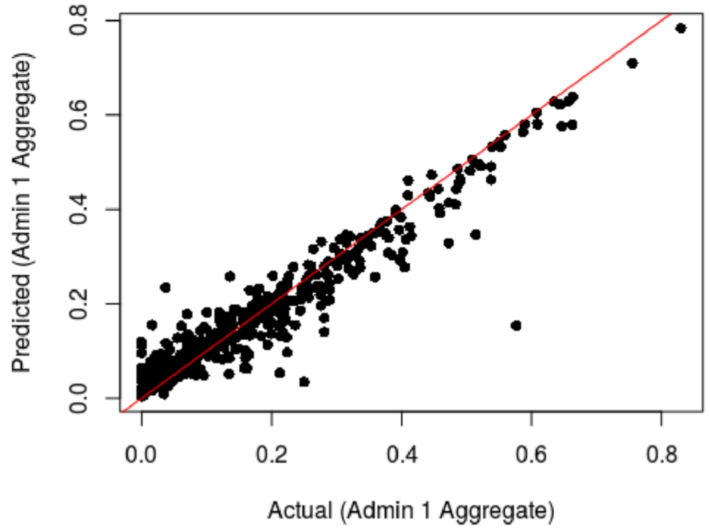
Confidence intervals and uncertainty were estimated using the weighted likelihood bootstrap, a method that generates samples from an approximate Bayesian posterior of a parametric model.

Table S6. Model performance of pixel level cross validation

Spatial aggregation	Error measure	Improved housing	Housing built with finished materials
Pixel level	Mean squared error	0.021	0.033
	Correlation %	81.9%	85.8%
Survey aggregate level	Mean squared error	0.0005	0.0021
	Correlation %	96.2%	97.3%

Table S7. Model performance of administrative division 1 cross validation

Spatial aggregation	Error measure	Improved housing	Housing built with finished materials
Administrative division 1	Mean squared error	0.0051	0.0137
	Correlation %	89.6%	90.8%



Extended Data Fig. 9 | Observed versus predicted prevalence of improved housing aggregated to district level (administrative division 1 level). Fit predictions for both observed and predicted prevalence were aggregated to the district level and plotted.

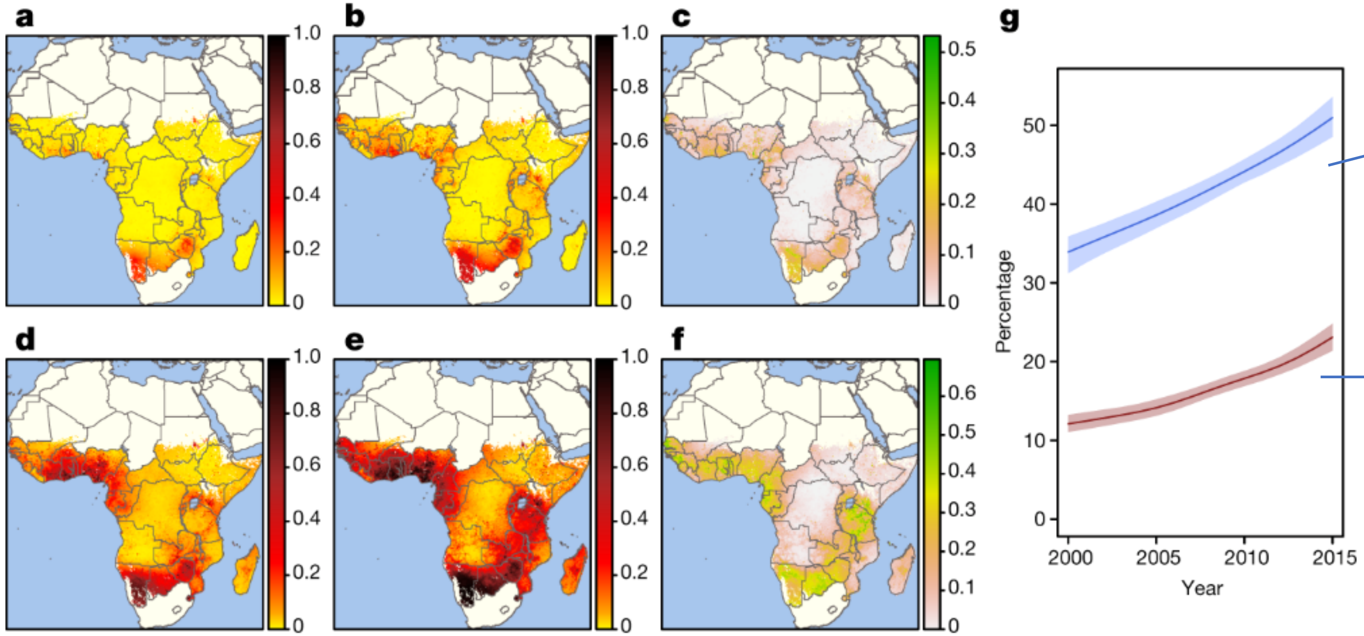
The predictive scores indicate excellent model performance, comparable to those from widely used, established models.

结果与讨论

A marked transformation of housing in sub-Saharan Africa from 2000 to 2015.

improved housing

houses built with finished materials



houses built with finished materials

improved housing

a, Prevalence of improved housing across sub-Saharan Africa in 2000 predicted at 5 × 5-km^2 resolution. **b**, Prevalence of improved housing in 2015 predicted at 5 × 5-km^2 resolution. **c**, Absolute difference in the prevalence of improved housing in 2000 and 2015. **d**, Prevalence of houses built with finished materials in 2000 predicted at 5 × 5-km^2 resolution. **e**, Prevalence of houses built with finished materials in 2015 predicted at 5 × 5-km^2 resolution. **f**, Absolute difference in prevalence of houses built with finished materials in 2000 and 2015. **g**, Increase in prevalence of improved housing (red line; shading, 95% confidence intervals) and housing built with finished materials (blue line) from 2000 to 2015. Results are derived from a geospatial model fitted to 62 surveys that represent 661,945 households (house construction materials) and 59 surveys that represent 629,298 households (house type). Houses were classified as improved if they had all of the following characteristics: improved water supply, improved sanitation, three or fewer people per bedroom and house made of finished materials (Extended Data Table 1 and Supplementary Methods). Maps were produced using the raster package (version 2.6-7) in R. The images were plotted using the rasterVis package (version 3.4).

结果与讨论

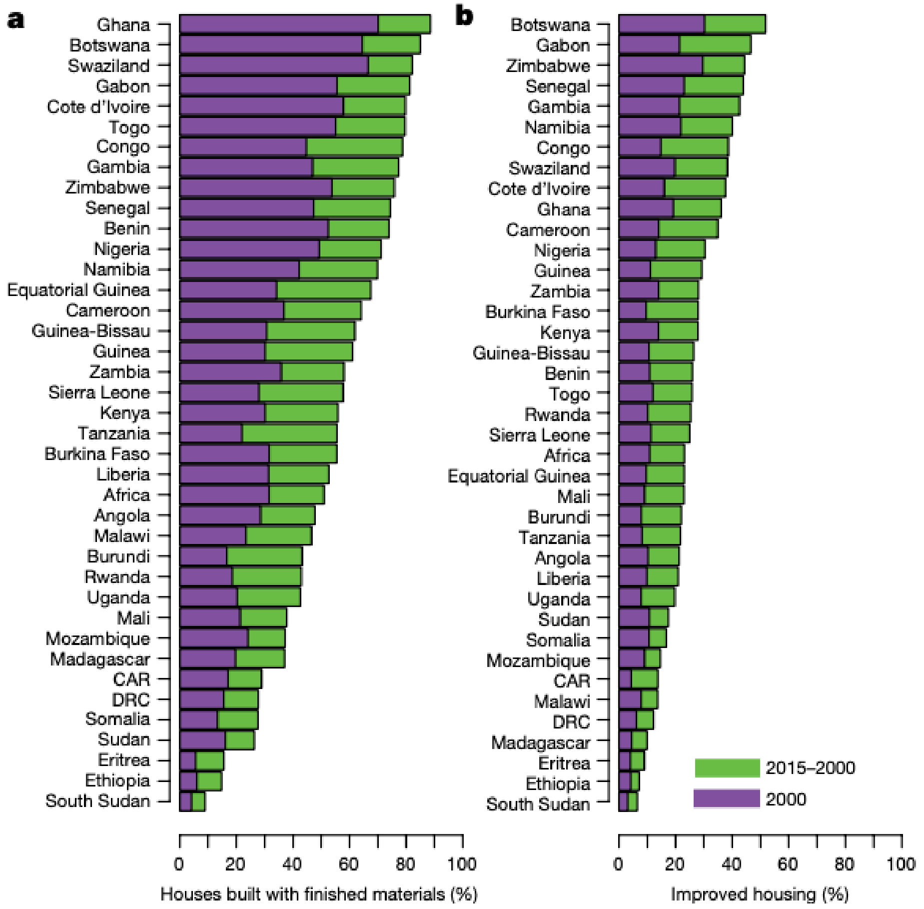
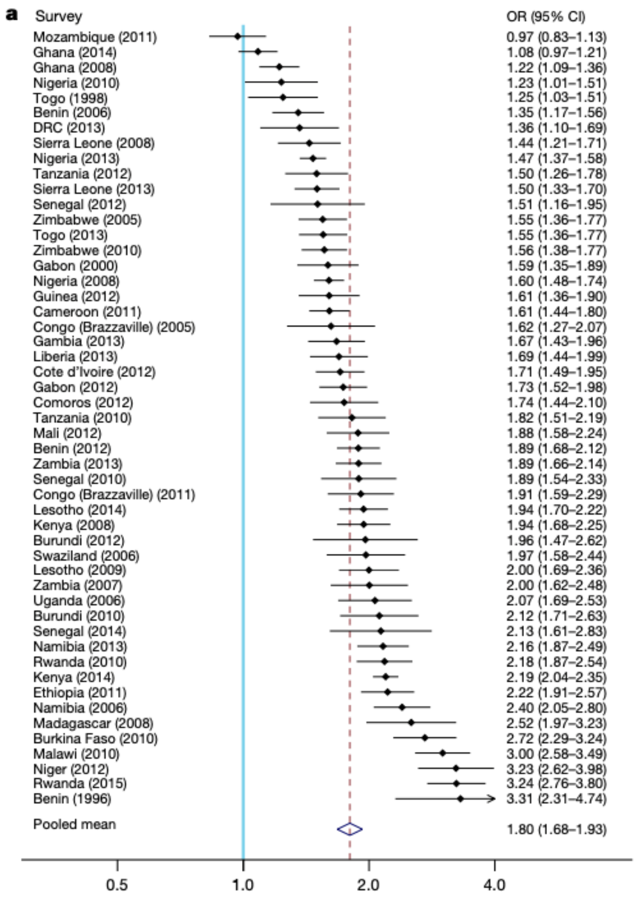
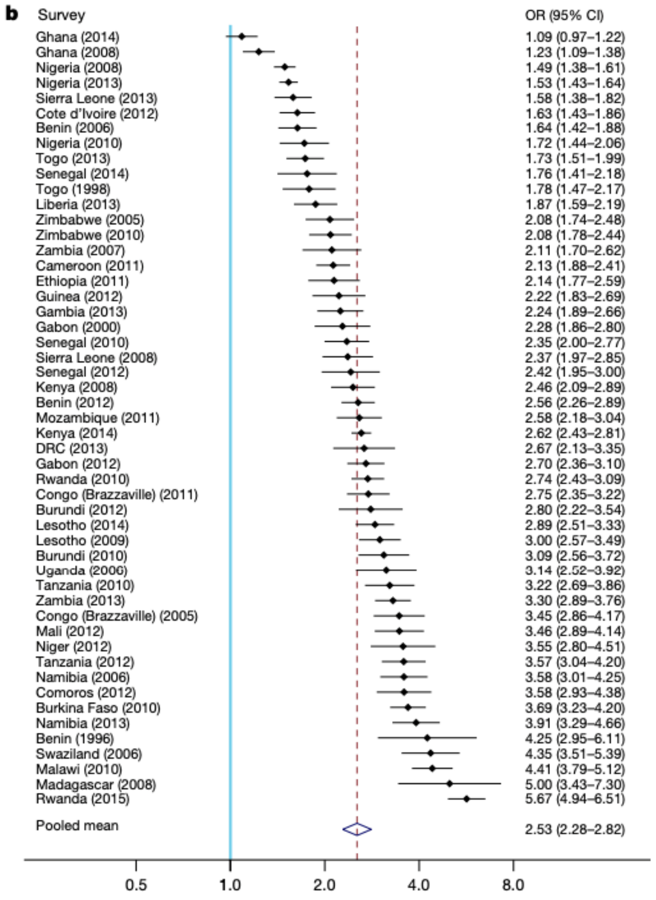


Fig. 2 | National-level changes in housing between 2000 and 2015. **a**, **b**, Plots show predicted population-weighted mean prevalence of houses built with finished materials (**a**) and improved housing (**b**). Bars represent each country in 2000 (purple) and 2015 (purple and green combined). Houses were classified as improved if they had all of the following characteristics: improved water supply, improved sanitation, three or fewer people per bedroom and house made of finished materials (Extended Data Table 1 and Supplementary Methods). CAR, Central African Republic; Congo, Republic of the Congo; DRC, Democratic Republic of the Congo.

- ✓ the prevalence of houses that were built with **finished materials** increased from 32% (29–33%) in 2000 to 51% (49–54%) in 2015
- ✓ the predicted prevalence of **improved housing** doubled from 11% (10–12%) in 2000 to 23% (21–25%) in 2015
- ✓ Between 2000 and 2015, 134 (118–147) million Africans in the analysed countries gained access to improved housing.
- ✓ However, unacceptable inequalities persist, with 53 (50–57) million urban inhabitants (47% (44–50%) of the total urban population of sub-Saharan Africa analysed) and 595 (585–607) million rural inhabitants (82% (80–83%) of the rural population) living in unimproved housing in 2015.

结果与讨论





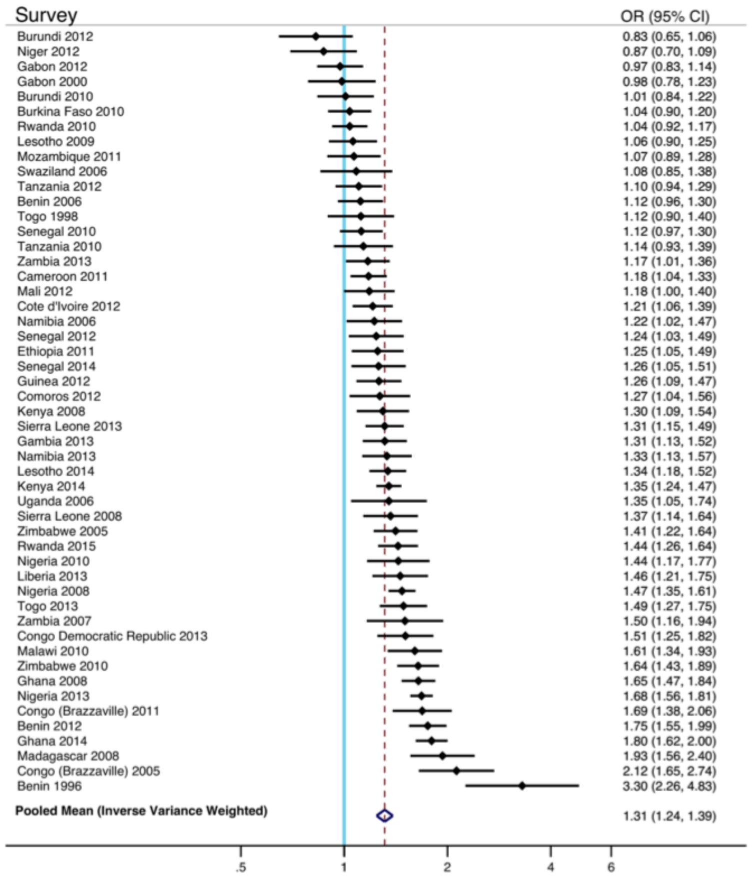
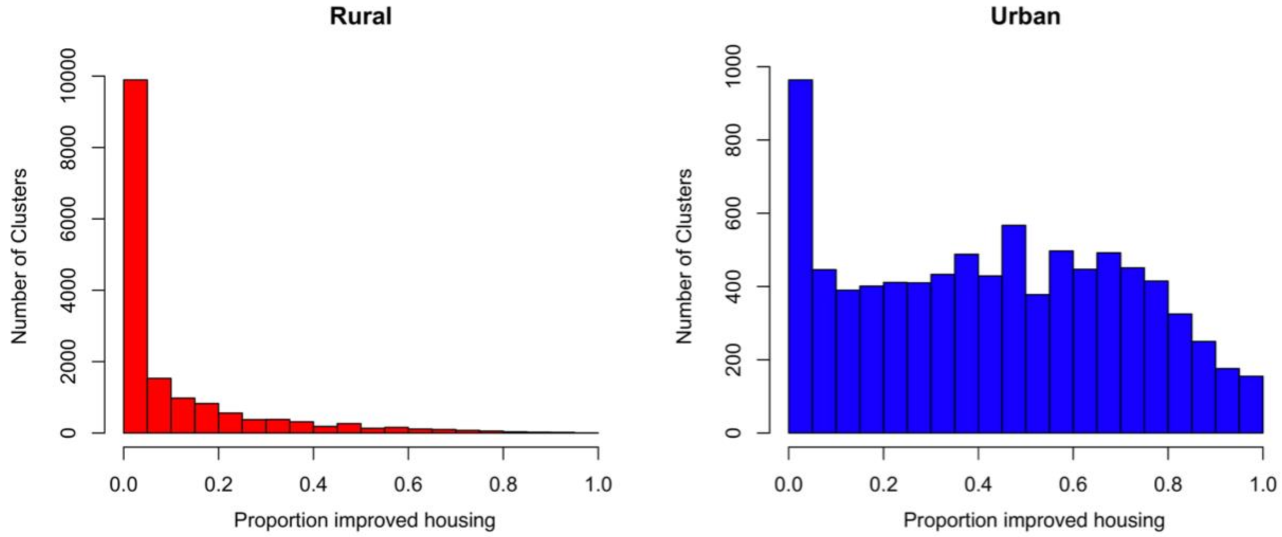


Fig. 3 | Association between house type, education and household wealth. a, Association between house type and education level. The pooled increase in odds of living in an improved house when the household head reported having completed more than primary education, compared to having primary education or less, is shown by the diamond and dashed red vertical line. The solid blue vertical line represents the null value (no difference between groups). Odds ratios (OR) are adjusted for wealth index, age of the household head and geographical cluster. Error bars show 95% confidence intervals. **b**, Association between house type and household wealth. The pooled increase in odds of living in an improved house among households in the upper 75% wealth quartile compared to all other households is shown. Odds ratios are adjusted for education level, age of the household head and geographical cluster. Data are from 48 Demographic and Health Surveys, two Malaria Indicator Surveys and one AIDS Indicator Survey, conducted between 1996 and 2015 (Supplementary Table 2).

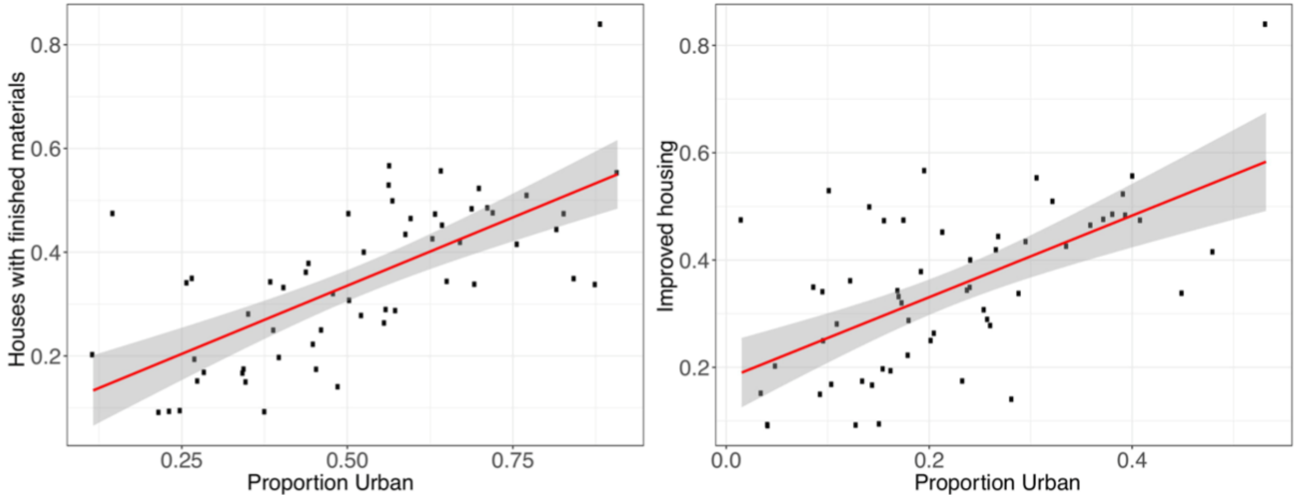
Extended Data Fig. 4 | Association between house type and age of the household head. The pooled increase in odds of living in an improved house when the age of the household head is over 55 years, compared to 55 years or less, is shown to the right of the vertical line representing the null value (no difference between groups). Odds ratios are adjusted for wealth index, education level of the household head and geographical cluster. Error bars show 95% confidence intervals. Data are from 48 DHS, 2 MIS and 1 AIS conducted between 1996 and 2015 (Supplementary Table 2).

- ✓ 80% higher in more **educated households**
- ✓ more than double in the **wealthiest households**
- ✓ 31% higher with increased **age of the household head**

结果与讨论



Extended Data Fig. 5 | Prevalence of improved housing in rural and urban survey clusters. Data are from 59 national household surveys from 31 countries in sub-Saharan Africa conducted between 1994 and 2015.



Extended Data Fig. 6 | Prevalence of house types in relation to survey-level prevalence of urban clusters. Left, house construction materials (adjusted $R^2 = 0.46$, $P < 0.001$). Right, house type (adjusted $R^2 = 0.35$, $P < 0.001$). Points represent each national survey included in the analysis.

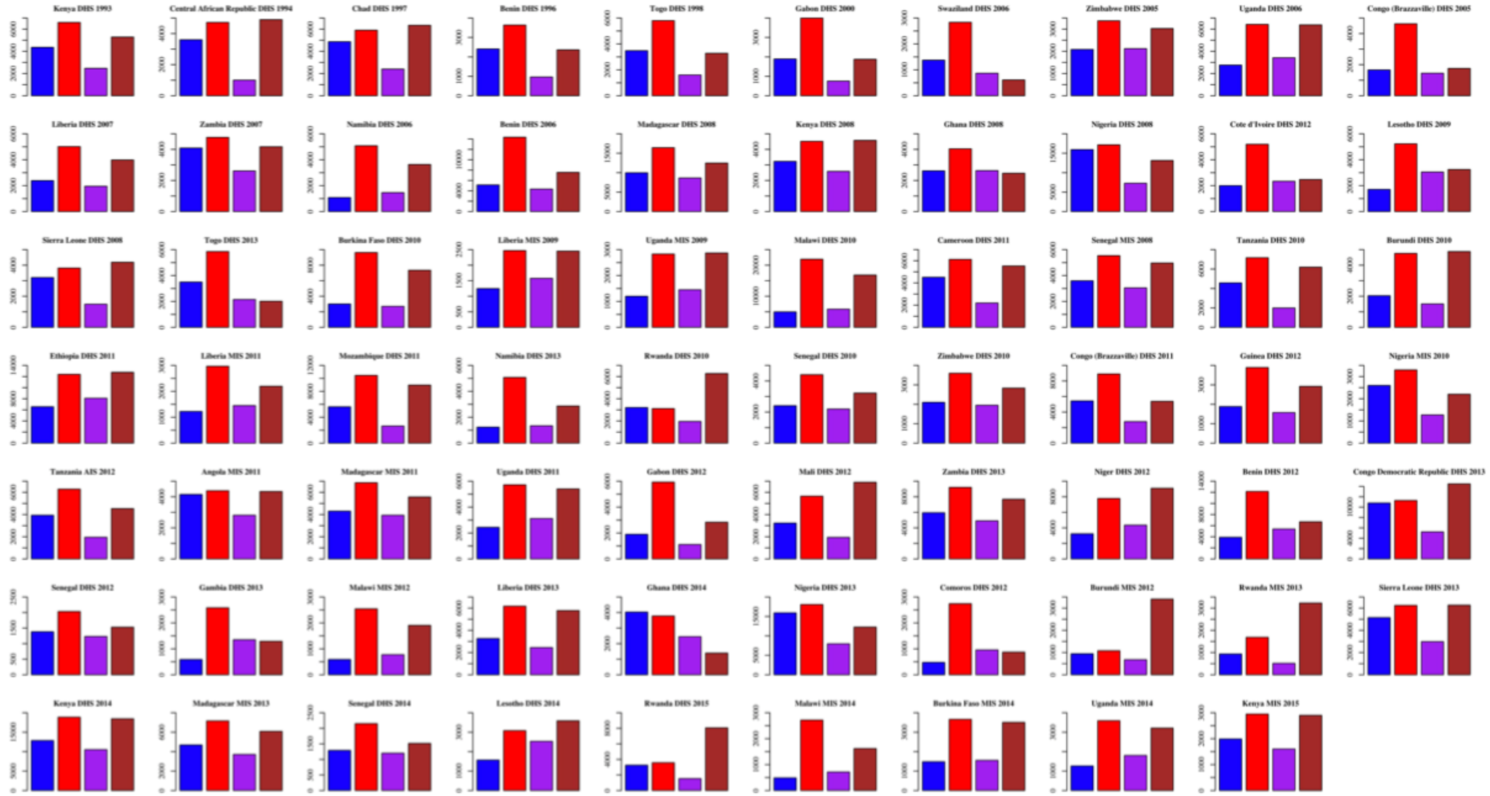
observed a higher prevalence of improved housing in urban survey clusters than rural survey clusters.

a 10% increase in the prevalence of urban clusters was associated with a 7.5% increase in improved housing

结果与讨论

We show a considerable reduction in the prevalence of urban unimproved housing across sub-Saharan Africa from 68% (65–71%) in 2000 to 47% (44–50%) in 2015.

However, nearly half of Africa’s urban population still lives in unimproved conditions, which is partly explained by widespread unimproved sanitation.



Extended Data Fig. 8 | Number of households per survey that lack the characteristics of improved houses. Characteristics shown are improved water source (blue), improved sanitation facilities (red), sufficient living area (purple) and finished house construction materials (brown). Data are from 1 AIS, 15 MIS and 53 DHS that had data on all four of these variables, conducted between 1993 and 2015. Out of a total of 69 surveys, households most frequently lacked improved sanitation facilities (52 surveys; 75%) and finished materials (16 surveys; 23%).

These findings highlight the urgent need for governments to improve water and sanitation infrastructure as households continue to spend individually on their homes.

结论

- ✓ the prevalence of improved housing doubled during 2000–2015, but that an unacceptably large proportion of people still live in unimproved housing in urban areas.

- ✓ house type was clearly associated at the household level with education, wealth and age of the household head

Thank you for your attention!