

1 Rainfall patterns influence poverty lev- 2 els throughout Sub-Saharan Africa

3 Xingang Li¹, Ying Qu¹, Ashok K. Mishra², Xin Yao¹, Liqiang Zhang¹, Qiao
4 Wang¹, Yang Li¹, Siyuan Chen¹, Lanpu Zhao³, Zhaocong Wu³, Lei
5 Liang¹, Zidong Zhu¹ and Liangpei Zhang³

6 ¹Faculty of Geographical Science, Beijing Normal University, Beijing, 100875, China.

7 ²Zachry Department of Civil & Environmental Engineering, Texas A&M University, TX,
8 USA.

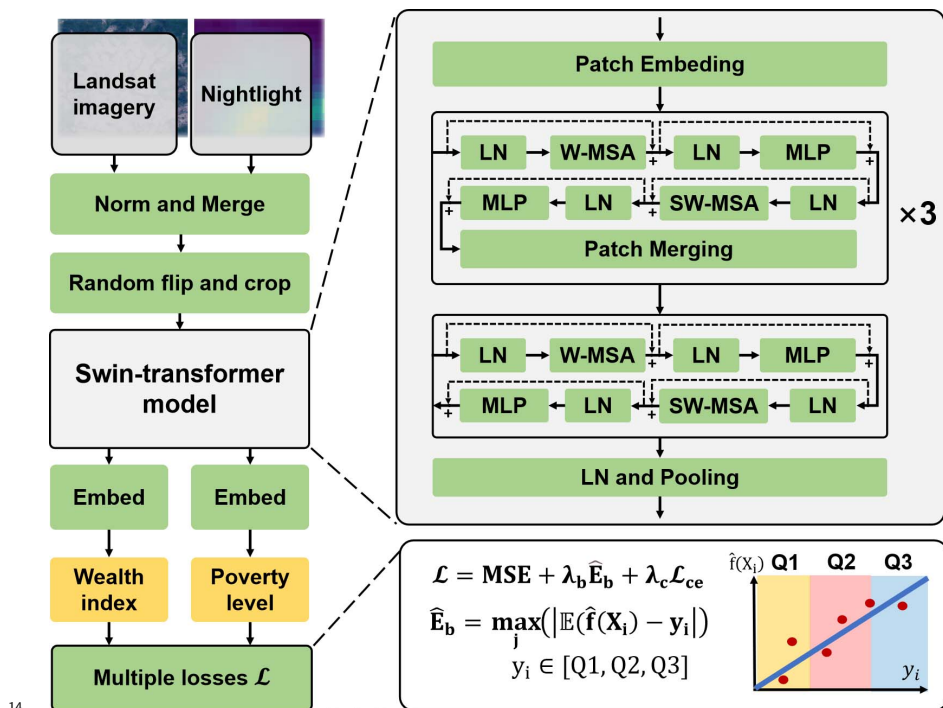
9 ³Aerospace Information Research Institute, Henan Academy of Sciences, Zhengzhou, China.

The File Includes:

1 Supplementary Figures (Figs. 1-11)

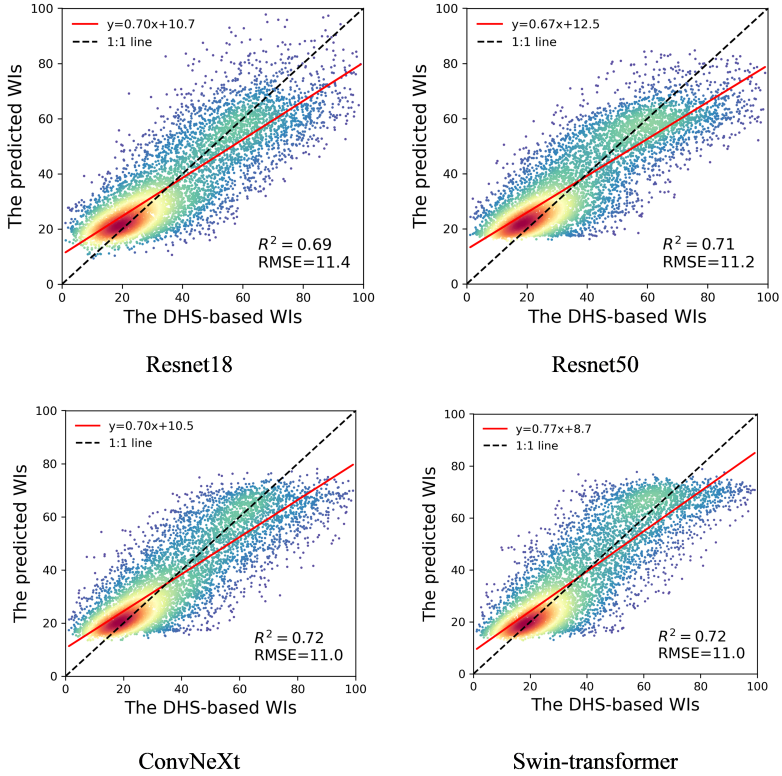
2 Supplementary Tables (Tables 1-19)

13 1 Supplementary Figures



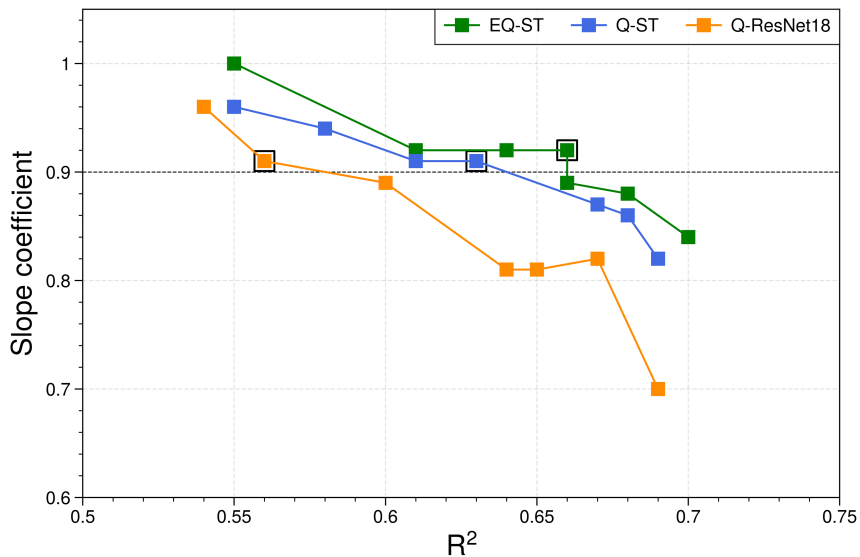
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15 **Supplementary Fig. 1** The abstract diagram of the deep learning-based framework.

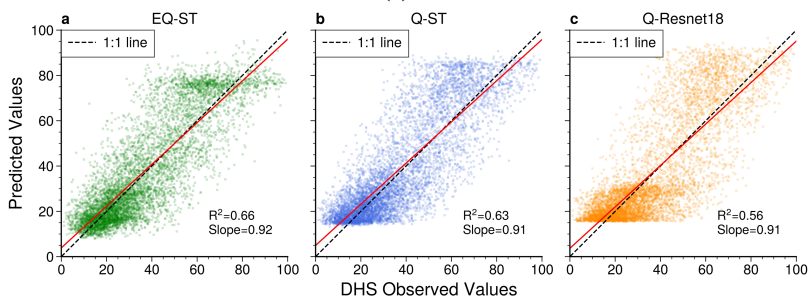


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17 **Supplementary Fig. 2** The results of the different end-to-end deep learning frameworks
 18 in predicting the IWIs at the community-level in SSA countries from 2010-2022.



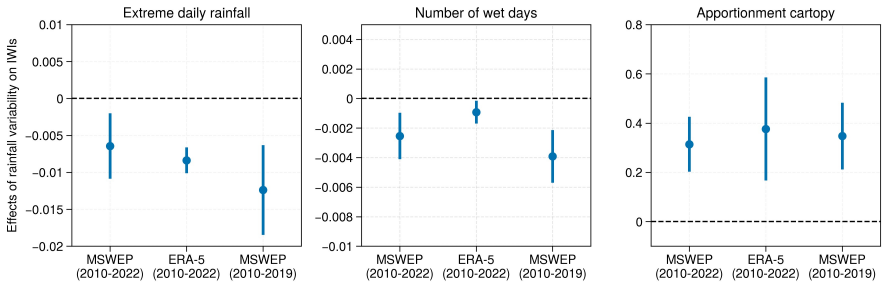
(a)



(b)

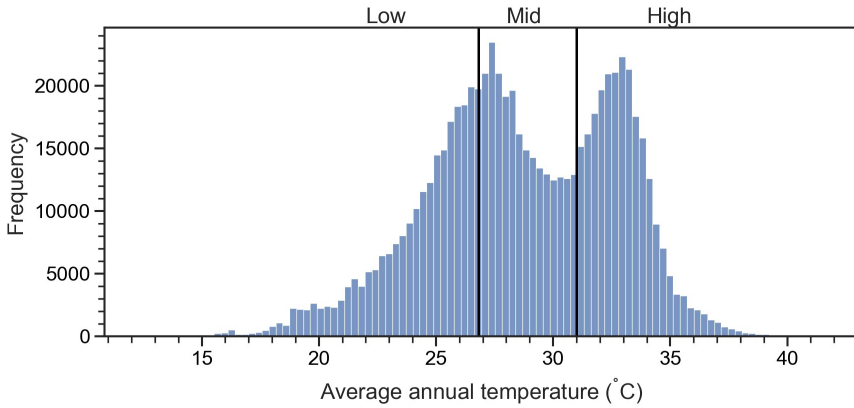
19

20 **Supplementary Fig. 3** The performance of the three models for estimating IWIs. (a)
 21 Relationship between the slope coefficient and R^2 for each subplot; (b) DHS observed wealth
 22 index values in test set on the horizontal axis and models predicted values on the vertical
 23 axis. The black dot line is a 45° line, and the red line is the best fit from regressing predicted
 24 on observed. Slope coefficient and the determination coefficient R^2 are shown in the lower-
 25 right corner of each subplot.



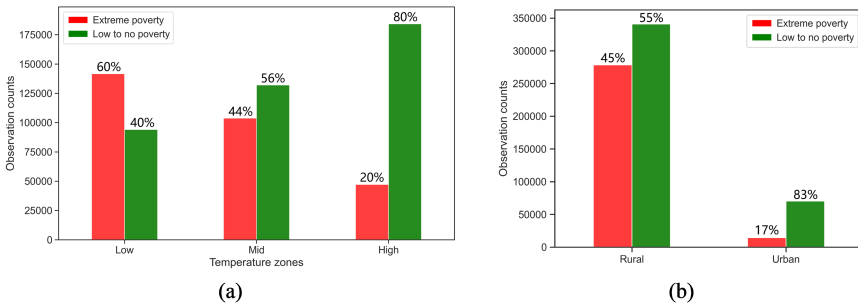
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27 **Supplementary Fig. 4** The robustness testing of the baseline model.



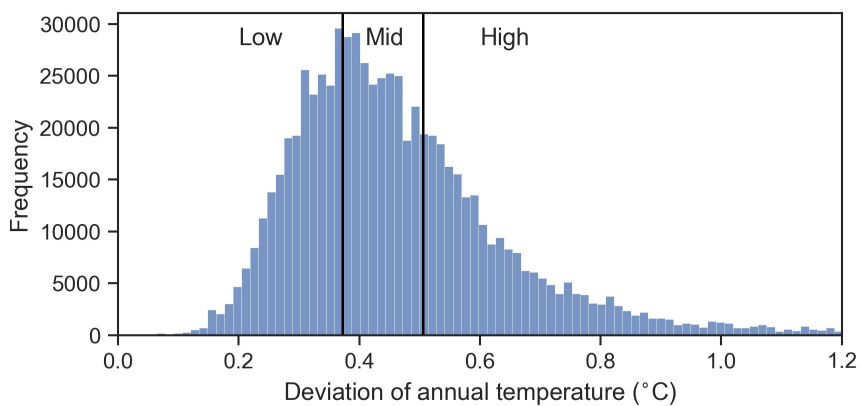
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29 **Supplementary Fig. 5** Temperature zone divisions. Low, mid, and high temperatures
30 represent the 0-33%, 33-66%, and 66-100% percentile intervals, respectively.



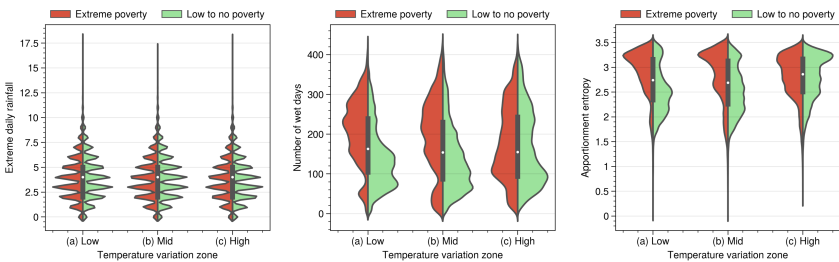
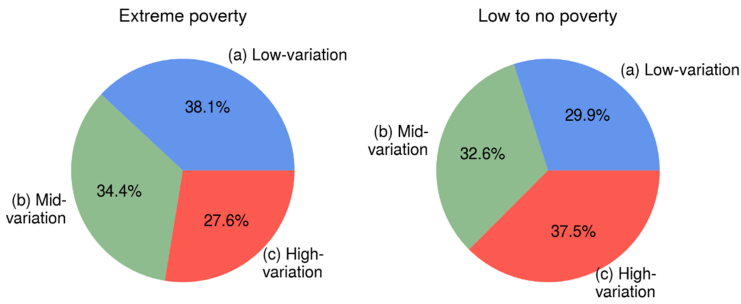
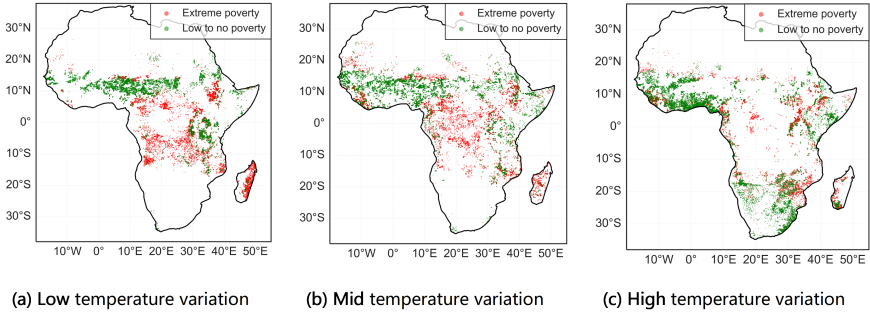
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32 **Supplementary Fig. 6** The ratios of households in different temperature zones (a) and
33 living environments (b).



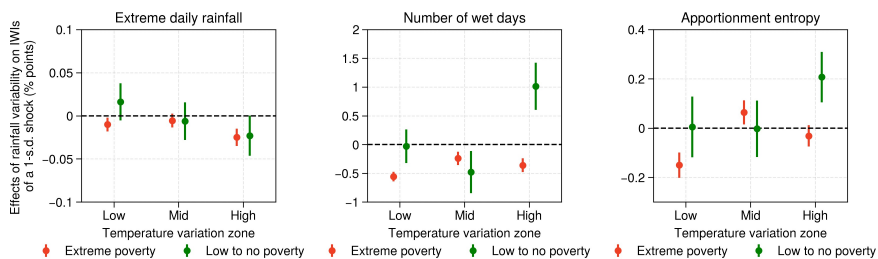
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35 **Supplementary Fig. 7** Temperature variation zone divisions. Low, mid, and high tem-
36 peratures represent the 0-33%, 33-66%, and 66-100% percentile intervals, respectively.



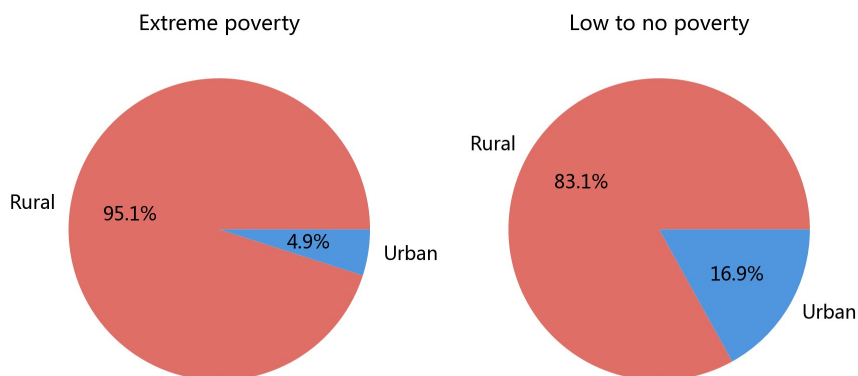
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38 **Supplementary Fig. 8** The spatial distribution and proportions of extreme poverty and
 39 low to no poverty households in different temperature variation zones exposed to rainfall
 40 variability. The first row shows the spatial distribution of extreme poverty households (in
 41 red) and low to no poverty households (in green). The pie charts illustrate the proportions of
 42 extreme poverty households and low-poverty households across different temperature varia-
 43 tion zones. The violin plots display the distribution of households in different poverty level
 44 exposed to the three rainfall metrics.



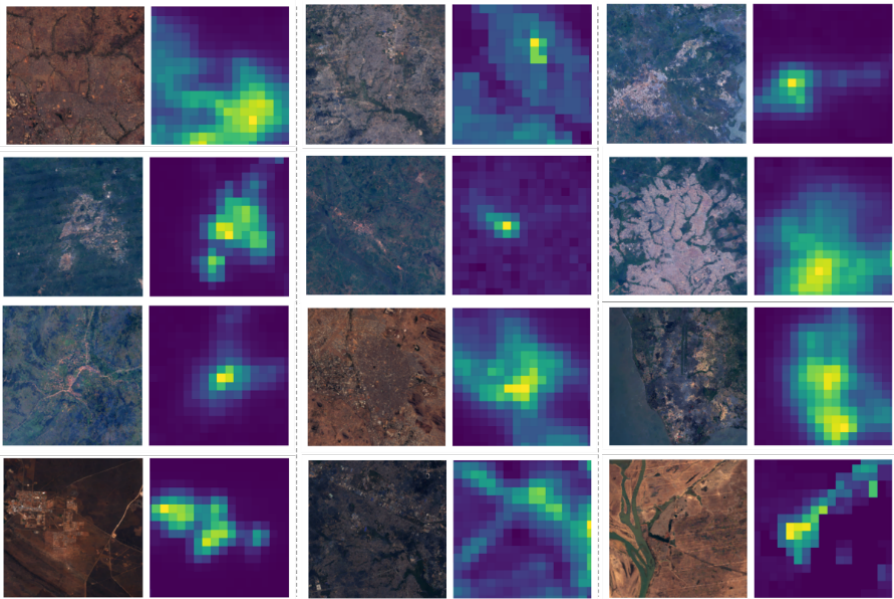
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46 **Supplementary Fig. 9** The effect of households living in different temperature variation
 47 zones affected by rainfall change.



48

49 **Supplementary Fig. 10** The ratio of households experiencing extreme poverty to those
 50 not experiencing extreme poverty (low to no poverty) across different living environments
 51 (rural or urban).



52

53

Supplementary Fig. 11 Examples of Landsat and nighttime light data.

54 **2 Supplementary Tables****Supplementary Table 1** Comparisons of different deep learning models for estimating IWIs.

Backbone	R^2	RMSE	Slope	Recall (<\$2.15 a day)	Recall (>\$6.85 a day)
Resnet-18	0.69	11.4	0.70	0.71	0.55
Resnet-50	0.71	11.2	0.67	0.68	0.20
ConvNeXt	0.72	11.1	0.70	0.74	0.44
Swin-Transformer	0.72	11.0	0.77	0.83	0.49

Supplementary Table 2 Comparisons of our model with other approaches.

Models	R^2	RMSE	Slope	Recall (<\$2.15 a day)	Recall (>\$6.85 a day)
Q-Resnet-18	0.56	13.7	0.91	0.80	0.61
Q-ST	0.63	12.6	0.91	0.84	0.41
EQ-ST	0.66	12.1	0.92	0.85	0.76

Supplementary Table 3 The base model and the robust analysis.

VARIABLES	MSWEP	ERA-5	MSWEP
	(base model) IWI	(2010-2022) IWI	(2010-2019) IWI
Extreme daily rainfall	-.00643*** [.00226]	-.00837*** [0.00090]	-.01237*** [.00310]
Number of wet days	-.00254*** [.00080]	-.00093** [.00039]	-.00392*** [.00091]
Apportionment entropy	.31410*** [.05688]	.37642*** [.10694]	.34775*** [.06907]
State Fixed Effect	YES	YES	YES
Year Fixed Effect	YES	YES	YES
Control variables	YES	YES	YES
Obs.	708302	708302	505927
Adjusted R-Square	.691	.691	.692
Within R-Square	.057	.057	.057

Robust standard errors in brackets, ***p<0.01, **p<0.05, *p<0.1

Supplementary Table 4 Demonstrating the explanatory power of individual rainfall measures.

VARIABLES	Base model	Explanatory power of individual measures		
	IWI	IWI	IWI	IWI
Extreme daily rainfall	-.00643*** [.00226]	-.01043*** [.00211]		
Number of wet days	-.00254*** [.00080]		-.00184** [.00081]	
Apportionment entropy	.31410*** [.05688]			.22916*** [.06319]
State Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
Control variables	YES	YES	YES	YES
Obs.	708302	708302	708302	708302
Adjusted R-Square	.691	.691	.691	.691
Within R-Square	.055	.055	.055	.055

Robust standard errors in brackets, ***p<0.01, **p<0.05, *p<0.1

Supplementary Table 5 The interdependence of rainfall measures.

VARIABLES	Base model	Interdependence of rainfall measures		
	IWI	IWI	IWI	IWI
Extreme daily rainfall	-.00643*** [0.00226]		-.00835*** [.00219]	-.00977*** [.00216]
Number of wet days	-.00254*** [.00080]	-.00259*** [0.00080]		-.00180** [.00081]
Apportionment entropy	.31410*** [.05688]	.32739*** [.05569]	.21466*** [.06414]	
State Fixed Effect	YES	YES	YES	YES
Year Fixed Effect	YES	YES	YES	YES
Control variables	YES	YES	YES	YES
Obs.	708302	708302	708302	708302
Adjusted R-Square	.691	.691	.691	.691
Within R-Square	.055	.055	.055	.055

Robust standard errors in brackets, ***p<0.01, **p<0.05, *p<0.1

Supplementary Table 6 The effect of rainfall variability on IWIs varies with poverty level grouping.

VARIABLES			Coefficient different	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-.00488*** (-3.94)	-.00248**** (-.75)	-.002	.385
Number of wet days	-.00524*** (-14.86)	.00298** (2.24)	-.008	.000
Apportionment entropy	-.0407 (-1.29)	.211*** (2.77]	-.252	.0000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	292651	415554		
R-Square	.591	.660		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 7 The effect of rainfall variability on IWIs of households in low temperature varies by poverty level grouping.

VARIABLES	Low temperature		Coefficient different	
	Extreme poverty	Low to no poverty	b0-b1	p-value
	Extreme daily rainfall	-0.0108*** (-5.90)	-0.00577 (-0.75)	-0.005
Number of wet days	-0.00679*** (-14.76)	0.0132*** (5.66)	-0.020	0.000
Apportionment entropy	-0.419*** (-7.89)	0.662*** (3.32)	-1.082	0.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	141700	94084		
R-Square	0.539	0.734		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 8 The effect of rainfall variability on IWIs of households in mid temperature zone varies by poverty level grouping.

VARIABLES	Mid temperature		Coefficient	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.00483** (-2.54)	-0.000414 (-0.07)	-0.004	0.270
Number of wet days	-0.00364*** (-6.82)	0.00910*** (4.18)	-0.013	0.000
Apportionment entropy	-0.361*** (-7.89)	0.722*** (4.73)	-1.083	0.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	103711	132105		
R-Square	0.643	0.660		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 9 The effect of rainfall variability on IWIs of households in high temperature zone varies by poverty level grouping.

VARIABLES	High temperature		Coefficient	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.0123*** (-3.89)	0.0101** (2.29)	-0.022	0.040
Number of wet days	0.00659*** (5.47)	-0.00994*** (-4.53)	0.0140	0.000
Apportionment entropy	0.391*** (7.79)	-0.107 (-1.22)	0.423	0.005
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	47172	189337		
R-Square	0.518	0.523		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 10 The effect of rainfall variability on IWIs of households in low temperature varies by poverty level grouping.

VARIABLES	Low temperature variation		Coefficient	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.00484** (-2.48)	0.00750 (1.46)	-0.012	0.040
Number of wet days	-0.00694*** (-13.19)	-0.000387 (-0.20)	-0.007	0.000
Apportionment entropy	-0.342*** (-5.77)	0.0101 (0.08)	-0.352	0.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	111377	124442		
R-Square	0.601	0.618		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 11 The effect of rainfall variability on IWIs of households in mid temperature variation zone varies by poverty level grouping.

VARIABLES	Low temperature variation		Coefficient	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.00484** (-2.48)	0.00750 (1.46)	-0.012	0.040
Number of wet days	-0.00694*** (-13.19)	-0.000387 (-0.20)	-0.007	0.000
Apportionment entropy	-0.342*** (-5.77)	0.0101 (0.08)	-0.352	0.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	111377	124442		
R-Square	0.601	0.618		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 12 The effect of rainfall variability on households in high temperature variation zone varies by poverty level grouping.

VARIABLES	High temperature variation		Coefficient different	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.0120*** (-4.90)	-0.0111** (-1.94)	-0.001	0.475
Number of wet days	-0.00394*** (5.94)	0.0109*** (4.85)	-0.015	0.000
Apportionment entropy	-0.0699 (-1.44)	0.463*** (3.98)	-0.533	0.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	80684	155781		
R-Square	0.530	0.713		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 13 The effect of rainfall variability on Rural households' IWIs varies by poverty level grouping.

VARIABLES	Rural		Coefficient different	
	Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.00351*** (-2.83)	-0.00657** (-2.35)	.003	.190
Number of wet days	-0.00540*** (-14.80)	.00209* (1.75)	-0.007	.000
Apportionment entropy	-.0240 (-.75)	.129** (2.05)	-0.153	.000
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	278220	345141		
R-Square	.606	.551		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 14 The effect of rainfall variability on Urban households' IWIs varies by poverty level grouping.

VARIABLES			Coefficient different	
	Urban Extreme poverty	Low to no poverty	b0-b1	p-value
Extreme daily rainfall	-0.0153** (-2.35)	0.0228*** (3.66)	-0.038	0.090
Number of wet days	-0.00326** (-2.26)	-0.00135 (-0.46)	-0.002	0.260
Apportionment entropy	-0.0653 (-0.43)	0.159 (0.80)	-0.224	0.315
State Fixed Effect	YES	YES		
Year Fixed Effect	YES	YES		
Control variables	YES	YES		
Obs.	14397	70396		
R-Square	.496	.872		

t statistics in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Supplementary Table 15 The year and month of the DHS survey.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Angola		3				12						
Benin			1					12				
Burkina Faso	8				9				1			
Burundi	10		12				12					
Cameroon		4							9			
Chad						1						
Comoros			10									
Congo Democratic Republic				10								
Ethiopia		2					3			4		
Gabon			3									
Gambia												1
Ghana					10		11	8		10		
Guinea			8						4			8
Kenya					7	7					11	
Lesotho					10							
Liberia		10		5			10			12		
Madagascar		4		5			6					5
Malawi	8		4		5	12		4				
Mali	9		12			10			9			10
Mozambique		8				7			5			
Namibia				7								
Niger			4									9
Nigeria	11			4		10			10			11
Rwanda		1				1					3	
Senegal	12			2	5	5	5	8	9	8	12	
Sierra Leone				8			7			6		
South Africa							8					
Tanzania	2		2			11		11				
Togo					1			10				
Uganda		9			12		9			1		
Zambia				12					10			
Zimbabwe	12					9						

Supplementary Table 16 Description of three poverty levels.

Quantile	Q1: Extreme poverty	Q2: Low poverty	Q3: No poverty
Description	Less than \$2.15 per person per day	Less than \$6.85 and greater than \$2.15 per person per day	More than \$6.85 per person per day
Proportion	$0 \leq y < 36.40\%$	$36.40\% \leq y < 87\%$	$y \geq 87\%$
Value	$0 \leq y < 24.1$	$24.1 \leq y < 62.8$	$y \geq 62.8$

Supplementary Table 17 The prediction performance comparison of Enhanced-Quantile loss function based Swin Transformer (EQ-ST), Quintile loss function based ResNet18 (Q-ResNet18) and Quintile loss function based Swin Transformer (Q-ST).

	EQ-ST		Q-ResNet18		Q-ST	
	R^2	Slope	R^2	Slope	R^2	Slope
1	0.70	0.84	0.67	0.82	0.69	0.82
2	0.68	0.88	0.64	0.81	0.68	0.86
3	0.67	0.89	0.60	0.89	0.67	0.87
4	0.66	0.92	0.65	0.81	0.65	0.89
5	0.64	0.92	0.56	0.91	0.63	0.91
6	0.63	0.92	0.56	0.92	0.61	0.92
7	0.55	1.00	0.54	0.96	0.58	0.94

Supplementary Table 18 The prediction performance in leave-one-country-out cross validation.

Name	Counts	R^2	RMSE	Slope
AGO	826	0.79	14.25	0.99
BDI	1119	0.61	9.59	0.82
BEN	1277	0.62	14.15	0.96
BFA	996	0.66	11.32	1.14
CMR	993	0.66	13.77	0.96
COD	489	0.83	8.52	1.10
COM	225	0.44	17.59	0.69
ETH	1487	0.79	12.75	0.88
GAB	324	0.72	13.95	0.79
GHA	806	0.63	11.41	0.98
GIN	865	0.79	10.20	0.93
GMB	262	0.78	13.73	0.83
KEN	2106	0.59	12.36	0.84
LBR	939	0.66	10.49	0.97
LSO	397	0.62	14.31	1.18
MDG	1433	0.62	11.05	0.94
MLI	1132	0.74	12.19	1.23
MOZ	1124	0.77	14.43	1.11
MWI	267	0.66	15.66	1.16
NAM	446	0.62	16.40	0.75
NER	465	0.71	13.67	0.87
NGA	3120	0.44	15.08	0.69
RWA	1477	0.66	10.09	0.97
SEN	1939	0.64	14.30	0.74
SLE	990	0.77	9.44	1.04
TCD	620	0.67	10.62	1.04
TGO	500	0.73	11.37	1.13
TZA	2062	0.66	11.96	1.00
UGA	1421	0.60	11.58	1.01
ZAF	626	0.44	17.30	0.59
ZMB	1224	0.69	13.82	0.95
ZWE	771	0.77	14.55	0.94
Average	1023	0.67	12.87	0.94

Supplementary Table 19 The prediction performance when the test set is in a specific year.

	R^2 (EQ-ST)	R^2 (Q-ST)	R^2 (Q-ResNet18)	Slope(EQ-ST)	Slope(Q-ST)	Slope(Q-ResNet18)
2010	0.67	0.67	0.62	1.00	0.87	0.89
2011	0.55	0.53	0.45	0.96	0.95	1.02
2012	0.56	0.48	0.37	0.92	0.81	0.81
2013	0.69	0.47	0.62	0.91	0.94	0.92
2014	0.57	0.66	0.41	0.90	0.92	0.93
2015	0.58	0.52	0.41	0.97	0.99	1.02
2016	0.80	0.79	0.76	0.85	0.89	0.92
2017	0.60	0.58	0.57	0.90	0.88	0.92
2018	0.60	0.56	0.45	0.93	0.94	0.92
2019	0.68	0.66	0.57	0.94	0.85	0.78
2020	0.54	0.52	0.50	0.83	0.81	0.87
2021	0.63	0.66	0.62	0.86	0.87	0.85
Average	0.62	0.59	0.53	0.91	0.89	0.90